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How Prey Density and Distribution Can Affect Predator Habitat Usage Pattern: a Case Study on Sand Cat (*Felis margarita*, Locke 1858) from Iran[1]

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Abstract—Prey-predator relationships can affect habitat selection of the animals greatly. In the recent investigation we tried to test how rodents can affect nocturnal sand cat habitat usage pattern. Microhabitat affinities of sand cat and its den site selection were investigated in Sistan and Baluchistan Province from early 2013 to late 2015 in Semsor area. The data acquired from 29 presence plots of individuals were compared by paired non-used plots; the results indicated that the presence of *Haloxylon ammodendron* and relative density of rodents mainly affected Sand cat microhabitat selection. We also found that the species den site selection was mainly influenced by the presence of tall shrubs such as *Haloxylon ammodendron* and *Tamarix* sp. We concluded that the habitat selection pattern of sand cat in the study area could be significantly influenced by rodents' microhabitat selection; however, such relationship may not be true in larger spatial scales like species home range.

Keywords: prey predator relationships, den site selection, habitat selection, sand cat, Iran

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INTRODUCTION

Sand cat, one of the little known small cats, is found in distinct biogeographic areas such as Sahara Desert of Africa, Arabian Peninsula, and Central Asia including Turkmenistan, Iran, Pakistan, and Afghanistan [1, 2]. This psammophillic species mainly chooses very arid and dry habitats like deserts, ranging from plains with little vegetation to rocky valleys with shrubs and trees [3–8]. Investigations carried out in Turkmenistan indicate that Sand cats avoid areas with less compacted soils [9]. Happolad related small mammals' microhabitat characteristics to sand cat's habitat selection [10]. Sand cats can tolerate extreme thermal conditions with daily surface temperatures reaching up to 51ºC during the daytime, while nighttime temperatures can drop as low as –0.5°C [1, 11]. Different kinds of rodents such as Jerboas [12], Girds, and Murids [13, 14] as well as ground nesting birds and their nestlings, eggs, lizards, and different kinds of invertebrates especially arthropods constitute sand cats feeding diet [7, 8, 15, 16].

Prey-predator relationships have been investigated by different researchers focusing on animal behavior. Different mechanisms are adopted by predators to forage effectively and conversely many behavioral clues have been evolved by preys to avoid them like odor, sound and visual clues [17]. Avoiding brighter lunar nights by Jerboas has been proved as antipredator mechanism in avoiding mammalian carnivores like sand cants and foxes as well as predator birds like owls [14, 18]. Based on optimal foraging theory it is expected that carnivores like sand cat selects area to maximize its gained energy during one night [19, 20].

There are no published documents about sand cat habitat selection. In this research we tried to introduce sand cat's habitat peculiarities both in individual presence points and around active dens in Bazman and Samsor located in Sistan and Baluchestan province where we recently recorded it as one part of the species range. We also tried to answer the question: can prey density acts as a stronger variable than habitat structural variables affecting predator habitat selection?

[1] The article is published in the original.

Fig. 1. Study area in Sistan and Baluchistan Province.

MATERIAL AND METHODS

Study Area

Sistan and Baluchistan province is regarded as the vastest province of Iran located in the south eastern Iran (Fig. 1). It has common borders with Afghanistan and Pakistan in the east and Oman Sea in the south. This study was conducted from March 2014 and July 2016, in an arid and sandy area (27087 ha) located in 150 km from the North-west of Iran-shahr, Bazman (28°24′–28°40′ N and 59°43′–60°56′ E). The altitude changes from 654 m to 1821 m above sea level and the climate is markedly arid. Temperature is different in day and night and changes from season-to-season with a mean monthly minimum of –5°C and a maximum of 56°C with an annual mean of 31°C. The climate of the area is very hot and desert-like. The relative humidity is very low with an irregular annual rainfall (less than 100 mm). Frosting is very rare and there are a few cloudy days. Due to warm, dry and burning winds and high temperature, there is a lot of evaporation in the area. Precipitation is usually in the form of rain and there is seldom snowing which mostly occurs in winter and early spring. The non-woody and woody shrub plants cover ranging between 5 and 10% of the study area, canopy generally between 10 and 50 cm of height with vegetation comprising different bush species such as *Haloxylon ammodendron*, *Zygophyllum eurypterum, Artemisia siberi, Hmada salicornica,* and *Tamarix* sp. Different species of Dipodies, Gerbils, and Girds are also found in the area. We also detected other carnivores like Sand fox (*Vulpes rueppellii*), Red fox (*Vulpes vulpes*), Blanford fox (*Vulpes cana*), Gray wolf (*Canis lupus*), and Striped hyaena (*Hyaena hyaena*) in the study area. There are some reports about the existence of Black bear (*Ursus thibetanus*) in mountainous areas surrounding the study site [2].

