BMC Zoology

RESEARCH Open Access

Estimation of mammalian wildlife density by REM method in a Mediterranean forest ecosystem (*Pinus brutia*) of Türkiye: how human footprint effects mammal community?

Yasin İlemin[1*]

Abstract

Background Determining the density of mammalian wildlife in an ecosystem is very important for the ecosystem conservation. The aim of this study is to reveal mammalian wildlife density and compare the effect human footprint index (HFI) on the Mediterranean ecosystems. The mammalian wildlife surveys were conducted between August 2013 and December 2013, using 21 camera traps with 2175 camera trap days in a Mediterranean forest ecosystem in İzmir, Türkiye. We used random encounter model (REM) method to estimate densities.

Results The population density for 5 mammals were; for red fox 7.89 ind./km^2 (±0.82 SE), wild boar 4.36 ind./km^2 (±0.46 SE), European hare 15.33 ind./km^2 (±03.37 SE), beech marten 0.99 ind./km^2 (±0.10 SE) and golden jackal 0.50 ind./km^2 (±0.05 SE). These results were compared with mammal community which was previously studied in another Mediterranean ecosystem in Muğla, Türkiye, includes caracal and has a lower human footprint index.

Conclusions According to results of this study human activity which can be revealed by Human footprint index (HFI) is one of the main parameter on Mediterranean ecosystem and it is effecting the density and occurence of species in mammal community. Both a higher human footprint index and the absence of caracal might cause higher density of red fox and European hare in İzmir, Türkiye. This study also suggests that caracal might be a serious suppressor on red fox which could be explained by competition. Caracal may also control the European hare in Mediterranean forest ecosystem of Anatolia. Thus, decreasing human footprint index and maintaining caracal suppressor effect are crucial for the conservation of the whole Mediterranean ecosystem.

Keywords REM, Mediterranean ecosystem, Caracal, Red fox, European hare, Human footprint index

*Correspondence:
Yasin İlemin
yasinilemin@mu.edu.tr
[1]Department of Environmental Protection and Technologies, Mugla Sitki Kocman University, Fethiye, Muğla, Türkiye

Background

Density and abundance estimations on mammals is vital for wildlife conservation. Camera trapping is a reliable tool for this purpose [1–6]. In ecological studies, "Capture-Marking-Recapture (CMR)" techniques (Peterson Method, Schanbel Method, Jolly-Seber Method) are used to calculate the population size of a species in a certain area [7]. CMR techniques can be easily applied to camera trapping studies. However, in order to make an accurate population size calculation with this method, animal species must be selected which have individual distinctive patterns on their furs such as lynx (*Lynx lynx*), jaguar (*Panthera onca*), snow leopard (*Panthera uncia*) and tiger (*Panthera tigris*) and wild cat (*Felis silvestris*) [8–11]. Otherwise, the method fails because of the individual recognition can not be determined. An alternative method is to calculate the density and abundance of mammalian species that are difficult to define individually, to create relative index of abundance of species [12]. With this method, only an index is revealed and does not give a population information in a certain area. This method also fails to avoid inconsistencies in capture rates because each species moves at different speeds [13]. On the other hand methods that provide accurate calculations for animal densities give a robust chance for conservation acts [14, 15]. This accurate estimates on density and abundance allow elaborative comparisons between study areas and different time scales [16, 17]. Population abundance and density results are necessary aspect for conservation action plans because it presents data on animal demography which is a critical parameter for future conservation projections. [18].

Rowcliffe et al. [19] introduced a new model for calculating the population size of species that do not have significant individual patterning differences in their fur. The Random Encounter Model (REM) is a novel method for estimating animal density from camera trap data and the method models encounter between camera traps and animals without the requirement for individual identification of animals and it has been widely applied in the last 15 years [19, 20].

As much as the species density in a mammal community in an ecosystem is determined by intraspecific and interspecific interactions the human impact in that ecosystem also shapes the mammal community. At this point, it is very important to measure and evaluate the anthropogenic influence on a mammal communities.

