ORIGINAL ARTICLE

Water resource selection of large mammals for water resources planning

Javad Najafi[1] · Azita Farashi[2] · AliAkbar Pasha Zanoosi[3] · Roya Yadreh[4]

Abstract

Iran is one of the driest countries in the world and shortage of water is one of the main concerns for wildlife conservation in this country. We have studied eight mammal species at Bafgh protected area at the center of Iran. We have investigated the physic-chemical parameters (salinity, chlorine, bicarbonate, carbonate, calcium, sodium, potassium, magnesium, total dissolved solids, dissolved oxygen, water temperature, electrical conductivity, and pH) and geo-ecological characteristics (altitude, slope, distance of settlements in rural area, distance of road, distance of stream, distance of protection station, distance of mine, distance of human-made construction, percent coverage of *Phragmites australis*, percent coverage of *Pistacia atlantica*, percent coverage of *Peganum harmala*, percent coverage of *Punica granatum*) of water bodies and their relationships with big mammals' visiting frequencies from these water bodies. We have developed species–environment relationships using a backward-selected logistic regression. A separate model has been developed for each species, because we expected that different species may respond differently to environmental parameters. Our results showed that slope, elevation, and distance of settlement, road, protection station, mine, and human-made construction are the most important variables in the selection of water sources for the studied species. Our results also indicated that natural water resources in summer had the highest importance for *Panthera pardus*, *Ovis orientalis*, *Vulpes vulpes*, *Felis silvestris*, and *Capra aegagrus*, while during the season the artificial water resource showed the highest priority for *Caracal caracal*, *Gazella bennettii*, and *Canis aureus*. Therefore, it is suggested that protected area managers pay more attention to natural water bodies to be sure that wildlife does not face water shortage in critical seasons.

Keywords Bafgh protected area · Geo-ecological characteristic · Logistic regression · Physic-chemical parameter · Species-environment relationships

Introduction

Surface water and renewable and nonrenewable groundwater is a critical resource for wildlife's water management in arid regions (Morgart et al. 2005; Shields et al. 2012;

✉ Azita Farashi
farashi@um.ac.ir

1 Department of Habitats and Biodiversity, Faculty of environment and energy, Islamic Azad University of Tehran–Sciences and Research Branch, Tehran, Iran

2 Department of Environmental Sciences, Faculty of natural resources and environment, Ferdowsi University of Mashhad, Mashhad, Iran

3 Faculty of Industrial & Mechanical Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran

4 Department of Environmental Sciences, Faculty of natural resource, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

Kluever 2015; Kluever et al. 2017; Tanner et al. 2017). Virtually any change in abundance and distribution of water can affect wildlife populations negatively mostly because of the possible conflict between the needs of humans and wildlife for water sources. For example, quality of water sources in Kolah Ghazi National Park, Iran, declined as a local issue of industrial and agricultural activities (Rouhani et al. 2005). Provision of water sources is assumed to be beneficial to wildlife populations and influence animal movements and distributions particularly during dry seasons (Rosenstock et al. 1999; Longshore et al. 2009; Simpson et al. 2011; Larsen et al. 2012; Shields et al. 2012). However, the possible interaction between water sources selection with selection of other resources on the landscape is unclear. To predict the possible side effects of change in the water availability on the surrounding ecosystem, it is necessary to understand the importance of individual habitat components relative to water resources (Barboza et al. 2008; Bleich et al. 2010).

Moreover, the habitat selection of individual animals depends on ecological factors (e.g., temperature, moisture content of forage, or availability of seasonal water sources), biological factors (e.g., predation and competition), and kind of species (Resetarits et al. 2005; McKee et al. 2015; Suárez-Castro et al. 2018). Considering spatial and temporal variability in the habitat selection, the resource selection function (RSF) can be an appropriate approach to model this variation (Manly et al. 2002; Aarts et al. 2008; van Beest et al. 2014). Such as many species distribution models, RSF is also based on spatial point processes and is sensitive to the size and spatial extent of the availability samples (Fortin et al. 2008; Mobæk et al. 2009; McLoughlin et al. 2010; van Beest et al. 2010; Northrup et al. 2013). In the present study, we are interested to understand how water resources are found by wildlife. This information will help us find out the proper locations to install handmade water resource inside the national parks and protected areas. The upside and downside of water resource development was unknown for decades. Based on Sanchez and Haderlie (1990) and Broyles (1995) water supplies could adversely affect wildlife populations and habitats because of increased disease transmission. In the other hands, the efficacy of water catchments for desert bighorn sheep has been challenged by Broyles and Cutler (1999).

Water resource is a limiting factor in the desert and it could be an important factor to define the distribution and productivity of many wildlife species (Rosenstock et al. 1999; Krausman et al. 2006; Rich et al. 2019). The concerns about shortage of water in these areas have become more because of the recent drought crisis. Therefore, water development can have a substantial effect on wildlife (Krausman et al. 2006). Iran is one of the dry countries in the world. Two-thirds of the country receives less than 250 mm of rainfall and arid or semiarid areas cover almost 90% of the country (Chavoshian et al. 2005; Boustani 2008). Therefore, one of the main concerns for wildlife conservation in particular in the central parts of Iran is shortage of water (Abbaspour and Sabetraftar 2005). In the present study, we investigated the physic-chemical parameters (salinity, chlorine, bicarbonate, carbonate, calcium, sodium, potassium, magnesium, total dissolved solids, dissolved oxygen, water temperature, electrical conductivity, and pH) and geo-ecological characteristics (altitude, slope, distance of settlements in rural area, distance of road, distance of stream, distance of protection station, distance of mine, distance of human-made construction, percent coverage of *Phragmites australis*, percent coverage of *Pistacia atlantica*, percent coverage of *Peganum harmala*, percent coverage of *Punica granatum*) of water bodies and their relationships with big mammals' visiting frequencies from these water bodies at Bafgh protected area, center of Iran. We aimed to develop a robust statistical framework to evaluate the available water resources in protected area especially during dry season. Such an evaluation will help planners to develop water resource in future.