Habitat Use

During two years from March 2014 to July 2016, we investigated Sand cat habitat selection and its relationship with prey density and dispersal in the South-eastern part of Iran (Fig. 1). By dividing the habitat to different major vegetation types, we tried to record encounter rates with sand cats in different experimental units (EU, habitat types) and compare them regarding measured environmental variables. The descriptions of the habitat types were based upon a dominant plant species as well as a bare soil cover. For mapping habitat types, at first we pointed the vegetation types on the map and recorded the areas of the habitat types using motorcycle. Since we had replication from each EU, we were able to compare the variables mean using ANOVA statistical analysis. We tried to standardize our trapping effort for both of predator and prey items with regard to the lunar moon status, sampling starting and ending time. We used spotlighting method using motorcycle to detect sand cats in different habitat types. Keeping the same traversed distance in searching for sand cats (about 10 km per night during 60 nights), we were able to compare predator relative density among the EUs. We also measured habitat structural variables in the cats presence points including mean woody plants' percent cover (using measurement tapes for shrubs and densitometer for trees), distance to the nearest traffic roads, human settlements, distance to the nearest water resources and elevation above sea level. We considered the arithmetic mean of the measures of each variable as the value of the variable for presence and paired plots. Totally 120 circular plots (r = 20 m) were stabilized in the presence points and the same number in the absence points where selected in 500 m away from the presence point in a random direction. We also investigated the den site selection by traversing line transections during the day. The species sign including track and hidden deification around dens was used to assure that they belonged to the sand cats. The mean values of the same habitat variables, recorded in 14 circular den plots (r = 20 m), were compared to the same number of paired plots located in 500 m away from the den plots [21].

Rodents' Relative Density

We used spotlighting method as well as live trapping method to assess the relative density of rodents in sand cats' activity sites. For this reason, we covered 100 sq. m rectangle areas around the species observation points. The experimental design performed to set Sherman traps distribution was nested grids [22]. Meanwhile, we searched more distant areas (within the radius of 300 meters away from trapping grids) for rodents which were not trappable with live traps. Totally 80 Sherman traps were used in sampling grids during each sampling effort (480 trap nights). During the early mornings all trapped animals were released at the trapping sites. Regarding rodents, which are not trappable, using Sherman traps like Jerboas we used flash light spotting method and recorded encounter rate [23]. Then the results of both methods were combined finally to gain rodents relative density.

Data Analysis

There were replicated habitat types throughout the study area providing the possibility of using ANOVA to assess the mean difference of variables among the habitat types [24]. Logistic regression was also used to determine the most influencing variables in the species activity sites. The overall significance of the model was based on log-likelihood χ^2 statistics, classification accuracy (based on a logistic cut point of 0.5 to classify sites as an occupied or unoccupied territories), and the Hosmer-Lemeshow Lack-of-Fit test. Paired T-test analysis was also used for assessing the mean difference of microhabitat characteristics among the two groups of plots. We used the principal component analysis (PCA) to reduce the microhabitat variables to a smaller number of independent components and to select microhabitats variables that best described differential microhabitat characteristics among classes using Varimax rotation method. Only the principal components (PCs) with eigenvalues greater than one were retained for further analysis. In all analyses, differences were considered statistically significant at $P < 0.05$. With regard to the low number of den plots, we used Wilcoxon Signed Rank Test to analyze the mean difference of habitat variables between two groups of data. We also used live trapping method to estimate rodents' density in the cats' activity points.

RESULTS

During the study period we encountered 29 different sand cats, since the cats were marked for the objectives planned in the first author PhD thesis [25]. The encounter rate of the species was significantly higher in *Haloxylon ammodendron* habitat type compared with other recorded habitat types including *Artemisia siberi*, *Zygophyllum eurypterum, Hamada salicornica, Tamarix* sp. and bare soil (ANOVA: $F = 83.21$, $n = 52$, $P < 0.05$). The least activity happened in bare soil habitat type. Data acquired from rodents sampling also showed that *Haloxylon ammodendron* habitat type provided the highest density of such prey items for sand cats (ANOVA: $F = 45.56$, $n = 89$, $P < 0.05$). The main rodent species recorded in our live traps and detected by spotlighting were *Gerbilus nanus*, *Meriones persicus*, *Tatera indica*, *Allactaga hotsoni*, and *Jaculus blanfordi*. Blanford Jerboa (*J. blanfordi*) was the most hunted prey item based on our direct observation that remained as signs around the dens. Baluchistan Gerbil (*G. nanus*) was the second frequently used prey item. The mean value of the paired T-test analysis of habitat variables between sand cat's activity plots and the paired non-used plots showed that the presence of vegetation cover (especially *H. ammodendron*) as well as rodents' relative density was the most affecting factors in the species habitat selection (Table 1). The same results were confirmed by binary logistic regression and PCA analysis. Of the six proximal and distal variables entering the model, the presence of *Haloxylon ammodendron* and rodents relative density made the greatest contribution to the model (Table 2). A Hosmer-Lemeshow Lack-of-Fit test ($\chi^2 = 21.41$, $p = 0.23$) indicates a good fit of the data to the logistic