The main aims of this study were:

- to reveal mammalian wildlife density of a Mediterranean forest ecosystem in İzmir province of Türkiye by random encounter model (REM) method and compare with an ecosystem where a similar study had been conducted in Muğla Province [21],
- to reveal and compare the effect human footprint index (HFI) on the Mediterranean ecosystems,
- to discuss presence or absence of caracal on the density of some medium sized mammals in a typical Mediterranean forest ecosystem which is dominated by Red pine (*Pinus brutia*) in Türkiye. The results were evaluated with the nearby mammalian communities of Muğla Province [21].

Methods

Study area

This study was carried out in Seferihisar/İzmir province that is located at Western Türkiye with a sampling area covered nearly 200 km2 (Fig. 1). On the other hand, the size of the study area in the Marmaris/Muğla region, where the results of this study were evaluated and where data was previously obtained with the same methodology, was approximately 650 km^2 [21].

The survey area (Seferihisar/İzmir) and Marmaris/Muğla region have same conditions in terms of climate and vegetation. Both area have typical Mediterranean climate with hot and dry summers and mild and rainy winters. The main vegetation of these regions are dominated by Turkish red pine (*Pinus brutia)* forest at different post-fire succession regeneration stages, maquies, mixed stands of red pine and maquies species such as *Quercus* spp., and *Erica* spp. The altitude ranges between sea level and 622 m a.s.l. in Seferihisar/Muğla. The altitude ranges between sea level and 1000 m a.s.l. in Marmaris /Muğla.

Data collection and analysis

The survey was conducted between August 2013 and December 2013, deploying 21 camera traps (Cuddeback Digital, Wisconsin, USA). The camera traps were placed approximately 3 km away from each other which means one camera trap station was located randomly in a 9 km^2 gird cell that is crucial for density estimations with the Random Encounter Model (REM) method which is coherent with literature and in total nearly 200 km^2 area was covered [15, 19–21]. No baits were used during the study and the natural distribution composition of the mammal communities in the study area was not affected. Camera trap sampling was not done in areas permanently used by people, settlements and actively used agricultural areas in parallel with the literature [15, 19–22]. The survey extended over 2175 camera trap days. Camera trap stations were visited monthly to download data and renew batteries. Camera-trap records were processed separately for each station in a data-sheet in the form of station number, photo date, photo time, species name, and if possible sex, group size and other notes. If more than one record of the same species was obtained on a camera within 10 min, we treated them as a single record