Material and methods

Study area and species

Bafgh Protected Area is located at 55° 35′ 30″ E latitude and 31° 30′ 30″ N longitude in the center of Iran and covers an area of 88,528 ha. This area has been assigned as the protected area in 1996 in order to conserve wildlife population and to prevent rangeland degradation. Bafgh has been categorized as extra-arid and arid climate region with mean annual precipitation of 70 mm and mean annual temperature of 16 °C. Springs, wells, air pumps, and small dams at high altitudes are the only water supplies of the region. One of the biggest threats for the area is mining in the neighborhood. The most important active mine is called Choghart which is located in the northwest of the study area. In total, 29 water sources including 15 natural, 10 modified by humans, and 4 artificial are located inside the protected area (Fig. 1). These are the main water bodies for wildlife in the protected area based on the current and historical maps and field work data (Table 1). Natural water sources derived from an underground formation from which water flows naturally to the surface of the earth. The natural water resources can also be changed where flow have been formed or modified for human activities such as navigation, drainage, and water storage as modified by humans and artificial water sources. We have studied eight large mammal species in the protected area. These included *Ovis orientalis* and *Capra aegagrus* as vulnerable, *Panthera pardus* as endangered, and *Vulpes vulpes*, *Canis aureus*, and *Felis silvestris* as least concern on global red list (IUCN, 2018), and *Gazella bennettii* and *Caracal caracal* as endangered on national red list (Karami et al. 2015).

Water source use

In winter and summer 2016, passive infra-red (PIR) cameras were installed (The Digital 3.2, Camtrakker Inc., Watkinsville, Georgia; Pixcontroller, universal controller board Sony DSC P-32 camera, Export, Pennsylvania; or PC900, Reconyx Inc., Holmen, Wisconsin) at known water sources with 3–4-m distance from water (Shields et al. 2012). All cameras had a test function and have been tested before use. The cameras have been located in a flat area without any barrier that blocked the view. In water resources with limited access, the cameras have been attached to the trees with a southerly direction. It helps to minimize false triggers from sun glare and reflection, especially in the dry season (Gillespie et al. 2015). These PIR cameras required both heat and motion to be activated. The cameras were set to detect any motion at 30-cm height above the water source surface. Moreover, we have visited each camera every 10–15 days throughout the sampling period to replace batteries and memory cards and to ensure that cameras were functioning properly. The sampling period was from 20 July until
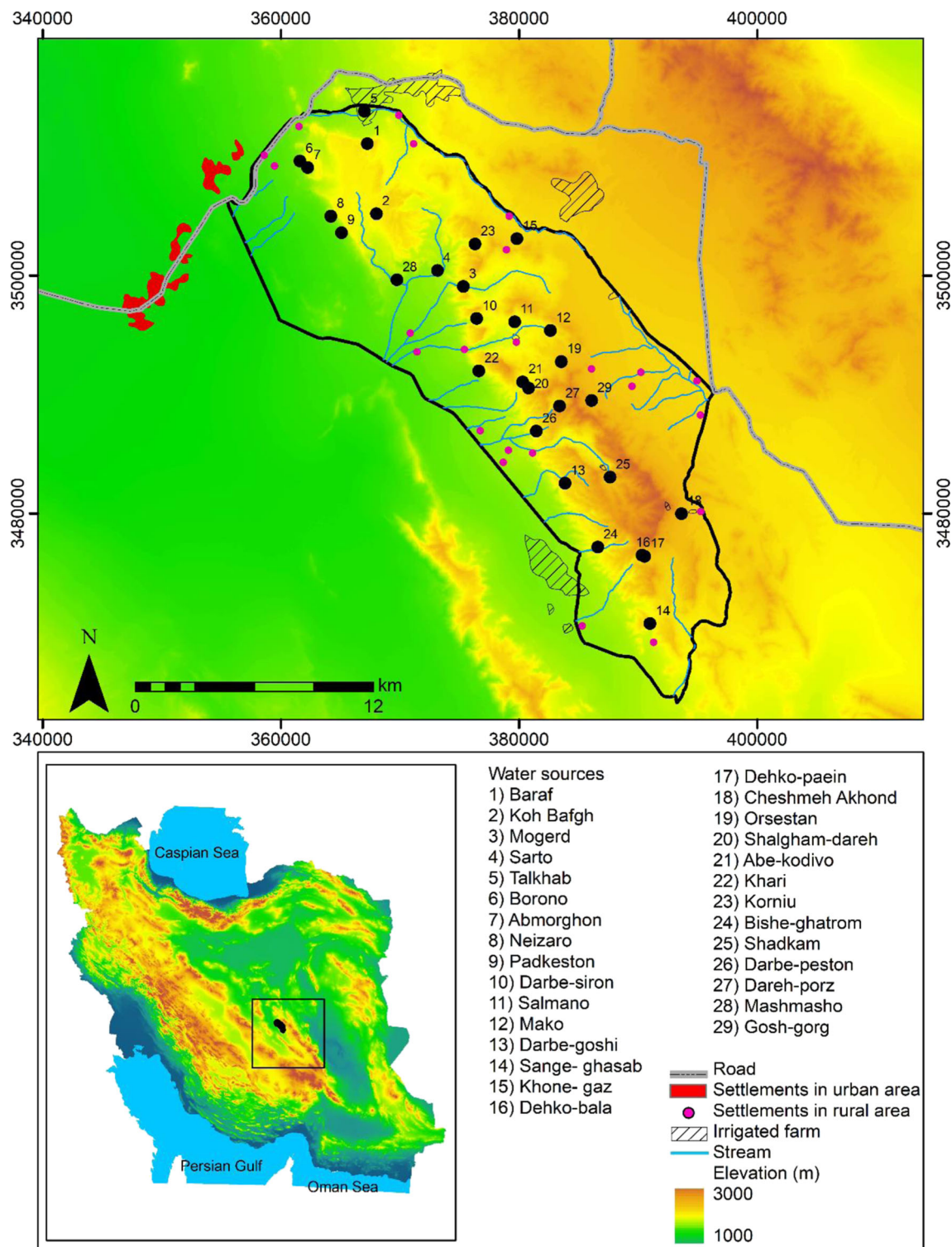
Fig. 1 Bafgh protected area and the water sources with view of digital elevation model

Water sources
1) Baraf
2) Koh Bafgh
3) Mogerd
4) Sarto
5) Talkhab
6) Borono
7) Abmorghon
8) Neizaro
9) Padkeston
10) Darbe-siron
11) Salmano
12) Mako
13) Darbe-goshi
14) Sange- ghasab
15) Khone- gaz
16) Dehko-bala

17) Dehko-paein
18) Cheshmeh Akhond
19) Orsestan
20) Shalgham-dareh
21) Abe-kodivo
22) Khari
23) Korniu
24) Bishe-ghatrom
25) Shadkam
26) Darbe-peston
27) Dareh-porz
28) Mashmasho
29) Gosh-gorg

20 August, and from 20 January until 20 February. We selected these period because water supply is minimal during summer and maximum during winter.