Table 1. Paired T test analysis results for individuals' activity sites and paired plots as well as standard error of the mean (SD) and degree of freedom (df). *H. ammodendron* (HAM), *Artemisia siberi* (*ASI*), *Zygophyllum eurypterum* (*ZYE*), *Hmada salicornica* (*HAS*), *Tamarix* sp (TAM) and bare soil percent cover (BSI)

Variables	Presence plots' mean (SD)	Paired Mean (SD)	Paired t (28)	*P*
HAM	62.21 (9.85)	12.31 (3.25)	21.48	<0.05
TAM	47.21 (8.21)	7.41 (2.45)	–18.50	<0.05
HAS	35.25 (6.35)	10.15 (3.48)	17.32	<0.001
ZYE	20.47 (5.35)	14.45 (4.50)	10.85	>0.05
ASI	3.50 (1.85)	4.20 (1.65)	8.21	>0.05
BSI	5.45 (0.59)	2.77 (0.34)	–6.65	>0.05

Table 2. The role of each variable in the regression model. Input variables in the regression model were proximal and distal variables including rodent's relative density (RRD), woody plants percent cover (WPC), distance to the nearest traffic roads (DNT), and distance to the nearest human settlements (DNH), distance to the nearest water resources (DWR) and elevation above sea level (ELV)

Variable	Significance	Exp(β)	Wald Statistics	Standard error	β	Nigelkerek R sq.
WPC	<0.001	0.20	29.50	0.08	0.24	0.81
RRD	<0.001	0.51	24.35	0.02	0.48	
DNT	<0.001	0.42	16.40	0.03	0.16	
DNH	<0.05	0.55	12.65	0.07	0.25	
ELV	<0.05	0.48	8.50	0.12	0.38	
DWR	<0.001	0.21	7.25	0.04	0.45	

model. The Graph resulted from Principal Component Analysis (PCA) analysis had two principal axes of which the first justified 48% and the second 34% (totally 82%) of the variance. The first principal component was assigned to the vegetation percent cover (especially *H. ammodendron*) and the second was related to the rodents' relative density in the investigated plots. Based on nonparametric Wilcoxon ranked test we found that *Haloxylon ammodendron and Zygophyllum eurypterum, Tamarix* sp. play significant role in the species den site selection ($P < 0.05$).

DISCUSSION

Our results about the habitat selection of sand cats indicated that the availability of food and cover influenced the species habitat use pattern and these two habitat welfare items have considerable correlation in the species habitat selection. The presence of vegetation cover in such desert area provides favorable microclimate, food, and cover for burrowing rodents as well as stability of the burrows. The role of soil stability for burrow site selection of the recorded rodents has been previously reported by different researchers [12, 23, 26–28]. It seems that the den site selection of the species is affected by cover properties such as producing optimal microclimate under crown shadow of tall shrubs as well as the availability of food items in the neighborhood. Avoiding soft and unstable soil texture by sand cats had been previously emphasized by Heptner and Sludskii [9]. Our results indicated that sand cat as one of the main predators in the study area mainly followed the prey micro-habitat selection pattern and its abundance. Such behavior in habitat selection affects the species fitness [29–31]. The presence of tall vegetation cover in desert habitats will provide refuges and other critical and key resources especially food [32, 33]. The role of prey items in affecting the predator microhabitat selection had been previously reported by different researchers [34–36]. Such investigations indicated that habitats with higher prey abundance would maximize prey encounter rate at microhabitat level while it might not affect larger spatial scales such as home range [37–40]. The association of small rodents with vegetation variables was also indicated by many researchers [21, 41, 42]. Other studies such as sand cat satellite bio-tracking will yield interesting results about the species movement and macrohabitat use in larger spatial scales.