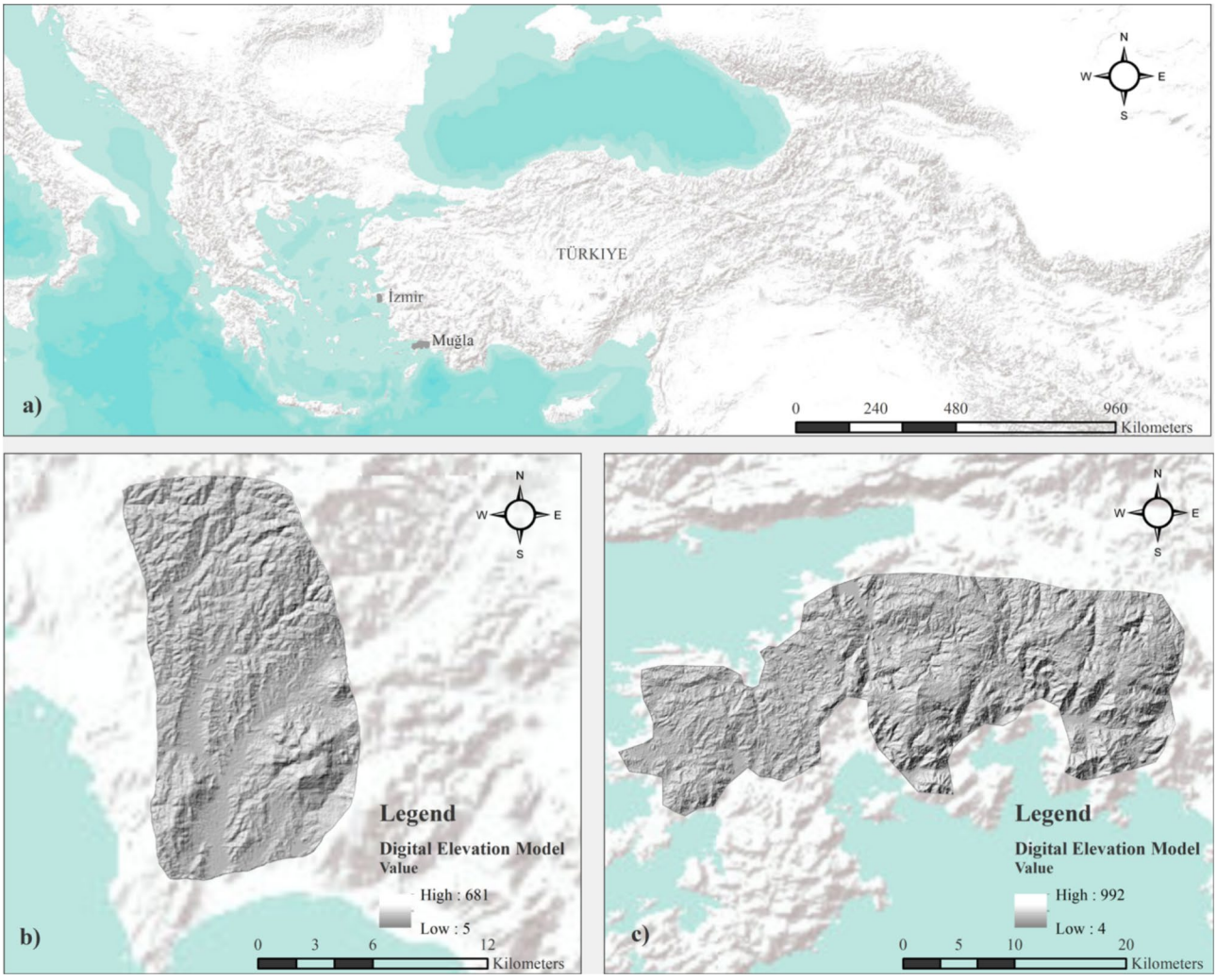

Fig. 1 Location of the study area İzmir province (**b**), Muğla province (**c**) and Türkiye (**a**)

[21]. The Random Encounter Model (REM) method was used to determine the density of the mammals in the study area and the number of individuals per km2. The REM method models encounter between camera traps and animals without the requirement for individual identification of animals and it has been widely applied in recent years [19, 20]. REM method estimates density as:

$$D = \frac{y}{t}\frac{\pi}{vr(2+\theta)}$$

where y is the number of records, t is the total camera-trap days, v is the range and r refers to the effective radius and angle of the camera detection zone, respectively. The r value was 0.0015; θ value was 0.392 [21]. In order to make a reliable calculation about the target species via REM method, a minimum of 50 records of that species must be taken [15, 22]. According to this recommendation 5 species densities were estimated within this study.

Table 1 Parameters used to calculate Random Encounter Model (REM) densities

Species	Records	Camera trap days	Speed (v)	Radius (*r*)	Angle (θ, in radians)
Vulpes vulpes	1264	2175	6.45[1]	0.015	0.3920
Sus scrofa	714	2175	6.59[2]	0.015	0.3920
Lepus europaeus	339	2175	0.89[3]	0.015	0.3920
Martes foina	135	2175	5.5[4]	0.015	0.3920
Canis aureus	116	2175	9.4[5]	0.015	0.3920

Note[1] [23], [2] [24], [3] [25], [4] [26], [5] [27]

Movement speeds (v) were taken from the published literature (Table 1).

In addition, the data of the study conducted in Muğla province, where the results of this study were compared, were obtained with the same methodology. Thus, comparisons between the two regions could been made reliably [21]. The wilderness of ecosystems was assessed in

two areas. One of the most consistent analyzes on the wilderness of a region made with the "Human Footprint Index" (HFI). HFI method was used to understand how this density was affected by human impact. This was done by characterizing several attributes and thus potential human pressure was assessed. There is a recent and widely used metric "The Human Footprint Index" [28]. It is derived from remotely-sensed and bottom-up survey information compiled on eight measured variables. The Human Footprint Index (HFI) represents not only the most current information of its type, but also the first temporally-consistent set of Human Footprint maps. Data on human pressures includes: (1) built environments, (2) population density, (3) electric infrastructure, (4) croplands, (5) pasture lands, (6) roads, (7) railways, and (8) navigable waterways. Firstly, each pressure was scaled on 0–10 which the 10 stands for highest human disturbance. Then these pressures are overlaid to estimate the standardized cumulative human pressure. The Human Footprint maps represents a range of uses as proxies for human disturbance of natural systems and can provide an increased understanding of the human pressures that drive macro-ecological patterns, as well as for tracking environmental change and informing conservation science and application. HFI values range from 0 (no human impact) to 50 (heavily human impacted). Using the "Human Footprint, 2018 Release (2009)" data the HFI index of both regions was revealed with the ArcGIS 10.8 (ESRI Inc. Redlands, California, USA) [29]. R studio program was used for analysis. Accordingly, the Kruskal-Wallis rank sum test was applied to understand whether there was a significant difference between the HIF values.