We used two different approaches to identify each individual mammal to measure the density of mammal species visiting the water sources. Firstly, we focused on morphological characteristic, following the protocols described by Ghoddousi et al. (2008), Singh (2008), Gupta et al. (2009) and Anile et al. (2012). Some examples of these characters are number, shape, dimension, and position of stripes, bands,

Table 1 Water sources in Bafgh protected area

Water source	Lat/long	Type
1) Baraf	367269/3511123	Modified by human
2) Koh Bafgh	368025/3505213	Modified by human
3) Mogerd	375322/3499090	Natural
4) Sarto	373157/3500446	Human- made
5) Talkhab	367017/3513850	Modified by human
6) Borono	361600/3509652	Modified by human
7) Abmorghon	362252/3509100	Natural
8) Neizaro	364208/3505008	Natural
9)Padkeston	365094/3503628	Modified by human
10) Darbe-siron	376449/3496400	Modified by human
11) Salmano	379635/3496113	Modified by human
12) Mako	382634/3495384	Natural
13) Darbe-goshi	383864/3482526	Natural
14) Sange-ghasab	391005/3470717	Natural
15) Khone-gaz	379829/3503132	Modified by human
16) Dehko-bala	390336/3476481	Natural
17) Dehko-paein	390555/3476387	Natural
18) Cheshmeh Akhond	393651/3479975	Modified by human
19) Orsestan	383547/3492772	Human-made
20) Shalgham-dareh	380799/3490551	Natural
21) Abe-kodivo	380313/3491077	Natural
22) Khari	376618/3492004	Natural
23) Korniu	376303/3502683	Natural
24) Bishe-ghatrom	386612/3477163	Natural
25) Shadkam	387643/3483045	Natural
26) Darbe-peston	381462/3486928	Modified by human
27) Dareh-porz	383410 3489039	Natural
28) Mashmasho	369747/3499668	Human-made
29) Gosh-gorg	386095/3489509	Human-made

and spots on the body, color pattern, and size for *Panthera pardus*, *Vulpes vulpes*, *Canis aureus*, *Felis silvestris*, *Gazella bennettii*, and *Caracal caracal*, and horn shape and horn size for *Ovis orientalis* and *Capra aegagrus*. Secondly, we got help from online platforms such as Online Citizen Science websites e.g., eMammal (McShea et al. 2016), iSpot (Silvertown et al. 2015), and BeeWatch (van der Wal et al. 2016) in order to access millions of volunteers and scientist to supply guidelines, additional information, classification data, and annotation tools to identify individual animals in camera trap images.

Physic-chemical analyses of water sources

Sampling of physic-chemical parameters was carried out every day from 1 August until 10 August in summer and from 30 January until 10 February in winter 2016 at 29 water bodies. Samples were collected at 30 cm below the surface water

using a water sampler and acid washed container to avoid any unpredicted changes. The sampler was an open water grab sampler (a bottle of 3 L). The samples of water were immediately transported to a laboratory under low-temperature conditions in ice boxes and stored in the laboratory at 4 °C. The physic-chemical variables (Table 2) were analyzed in the laboratory according to APHA's (2012) methods, and total dissolved solids, dissolved oxygen, temperature, electrical conductivity, pH, and salinity were detected in situ.

Determining geo-ecological characteristics of water sources

Geo-ecological variables that have been incorporated in our study were topographic, land cover/land use characteristics, and vegetation variables (Table 2). Topographic variables have been obtained from a digital elevation model (DEM) that was generated by the national cartographic center of Iran (NCC) at 1:25000 scale. Land use/land cover variables were obtained from the Iranian Department of Environment at 1:25000 scale. We used distance analysis (IDRISI Selva) on the Boolean version of each variable to see if water resource selection changes with distance from them. Vegetation variables have been obtained from field work. Each water resource has been covered with a 3×3-m sampling plot to survey vegetation cover. Within each plot, plant species were identified and relative percentage coverage was estimated to the nearest 5% with the grid.

Statistical analyses

We have used a one-way ANOVA and Duncan test to see if the environmental parameter (chemical and geo-ecological) are significantly different between water resources. The multi-collinearity test has been performed among the environmental variables to prevent the possible bias in the results (Pandit et al. 2013). We developed species–environment relationships (SERs) using a backward-selected logistic regression (p value 0.05) and density of mammal species visiting the water sources (Lynn et al. 2008). We have developed a separate model for each species, because we expected that species may respond to their environment differently. The relative support for logistic regression models has been assessed on the basis of corrected Akaike's information criterion (AIC_c) (Akaikei 1973; Wang et al. 2005; Michaletz et al. 2018). Models with $\Delta AICc < 2$ are equally plausible given the data and suggesting substantial support. The relative likelihood of models to the best-supported model has been compared using the ratio of model weights (wi) (Burnham and Anderson 2002).

All statistical analyses were performed in the R statistical software version 3.2.4 by *MASS* and *car* package (R Core Team 2016).

Table 2 Environmental parameters with their mean, range of variation, and statistical difference observed during the study period. Statistical results are for one-way ANOVA and Duncan's test (main effects: S, season; W, water source; interaction, $S \times W$, $*p < 0.05$; $**p < 0.01$)