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REFERENCES

1. Cunningham, P., Status of the Sand Cat, *Felis margarita*, in the United Arab Emirates, *Zool. Middle East,* 2002, vol. 25, no. 1, pp. 9–14.
2. Ghafaripour, S., Naderi, M., and Rezaei, H.R., Investigating abundance, density and potential threats of Sand cat in the South-Eastern parts of Iran. *J. Wildl. Biodivers.,* 2017, vol. 1, no. 1, pp. 47–55
3. Schauenberg, P., Données nouvelles sur le chat des sables *Felis margarita* Loche, 1858, *Suisse Zool.,* 1974, vol. 48, pp. 949–969.
4. Hemmer, H., Gestation period and postnatal development in felids, in *The World's Cats,* Eaton, R.L., Ed., Seattle, WA: Carnivore Research Institute, Univ. of Washington, 1976, pp. 143–165.
5. Gasperetti, J., Harrison, D.L., and Biittiker W, The Carnivora of Arabia, *Fauna of Saudi Arabia,* 1986, vol. 7, pp. 397–461.
6. Harrison, D.L., and Bates, P.J.J., *The Mammals of Arabia,* 2nd ed., Sevenoaks, UK: Harrison Zoological Museum, 1991.
7. Abbadi, M., Israel's elusive feline: Sand cats, *Cat News,* 1992, vol. 18, pp. 15–16.
8. Dragesco-Joffe, A., Le chat des sables, un redoutable chasseur de serpents, in *La Vie Sauvage du Sahara*,

Lausanne, Switzerland: Delachaux et Niestlé, 1993, pp. 129–133.