Results

Nine different mammalian species were recorded during the camera trapping survey (Table 2; Fig. 2).

Table 2 Recorded species during the survey period

Number	Species	Total number of events in 2175 camera trap days
1	*Vulpes vulpes* (red fox)	1264
2	*Sus scrofa* (Wild boar)	714
3	*Lepus europaeus* (European hare)	339
4	*Martes foina* (beech marten)	135
5	*Canis aureus* (golden jackal)	116
6	*Meles meles* (European badger)	21
7	*Erinaceus concolor* (Southern white-breasted hedgehog)	18
8	*Hystrix indica* (Indian crested porcupine)	8
9	*Felis silvestris* (European wildcat)	2

The population density for 5 mammals were calculated as (mean individuals per km^2, SE and 95% CI); red fox was 7.89 +/- 0.82; (6.56–9.82), wild boar was 4.36 +/- 0.46; (3.64–5.44), European hare was 15.33 +/- 3.37; (11.23–23.93), beech marten was 0.99 +/- 0.10; (0.83–1.23) and golden jackal was 0.50 +/- 0.05; (0.42–0.61).

According to human footprint index calculations, the value for İzmir/Seferihisar was 8–38, while it was 6–33 for Muğla/Marmaris. The distribution of HFI values among the areas is presented in Fig. 3.

It was tested whether there was a significant difference between these results. Accordingly, the human impact in Izmir/Seferihsar was found to be higher than in Muğla/Marmaris ($p<2.2e\text{-}16$).

Discussion

In this study, first robust density estimation and comparison were revealed via REM (random encounter model) method and how these data were affected by anthropogenic influence. The European hare density in the study area was the highest with 15.33 ind./km^2 and golden jackal density was the lowest with 0.55 ind./km^2 (Table 3). Results were showed that REM method is secure methodology to compute mammal community which recorded by camera traps as emphasize by previous studies [17, 20].

Results were compared with a previous study conducted in a very similar ecosystem (Muğla). Red fox and European hare density in İzmir were distinctly higher than Muğla. This may be explained by two way; lower human footprint and presence of caracal in Muğla.

Human activity which can be revealed by Human footprint index (a measure of anthropogenic influence on habitats) is an important determinant of fox diet composition and occurence in an ecosystem [30]. Habitat change through rural and urban expansion negatively impacts most wildlife species. However, anthropogenic food sources in habitats may benefit some species like red foxes [31, 32]. The red fox is described as one of the most adaptable of the wild carnivores [17, 33]. Its success in urban areas and croplands probably derives from its high ecological and behavioural tolerance. As a medium-sized omnivore, which is both an agile predator and scavenger, it can easily disperse and colonize new human made habitats [34]. Our study area in İzmir/Seferihisar is highly effected by human in terms of settlement and cropland which is an ecological opportunity for red fox. On the other hand in Muğla/Marmaris Köyceğiz region has a lower human footprint which has diet limitations for red fox. Another explanation for the lower red fox density in Muğla could be the presence of caracal. Caracal is an apex predator and keystone species in Mediterranean ecosystems of Türkiye [35]. It could be a suppressor for the red fox population. Studies on similar felidae species