Variables	Abbrev.	Winter Mean	SD	Min	Max	Summer Mean	SD	Min	Max	ANOVA S	W	S×W	Duncan S	W
Geo-ecological variable														
Altitude	GE-A	1600.39	45.001	1501.38	1641.41	1600.39	45.001	1501.38	1641.41	**	**	—	**	**
Slope	GE-S	20.143	1.001	19.141	28.145	20.143	1.001	19.141	28.145	**	**	—	**	**
Distance of settlements in rural area	GE-DSR	8453.246	32.219	8050.806	9455.687	8453.246	32.219	8050.806	9455.687	**	**	—	**	**
Distance of road	GE-DR	811.384	98.808	395.747	847.022	811.384	98.808	395.747	847.022	**	**	—	**	**
Distance of stream	GE-DS	353.598	8.001	293.596	393.600	353.598	8.001	293.596	393.600	**	**	—	*	**
Distance of protection station	GE-DP	11,000.591	5.219	3367.152	13,368.030	11,000.591	5.219	3367.152	13,368.030	**	**	—	**	**
Distance of mine	GE-DM	8092.384	32.001	8002.382	8592.386	8092.384	32.001	8002.382	8592.386	**	**	—	*	*
Distance of human-made construction	GE-DH	2255.660	27.001	1255.658	3255.662	2255.660	27.001	1255.658	3255.662	**	**	—	**	**
Percent coverage of *Phragmites australis*	GE-PH	0.015	0.011	0.003	0.097	0.015	0.011	0.003	0.097	**	**	—	*	*
Percent coverage of *Pistacia atlantica*	GE-PI	0.174	0.018	0.012	0.576	0.174	0.018	0.012	0.576	**	**	—	*	*
Percent coverage of *Peganum harmala*	GE-PE	0.108	0.041	0.001	0.510	0.108	0.041	0.001	0.510	**	**	—	**	**
Percent coverage of *Punica granatum*	GE-PU	0.139	0.031	0.008	0.541	0.139	0.031	0.008	0.541	**	**	—	**	**
Physico-chemical variable														
pH	PC-PH	7.896	0.001	7.894	7.898	8.019	0.001	8.017	8.022	—	—	*	—	—
Electrical conductivity (μs cm^{-1})	PC-EC	2.902	0.001	2.901	2.904	2.482	0.001	2.480	2.483	—	—	—	—	—
Water temperature (C°)	PC-T	15.908	1.219	13.483	18.349	24.498	1.219	22.057	26.939	—	—	*	—	—
Dissolved oxygen (mg L^{-1})	PC-DO	6.604	0.001	6.602	6.606	4.668	0.001	4.666	4.670	—	—	*	—	—
Total dissolved solids (mg L^{-1})	PC-TD	1.585	0.001	1.583	1.587	1.224	0.001	1.242	1.246	—	—	—	—	—
Magnesium (mg L^{-1})	PC-M	7.160	0.001	7.158	7.162	4.048	0.001	4.047	4.050	—	—	*	—	—
Potassium (mg L^{-1})	PC-P	0.505	0.181	0.142	0.868	4.639	0.181	4.227	5.002	—	—	*	—	—
Sodium (mg L^{-1})	PC-S	26.194	0.246	25.703	26.686	200.522	0.246	200.061	201.044	—	—	*	—	—
Calcium (mg L^{-1})	PC-CL	7.227	0.001	7.225	7.229	10.829	0.001	10.827	10.831	—	—	*	—	—
Carbonate (mg L^{-1})	PC-CA	26.222	0.001	26.220	26.223	1.246	0.001	1.245	1.248	—	—	*	—	—
Bicarbonate (mg L^{-1})	PC-BI	11.327	0.114	11.100	11.555	4.405	0.114	4.177	4.633	—	—	*	—	—
Chlorine (mg L^{-1})	PC-CH	30.177	0.001	30.176	30.179	15.128	0.001	15.127	15.130	—	—	*	—	—
Salinity	PC-S	2.229	0.001	2.297	2.301	1.153	0.001	1.151	1.155	—	—	*	—	—

Results

Water source use

We obtained about 3000 photographs of camera traps at 29 water bodies over the 60 days. The list of captured species and number of individuals has been presented in. Our obtained results showed that Mogerd water resource had the most visits during winter and Mashmasho and Mogerd had the most visits during summer in terms of the number of species and individuals. The water bodies Cheshmeh Akhond and Salmano have only been visited by *Ovis orientalis* during both winter and summer.

Environmental variable

Water temperature followed a typical seasonal trend, with a minimum of 13.5 °C in winter and a maximum of 26.9 °C in summer. pH showed a range between 7.8 and 8.0. The maximum concentration of Do was recorded in winter (6.6 mg L^{-1}). The total dissolved solids, electrical conductivity, magnesium, carbonate, bicarbonate, chlorine, and salinity values showed a decreased trend from winter to summer while potassium, sodium, and calcium had higher values during the summer. The amount of carbonate, potassium, and sodium highly changed during study period. The results of one-way ANOVA have been presented in Table 2. All geo-ecological variables had a significant difference among types of water sources while the physic-chemical variables showed none significant difference among water sources. There no differences between the geo-ecological variables between the different seasons and they are the same in winter and summer. The results of Duncan's test showed that the natural water resources and water resources that were modified by humans were located in one group and artificial water resource was located in a separate group.

Logistic regression model

Out of 25 environmental variables, we remove physich-chemical ones from the regression analysis since they did not show any significant difference with each other. Therefore, we used 12 geo-ecological variables in the regression analysis. Our results showed that the correlation among these 12 variables is very low.

The results of logistic regression are presented in Table 3. The best model has been selected by AIC_c. Distance from human-made constructions was the most important environmental variable for water source selection by *P. pardus*, *F. silvestris*, *G. bennettii*, and *C. aegagrus*. The distance of settlements in rural area was the most important environmental variable for *C. caracal*, *C. aureus*, and *O. orientalis*. In contrast, distance from stream and occurrence of *P. australis* had no contributions to the model development of all species

(Table 3). Some variables showed importance only for some specific species. For example, altitude was not important for water source selection by *C. caracal*, *C. aureus*, and *V. vulpes* while the same variables played a more important role for other species. The results also showed that the positive or negative effects of the variables are the same among different species. The obtained results showed that the studied species preferred water sources near mines, located in low-altitude plains, and with few vegetation cover. However, our model suggested that these species tended to avoid water sources near the road, settlements, protection station, and human-made construction.

Discussion

The water bodies provided by human may help reduce the current conflict between the needs of humans and wildlife for water (Simpson et al. 2011; Larsen et al. 2012). Getting more knowledge about the conditions of water sources that are used by wildlife will help to develop strategies to conserve and manage species that rely on this resource (Whiting et al. 2010; Shields et al. 2012). Our results indicated that large mammal species visited water sources with multiple frequencies. Despite the population size, our results showed that the dependence of herbivores to water resource is higher than carnivores (Fig. 2). In general, water requirements are highest for herbivores, intermediate for omnivores, and lowest for carnivores (Wolff 2001). Carnivores are less affected by water shortage because they acquire much of their water from prey (MacDonald et al. 1984; Golightly Jr and Ohmart 1984; Wolff 2001). However, when water becomes scarcer the prey number declined. Therefore the ambushing near water sources increase, where prey is known to frequently visit (Calvert 2015).

Slope and elevation were important predictors for number of water source visits that is in line with previous studies (Cain et al. 2008; Calvert 2015). Results showed the importance of topographic variables for *C. aegagrus*, *G. bennettii*, *O. orientalis*, *F. silvestris*, and *P. pardus* that preferred water sources which are located in lower elevation has a gradual slope. Conversely, topographic variables were not important to *V. vulpes*, *C. aureus*, and *C. caracal.*

The terrain condition of water bodies could be an adaptation for escape from both predators and other ungulate competitors (McCutchen 1981; Calvert 2015). Our results revealed that the vegetation cover had a very low effect on water selection by most species. However, Hicks and Elder 1979; Lawhead 1984; Kamler and Gipson 2000; Calvert 2015 have found vegetation cover as an important variable for water bodies selection by large mammal species.