9. Heptner, V.H. and Sludskii, A.A., *Mammals of the Soviet Union,* vol. 3: *Carnivores (Feloidea),* English Transl., Hoffmann, R.S., Ed., Washington, DC: Smithsonian Inst., Natl. Science Foundation, 1992.
10. Happold, D.C.D., Small mammals, in *Key Environments: Sahara Desert,* Cloudsley-Thompson, J.L., Ed., London: Pergamon, 1984, pp. 251–275.
11. Goodman, S.M, and Helmy, I., The sand cat *Felis margarita* Loche, 1858 in Egypt, *Mammalia,* 1986, vol. 50, pp. 120–1231.
12. Russell Cole, F., and Wilson, D.E., *Felis margarita* (Carnivora: Felidae), *Mammal. Species*, 2015, vol. 47, no. 924, pp. 63–77
13. Hemami, M.R., Naderi, G.H., Karami, M., and Mohammadi, S., Nocturnal activity of Iranian Jerboa *Allactaga firouzi* (*Mammalia: Rodentia: Dipodidae*), *Mammalia,* 2011, vol. 75, pp. 42–57
14. Darabi, M., Zeini, Z., Karimi, A. and Kaveh, A., Nocturnal activity and habitat selection of Hotson Jerboa, *Allactaga hotsoni* Thomas, 1920 (Rodentia: Dipodidae). *J. Wildl. Biodivers.,* 2017, vol. 1, no. 1, pp. 33-36.
15. Postanowicz, R., Sand cat (*Felis margarita*). http://www.lioncrusher.com/animal.asp?animal=67. Cited June 11, 2015.
16. De Smet, K., The distribution and habitat choice of larger mammals in Algeria, with special reference to nature protection. *Ph.D. Thesis,* University of Ghent, 1989
17. Ferrero, D.M., Lemon, J.K., Fluegge, D., Pashkovski, S.L., Korzan, W.J., Datta, S.R., et al., Detection and avoidance of a carnivore odor by prey, *Proc. Natl. Acad. Sci. U. S. A.,* 2011, vol. 108, pp. 11235–11240.
18. Stephens, D.W., and Charnov, E.L., Optimal foraging: Some simple stochastic models, *Behav. Ecol. Sociobiol.,* 1982, vol. 10, pp. 251–263.
19. Stephens, D.W., and Krebs J.R., *Foraging Theory,* Princeton, NJ: Princeton Univ. Press, 1986.
20. Naderi, G.H., Hemami, M.H., Riazi, B., and Alesheikh, A., Notes on ecological peculiarities of *Allactaga firouzi* Womochel, 1978 (Mammalia: Dipodidae), *Zool. Middle East,* 2009, vol.47, pp. 21–28.
21. Krebs, C. J., *Ecological Methodology,* 2nd ed., Melo Park, CA: Addison–Wesley, 1999.
22. Naderi, G.H., Mohammadi, S., Imani, A., and Karami, M., Habitat selection and burrow structure of Blanford's Jerboa, *Jaculus blanfordi* (Mammalia: Rodentia) from Central Desert of Iran, *Acta Zool. Bulg.,* 2014, vol. 66, no. 2, 225–228.
23. Naderi, G.H, Hemami, M., Riazi, B., Alesheikh, A., Iranian Jerboa abundance and habitat selection, *Ph.D. Thesis,* Tehran, Iran: Islamic Azad University, Science and Research Branch, 2009.
24. Ghafaripour S., Naderi, M., Riazi, B. and Rezaei, H.R., Ecology and biology of sand cat in Sistan and Baluchistan Province, *Ph.D. Thesis,* Tehran, Iran: Islamic Azad University, Science and Research Branch, 2016.
25. Murray, G.B., and Vestal, B.M., Effects of environmental structure on the burrow distribution of thirteen-lined ground squirrels, *Spermophilus tridecemlineatus* (Sciuridae), *Southwest. Nat.,* 1979, vol. 24, no. 1, pp. 79–86.
26. Laundre, J.W., and Appel, N.K., Habitat preferences for burrow sites of Richardson's ground squirrels in southwestern Minnesota, *Prairie Nat.,* 1986, vol. 18, no. 4, pp. 235–239.
27. Naderi, Gh., Hemami, M.R., Mohammadi, S., Riazi, B., Karami, M., Kaboli, M., Alesheikh, A., Effects of vegetation and soil conditions on burrow structure and site ion of rare desert rodent Iranian jerboa (*Allactaga firouzi*), *Pol. J. Ecol.,* 2011, vol. 59, no. 2, pp. 403–410.
28. Bearhop, S., Hilton, G.M., Votier, S.C., and Waldron, S., Stable isotope ratios indicate that body condition in migrating passerines is influenced by winter habitat, *Proc. R. Soc. Lond. B: Biol. Sci.,* 2004, vol. 271, no. 4, pp. 215–218.
29. Norris, D.R., Marra, P.P., Kyser, T.K., and Sherry, T.W., Tropical winter habitat limits reproductive success on the temperate breeding grounds in a migratory bird, *Proc. R. Soc. Lond. B: Biol. Sci.,* 2004, vol. 271, pp. 59–64.
30. Gunnarsson, T.G., Gill, J.A., Newton, J., Potts, P.M., and Sutherland, W.J., Seasonal etching of habitat quality and fitness in a migratory bird. *Proc. R. Soc. Lond. B: Biol. Sci.,* 2005, vol. 272, pp. 2319–2323.
31. Charnov, E.L., Optimal foraging, the marginal value theorem, *Theor. Popul. Biol.,* 1976, vol. 9, pp. 129–136.
32. Fortin, D., Fryxell, J.M., O'Brodovich, L., and Frandsen, D., Foraging ecology of bison at the landscape and plant community levels: The applicability of energy maximization principles, *Oecologia,* 2003, vol. 134, pp. 219–227.
33. Comins, H.N., and Hassell, M.P., The dynamics of optimally foraging predators and parasitoids, *J. Anim. Ecol.,* 1979, vol. 48, pp. 335–351.
34. Pyke, G.H., Optimal foraging theory: A critical review, *Annu. Rev. Ecol. Syst.,* 1984, vol. 15, pp. 523–575.
35. Ropert-Coudert, Y., Kato, A., Wilson, R.P., and Cannell, B., Foraging strategies and prey encounter rate of free-ranging little penguins, *Mar. Biol.,* 2006, vol. 149, pp. 139–148.
36. Martínez, J.A., Serrano, D. and Zuberogoitia, I., Predictive models of habitat preferences for the Eurasian eagle owl *Bubo bubo*: A multiscale approach, *Ecography,* 2003, vol. 26, pp. 21–28.
37. Ciarniello, L.M., Boyce, M.S., Seip, D.R. and Heard, D.C., Grizzly bear habitat selection is scale dependent, *Ecol. Appl.,* 2007, vol. 17, pp. 1424–1440.
38. Mayor, S.J., Schaefer, J.A., Schneider, D.C., and Mahoney, S.P., Spectrum of selection: New approaches to detecting the scale-dependent response to habitat, *Ecology,* 2007, vol. 88, pp. 1634–1640.
39. Glaudas X. and Rodríguez-Robles J.A., A two-level problem: Habitat selection in relation to prey abundance in an ambush predator, the speckled rattlesnake (*Crotalus mitchellii*), *Behavior,* 2011, vol. 148, pp.1491–1524.
40. Murúa R and González LA., Microhabitat selection in two Chilean cricetid rodents, *Oecologia,* 1982, vol. 52, pp. 12–15.
41. Dalmagro, A.D., and Vieira, E.M., Patterns of habitat utilization of small rodents in an area of Araucaria forest in Southern Brazil, *Austral. Ecol.,* 2005, vol. 30, pp. 353–362.