Based on Fig. 2, natural water resources in summer had the highest importance for *P. pardus*, *O. orientalis*, *V. vulpes*, *F. silvestris*, and *C. aegagrus*, while during summer season the

Table 3 Summary statistics for the five candidate logistic regression models (the best model is in italics; *K*, number of estimable parameters; AIC$_c$, sample size corrected Akaike's information criterion; Δ*i*, difference between the AIC$_c$ value of the *i*th model and that of the best model; wi, Akaike weight)

Species	Model	Variables	K	Wi	AICc	Δi
P. pardus	*1*	*GE-A (− 0.20), GE-S (0.11), GE-DSR (0.15), GE-DP (0.20), GE-DM (− 0.14), GE-DH (0.33), constant (− 1.11)*	8	0.50	289.78	0.00
	2	GE-A (−0.18), GE-S (0.10), GE-DSR (0.04), GE-DP (0.22), GE-DM (− 0.45), GE-DH (0.08), constant (− 2.66)	8	0.26	322.87	33.09
	3	GE-A (−0.15), GE-S (0.10), GE-DSR (0.05), GE-DP (0.24), GE-DM (− 0.14), GE-DH (0.20), constant (− 9.70)	7	0.11	380.96	91.18
	4	GE-A (−0.18), GE-S (0.91), GE-DSR (0.13), GE-DM (− 0.19), GE-DH (0.20), constant (2.09)	6	0.14	367.40	77.62
	5	GE-A (−0.19), GE-S (0.11), GE-DSR (0.18), GE-DP (0.52), GE-DM (− 0.13), GE-DH (0.21), constant (− 5.10)	8	0.20	350.83	61.05
F. silvestris	*1*	*GE-A (− 0.20), GE-S (0.11), GE-DSR (0.13), GE-DR (0.11), GE-DP (0.21), GE-DM (− 0.11), GE-DH (0.35), GE-PE (− 0.18), constant (0.66)*	9	0.49	250.79	0.00
	2	GE-A (−0.22), GE-S (0.19), GE-DSR (0.12), GE-DR (0.10), GE-DP (0.20), GE-DH (0.30), GE-PE (− 0.17), Constant (0.13)	8	0.14	330.42	79.63
	3	GE-A (−0.20), GE-S (0.10), GE-DSR (0.18), GE-DR (0.16), GE-DP (0.26), GE-DM (− 0.15), GE-DH (0.20), GE-PE (− 0.11), Constant (0.16)	9	0.20	277.38	26.59
	4	GE-A (−0.19), GE-S (0.15), GE-DSR (0.16), GE-DR (0.16), GE-DP (0.21), GE-DM (− 0.15), GE-DH (0.20), GE-PE (− 0.19), Constant (0.10)	9	0.01	420.54	169.75
	5	GE-A (−0.17), GE-S (0.10), GE-DSR (0.13), GE-DR (0.17), GE-DP (0.21), GE-DM (−0.15), GE-DH (0.17), GE-PE (−0.10), Constant (0.19)	9	0.01	411.79	161.00
C. caracal	*1*	*GE-S (0.11), GE-DSR (0.50), GE-DP (0.27), constant (7.55)*	4	0.62	190.57	0.00
	2	GE-S (0.15), GE-DSR (0.10), GE-DP (0.01), constant (3.02)	4	0.37	198.54	7.97
	3	GE-A (− 0.18), GE-DSR (0.19), constant (4.20)	3	0.35	200.19	9.62
	4	GE-S (0.18), GE-DSR (0.13), GE-DP (0.20), constant (2.22)	4	0.25	234.88	44.31
	5	GE-S (1.11), GE-DSR (0.10), GE-DP (1.03), constant (1.89)	4	0.22	245.50	54.93
C. aureus	*1*	*GE-S (0.10), GE-DSR (0.60), GE-PU (− 0.27), constant (4.00)*	4	0.61	255.70	0.00
	2	GE-S (0.10), GE-DSR (0.84), GE-PU (− 0.13), constant (6.05)	4	0.29	288.43	32.73
	3	GE-S (0.11), GE-DSR (0.11), GE-PU (− 0.15), constant (0.68)	4	0.10	348.61	92.91
	4	GE-S (0.12), GE-DSR (0.30), GE-PU (− 0.96), constant (0.25)	4	0.01	388.32	132.62
	5	GE-S (1.14), GE-DSR (0.10), GE-PU (− 0.19), constant (2.05)	4	0.27	294.94	39.24
V. vulpes	*1*	*GE-PI (− 0.26), GE-PU (− 0.17), constant (2.40)*	2	0.49	132.37	0.00
	2	GE-PI (− 0.20), GE-PU (− 0.84), constant (5.10)	2	0.22	156.54	24.17
	3	GE-PI (− 0.42), GE-PU (− 0.16), constant (2.45)	2	0.21	190.60	58.23
	4	GE-PI (−0.21), GE-PU (− 1.25), constant (3.80)	2	0.17	203.19	70.82
	5	GE-PI (− 0.50), GE-PU (− 0.16), constant (7.77)	2	0.07	233.38	101.01
O. orientalis	*1*	*GE-A (− 0.20), GE-S (0.10), GE-DSR (0.76), GE-DP (0.21), GE-DM (− 0.14), GE-PI (− 0.23), GE-PE (− 0.15), GE-PU (− 0.13), constant (2.90)*	9	0.52	287.47	0.00
	2	GE-A (−0.20), GE-S (0.10), GE-DSR (0.87), GE-DP (0.01), GE-DM (− 0.19), GE-PU (− 0.14), constant (7.22)	7	0.27	322.49	35.02
	3	GE-A (−0.10), GE-S (0.11), GE-DSR (0.16), GE-DP (0.09), GE-DM (− 0.15), GE-PI (− 0.15), GE-PU (− 0.77), constant (1.20)	9	0.33	305.18	17.71
	4	GE-A (−0.22), GE-S (0.10), GE-DSR (0.16), GE-DP (0.21), GE-DM (−0.11), GE-PI (−0.29), GE-PE (−1.17), GE-PU (−0.16), constant (4.33)	9	0.32	310.29	22.82
	5	GE-A (−0.22), GE-S (1.14), GE-DSR (0.16), GE-DP (0.16), GE-DM (−0.11), GE-PI (− 0.29), GE-PU (− 0.12), GE-PU (− 0.75), constant (2.20)	9	0.35	299.56	12.09
G. bennettii	*1*	*GE-A (− 0.20), GE-S (0.11), GE-DSR (0.16), GE-DR (0.16), GE-DP (0.21), GE-DM (− 0.15), GE-DH (0.34), constant (0.87)*	8	0.49	205.31	0.00
	2	GE-A (−0.18), GE-S (0.89), GE-DSR (0.16), GE-DR (0.16), GE-DM (−0.15), GE-DP (0.01), GE-DH (0.26), constant (2.33)	8	0.10	298.55	93.24
	3	GE-A (−0.19), GE-S (0.10), GE-DSR (0.16), GE-DR (2.16), GE-DP (0.21), constant (1.03)	6	0.01	333.49	128.18
	4	GE-A (−0.19), GE-S (0.85), GE-DSR (0.16), GE-DR (0.14), GE-DP (0.21), GE-DM (−0.15), GE-DH (0.28), constant (8.77)	7	0.13	285.99	80.68
	5	GE-A (−0.20), GE-S (0.90), GE-DSR (0.16), GE-DR (0.18), GE-DP (0.24), GE-DM (−0.15), GE-DH (0.29), constant (9.67)	7	0.25	240.82	35.51

Table 3 (continued)

Species	Model	Variables	K	Wi	AICc	Δi
C. aegagrus	1	GE-A (−0.22), GE-S (0.10), GE-DSR (0.16), GE-DR (0.15), GE-DP (0.21), GE-DM (−0.10), GE-DH (0.30), constant (0.33)	8	0.49	192.32	0.00
	2	GE-A (−0.22), GE-S (0.11), GE-DSR (0.16), GE-DR (0.15), GE-DP (0.21), GE-DM (−0.15), GE-DH (1.30), constant (0.37)	8	0.22	244.50	52.18
	3	GE-A (−0.22), GE-S (0.11), GE-DSR (0.10), GE-DR (0.12), GE-DP (0.11), GE-DM (−0.11), GE-DH (1.30), constant (0.63)	8	0.01	342.65	150.33
	4	GE-A (−0.21), GE-S (0.12), GE-DSR (0.15), GE-DR (0.16), GE-DP (0.20), GE-DM (−0.13), GE-DH (0.31), constant (1.30)	8	0.30	222.30	29.98
	5	GE-A (−0.20), GE-S (0.94), GE-DSR (0.16), GE-DR (3.11), GE-DP (0.80), constant (0.99)	6	0.12	277.24	84.92

artificial water resource showed the highest priority for *C. caracal*, *G. bennettii*, and *C. aureus*. Therefore, it is suggested that protected area managers pay more attention to natural water bodies to be sure that wildlife does not face water shortage in critical seasons. Therefore, it is crucial to consider water resource in any conservation and management plans of wildlife habitats (Whiting et al. 2010). Beside natural water bodies, the construction of artificial ones is important for the conservation of populations of species (Marshal et al. 2006; Whiting et al. 2010).

The results of the logistic regression for *P. pardus* and *C. aegagrus* were very similar, but different from *O. orientalis*. These results are important from two points of view: (1) Although *P. pardus* feed on different deer species, gazelles, small mammals, birds, and even insects, but the major prey species for this species in Iran are *C. aegagrus* (Karami et al. 2015; Ebrahimi et al. 2017). Therefore, the distribution of wild goats plays a major role to define the distribution range of the species. (2) Many studies showed that *P. pardus* and *C. aegagrus* used similar habitat types and were mostly distributed in the rocky mountains (e.g., Ziaee 2009; Ebrahimi et al. 2017; Farashi et al. 2017). This is in line with our obtained results.

Our study showed that the water physic-chemical parameters play no role in water source selection by mammal's species. Based on our knowledge, there is no clear evidence that the water quality of anthropogenic water bodies is problematic for wildlife. Several investigators have concluded that artificial water resource in desert do not create a health threat for wildlife (Rosenstock et al. 2004, 2005; Bleich et al. 2006; Simpson et al. 2011). It is possible that specific water elements do not meet the guidelines of water quality for livestock (the guidelines are developed to allow an assessment of the acceptability of water quality for livestock (Wolff 1988; Higgins et al. 2008; Alkire 2008; Olkowski 2011) at artificial water developments, but they have rarely occurred (Rosenstock et al. 2005; Bleich et al. 2006).

Our results recommended that new catchments in Bafgh protected area must be placed in area with low elevation and high slopes. Moreover, they must be near a mine and far from road, settlements, protection station, and human-made constructions.

With respect to the dry climate of Iran and the recent reports of wildlife death because of water shortage, creating a water network inside of the protected areas in Iran seems to be very essential. Although we had shortage of available data especially for *C. aureus* and *F. silvestris*, but we tried to make a framework for a conservational planner to build appropriate artificial water resource for wildlife. However, to have a better judgment about each species, we need further studies with a wider range of data (including biotic variables, abiotic variables, and their interactions). Moreover, beside the
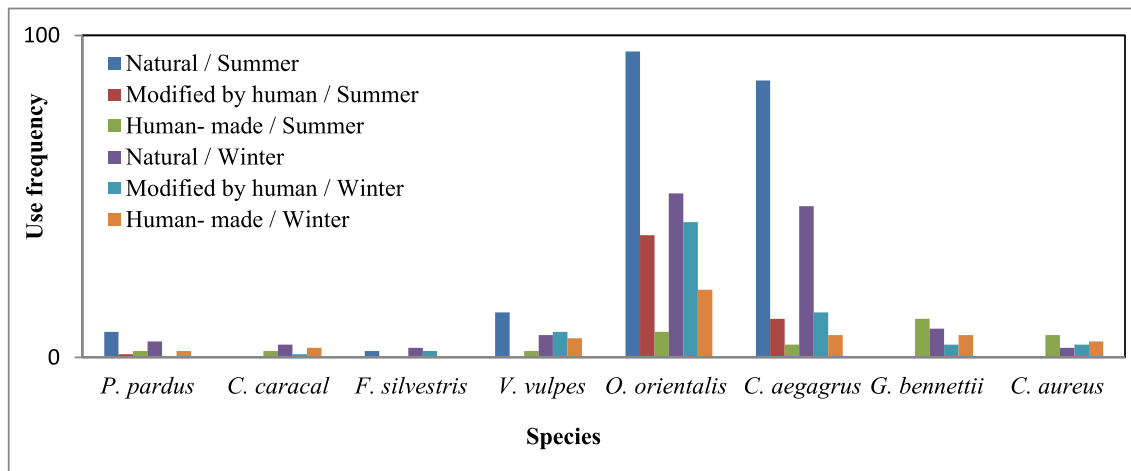
Fig. 2 The priority in water resource usage for different species during summer and winter seasons

effects of other factors in determining water resource selection, future studies should also consider niche shift and the effects of climatic changes on species' natural distribution.

References

Aarts G, MacKenzie M, McConnell B, Fedak M, Matthiopoulos J (2008) Estimating space-use and habitat preference from wildlife telemetry data. Ecography 31(1):140–160

Abbaspour M, Sabetraftar A (2005) Review of cycles and indices of drought and their effect on water resources, ecological, biological, agricultural, social and economical issues in Iran. Int J Environ Stud 62(6):709–724

Akaikei, H. (1973). Information theory and an extension of maximum likelihood principle. In Proc. 2nd Int. Symp. on Information Theory (pp. 267–281)

Alkire D (2008) Livestock water guidelines. Samuel Roberts Noble Foundation

Anile S, Amico C, Ragni B (2012) Population density estimation of the European wildcat (*Felis silvestris silvestris*) in Sicily using camera trapping. Wildl Biol Pract 8(1):1–12

Barboza PS, Parker KL, Hume ID (2008) Integrative wildlife nutrition. Springer Science & Business Media

Bleich VC, Andrew NG, Martin MJ, Mulcahy GP, Pauli AM, Rosenstock SS (2006) Quality of water available to wildlife in desert environments: comparisons among anthropogenic and natural sources. Wildl Soc Bull 34(3):627–632

Bleich VC, Marshal JP, Andrew NG (2010) Habitat use by a desert ungulate: predicting effects of water availability on mountain sheep. J Arid Environ 74(6):638–645

Boustani, F. (2008). Sustainable water utilization in arid region of Iran by Qanats. In Proceeding of World Academy of Science, Engineering and Technology (Vol. 33, pp. 213–216)

Broyles B (1995) Desert wildlife water developments: questioning use in the Southwest. Wildl Soc Bull (1973–2006) *23*(4):663–675

Broyles B, Cutler TL (1999) Effect of surface water on desert bighorn sheep in the Cabeza Prieta National Wildlife Refuge, southwestern Arizona. Wildl Soc Bull:1082–1088

Burnham KP, Anderson DR (2002) Multimodel inference: understanding AIC and BIC in model selection. Sociological Methods & Research 33(2):261–304

Cain JW III, Krausman PR, Morgart JR, Jansen BD, Pepper MP (2008) Responses of desert bighorn sheep to removal of water sources. Wildlife Monographs, 171(1):1–32

Calvert, J. (2015). Large mammal water use on the Barry M. Goldwater range-east in Southwestern Arizona (Doctoral dissertation)

Chavoshian, S. A., Takeuchi, K., & Funada, S. (2005). An overview to transboundary and shared water resources management in Iran, technical challenges and solutions. *The role of water sciences in transboundary river basin management,* Proc. Thailand, 189–195

Ebrahimi A, Farashi A, Rashki A (2017) Habitat suitability of Persian leopard (*Panthera pardus saxicolor*) in Iran in future. Environ Earth Sci 76(20):697

Farashi A, Shariati M, Hosseini M (2017) Identifying biodiversity hotspots for threatened mammal species in Iran. Mamm Biol 87: 71–88

Fortin D, Morris DW, McLoughlin PD (2008) Habitat selection and the evolution of specialists in heterogeneous environments. Israel J Ecol Evolution 54(3–4):311–328

Ghoddousi A, Hamidi AHK, Ghadirian T, Ashayeri D, Moshiri H, Khorozyan I (2008) The status of the persian leopard in Bamu National Park, Iran. Cat News 49:10–13

Gillespie, G. R., Brennan, K., Gentles, T., Hill, B., Low Choy, J., Mahney, T., ... & Stokeld, D. (2015). A guide for the use of remote cameras for wildlife survey in northern Australia. *National Environmental Research Program, Northern Australia Hub: Charles Darwin University,* Casuarina, NT

Golightly RT Jr, Ohmart RD (1984) Water economy of two desert canids: coyote and kit fox. J Mammal 65(1):51–58

Gupta S, Mondal K, Sankar K, Qureshi Q (2009) Estimation of striped hyena Hyaena hyaena population using camera traps in Sariska Tiger Reserve, Rajasthan, India. J Bombay Nat Hist Soc 106(3):284

Hicks LL, Elder JM (1979) Human disturbance of Sierra Nevada bighorn sheep. J Wildl Manag 43:909–915

Higgins, S. F., Agouridis, C. T., & Gumbert, A. A. (2008). Drinking water quality guidelines for cattle. *University of Kentucky Cooperative Extension Service ID-170*

IUCN Standards and Petitions Subcommittee. (2018). Guidelines for using the IUCN red list categories and criteria version 2. Prepared by the standards and petitions subcommittee. http://cmsdocs.s3. amazonaws.com/RedListGuidelines.pdf

Kamler JF, Gipson PS (2000) Home range, habitat selection, and survival of bobcats, *Lynx rufus*, in a prairie ecosystem in Kansas. Canadian Field-Naturalist 114(3):388–394

Karami M, Ghadirian T, Faizolahi K (2015) The atlas of the mammals of Iran. Iran Department of the Environment, Tehran, Iran

Kluever BM (2015) Relationships between water developments and select mammals on the US Army Dugway proving ground. Utah State University, Utah

Kluever BM, Gese EM, Dempsey SJ (2017) Influence of free water availability on a desert carnivore and herbivore. Current Zoology 63(2):121–129

Krausman PR, Rosenstock SS, III JWC (2006) Developed waters for wildlife: science, perception, values, and controversy. Wildl Soc Bull 34(3):563–569

Larsen RT, Bissonette JA, Flinders JT, Whiting JC (2012) Framework for understanding the influences of wildlife water developments in the western United States. Calif Fish Game 98(3):148–163

Lawhead DN (1984) Bobcat *Lynx rufus* home range, density and habitat preference in South-Central Arizona. Southwest Nat 29:105–113

Longshore KM, Lowrey C, Thompson DB (2009) Compensating for diminishing natural water: predicting the impacts of water development on summer habitat of desert bighorn sheep. J Arid Environ 73(3):280–286

Lynn JC, Rosenstock SS, Chambers CL (2008) Avian use of desert wildlife water developments as determined by remote videography. West N Am Naturalist 68(1):107–112

MacDonald ML, Rogers QR, Morris JG (1984) Nutrition of the domestic cat, a mammalian carnivore. Annu Rev Nutr 4(1):521–562

Manly BFJ, McDonald LL, Thomas DL, McDonald TL, Erickson WP (2002) Resource selection by animals: statistical design and analysis for field studies, 2nd edn. Kluwer Academic Publishers, Dordrecht, The Netherlands

Marshal JP, Bleich VC, Krausman PR, Reed ML, Andrew NG (2006) Factors affecting habitat use and distribution of desert mule deer in an arid environment. Wildl Soc Bull 34(3):609–619

McCutchen HE (1981) Desert bighorn zoogeography and adaptation in relation to historic land use. Wildl Soc Bull:171–179

McKee CJ, Stewart KM, Sedinger JS, Bush AP, Darby NW, Hughson DL, Bleich VC (2015) Spatial distributions and resource selection by mule deer in an arid environment: responses to provision of water. J Arid Environ 122:76–84

McLoughlin PD, Morris DW, Fortin D, Vander Wal E, Contasti AL (2010) Considering ecological dynamics in resource selection functions. J Anim Ecol 79(1):4–12

McShea WJ, Forrester T, Costello R, He Z, Kays R (2016) Volunteer-run cameras as distributed sensors for macrosystem mammal research. Landscape Ecology 31(1):55–66

Michaletz ST, Kerkhoff AJ, Enquist BJ (2018) Drivers of terrestrial plant production across broad geographical gradients. Glob Ecol Biogeogr 27(2):166–174

Mobæk R, Mysterud A, Egil Loe L, Holand Ø, Austrheim G (2009) Density dependent and temporal variability in habitat selection by a large herbivore; an experimental approach. Oikos 118(2):209–218

Morgart JR, Hervert JJ, Krausman PR, Bright JL, Henry RS (2005) Sonoran pronghorn use of anthropogenic and natural water sources. Wildl Soc Bull 33(1):51–60

Northrup JM, Hooten MB, Anderson CR Jr, Wittemyer G (2013) Practical guidance on characterizing availability in resource selection functions under a use–availability design. Ecology 94(7):1456–1463

Olkowski, A. A. (2011). Livestock water quality: a field guide for cattle, horses, poultry and swine. Agriculture & Agri-Food Canada

Pandit SN, Zhao Y, Ciborowski JJ, Gorman AM, Knight CT (2013) Suitable habitat model for walleye (*Sander vitreus*) in Lake Erie: implications for inter-jurisdictional harvest quota allocations. J Great Lakes Res 39(4):591–601

R Core Team (2016) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org

Resetarits, W., Binckley, C. A., & Chalcraft, D. R. (2005). Habitat selection, species interactions, and processes of community assembly in complex landscapes. *Metacommunities: spatial dynamics and ecological communities.* University of Chicago Press, Chicago, 374–398

Rich LN, Beissinger SR, Brashares JS, Furnas BJ (2019) Artificial water catchments influence wildlife distribution in the Mojave Desert. J Wildl Manag 83(4):855–865

Rosenstock SS, Ballard WB, Devos JC Jr (1999) Benefits and impacts of wildlife water developments. J Range Manag 52:302–311

Rosenstock SS, Rabe MJ, O'brien CS, Waddell RB (2004) Studies of wildlife water developments in southwestern Arizona: wildlife use, water quality, wildlife diseases, wildlife mortalities, and influences on native pollinators. Tech Guid Bull 8:1–15

Rosenstock SS, Bleich VC, Rabe MJ, Reggiardo C (2005) Water quality at wildlife water sources in the Sonoran Desert, United States. Rangel Ecol Manag 58(6):623–627

Rouhani, F., Jalili, KH., Mokhtari, K. (2005). Determination of the quantitative and qualitative status of water resources based on wildlife requirements in Kolah-Ghazi National Park. Water resources management conference, Tehran, Iran

Sanchez, J. E., & Haderlie, M. K. (1990). Water management on Cabeza Prieta and Kofa National Wildlife Refuges. In Proceedings of the wildlife water development symposium (Vol. 30, pp. 73–77)

Shields AV, Larsen RT, Whiting JC (2012) Summer watering patterns of mule deer in the Great Basin Desert, USA: implications of differential use by individuals and the sexes for management of water resources. Sci World J 2012:1–9

Silvertown J, Harvey M, Greenwood R, Dodd M, Rosewell J, Rebelo T, Ansine J, McConway K (2015) Crowdsourcing the identification of organisms: a case-study of iSpot. ZooKeys 480:125–146

Simpson NO, Stewart KM, Bleich VC (2011) What have we learned about water developments for wildlife? Not enough! Calif Fish Game 97(4):190–209

Singh, P. (2008). *The population estimation and feeding habits of Striped Hyena (Hyaena hyaena) in related to land use pattern in semiarid region of Rajasthan* (doctoral dissertation, M. Sc., thesis submitted to Manipal University, India)

Suárez-Castro AF, Simmonds JS, Mitchell MG, Maron M, Rhodes JR (2018) The scale-dependent role of biological traits in landscape ecology: a review. Current Landscape Ecology Reports 3(1):12–22

Tanner EP, Elmore RD, Davis CA, Fuhlendorf SD (2017) Wintering bird responses to the presence of artificial surface water in a semi-arid rangeland. Wildl Biol 2017:wlb-00315

Van Beest FM, Mysterud A, Loe LE, Milner JM (2010) Forage quantity, quality and depletion as scale-dependent mechanisms driving habitat selection of a large browsing herbivore. J Anim Ecol 79(4):910–922

van Beest FM, Uzal A, Vander Wal E, Laforge MP, Contasti AL, Colville D, McLoughlin PD (2014) Increasing density leads to generalization in both coarse-grained habitat selection and fine-grained resource selection in a large mammal. J Anim Ecol 83(1):147–156

van der Wal R, Sharma N, Mellish C, Robinson A, Siddharthan A (2016) The role of automated feedback in training and retaining biological recorders for citizen science. Conserv Biol 30(3):550–561

Wang Q, Ni J, Tenhunen J (2005) Application of a geographically-weighted regression analysis to estimate net primary production of Chinese forest ecosystems. Glob Ecol Biogeogr 14(4):379–393

Whiting JC, Bowyer RT, Flinders JT, Bleich VC, Kie JG (2010) Sexual segregation and use of water by bighorn sheep: implications for conservation. Anim Conserv 13(6):541–548

Wolff P (1988) Guidelines for livestock drinking water quality in dry areas. J Agr Trop 89(2):85–94

Wolff, F. (2001). *Vertebrate ecology in caatinga: A. Distribution of wildlife in relation to water. B. Diet of pumas (Puma concolor) and relative abundance of felids* (doctoral dissertation, Tesis de Maestría, University of Missouri-St. Louis)

Ziaee H (2009) Field guide to mammals of Iran. Wildlife Center Publication, Tehran, p 450 **(in Persian)**

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.