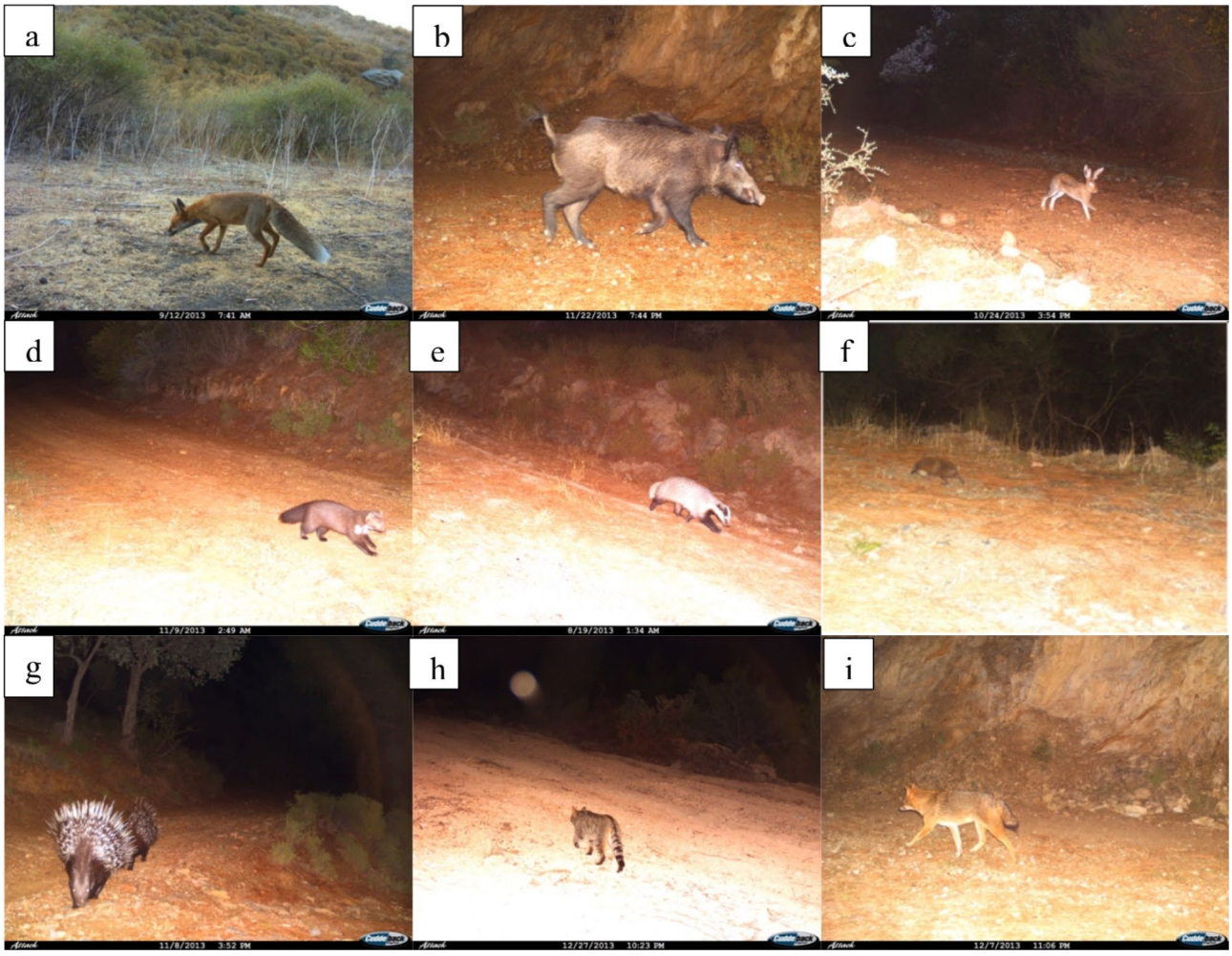

Fig. 2 Mammalian species detected during the research. (**a**) red fox, (**b**) wild boar, (**c**) European hare, (**d**) beech marten, (**e**) European badger, (**f**) Southern white breasted hedgehog, (**g**) indian crested porcupine, (**h**) European wildcat, (**i**) golden jackal

such as lynx were indicating interspecies competition. Researches revealed that fifty per cent of fox mortalities in the radio-tracking study (four of eight) were lynx predation [34, 36]. Canid species such as black-backed jackal, bat-eared fox and cape fox were ordinary prey items for caracal in Africa [37]. Another recent study in Türkiye showed the co-occurrence of caracal and red fox. This co-occurrence suggests that European hare is a common prey for them [38]. Our study area had a very high European hare density while in Muğla the European hare density was very low. These results suggest that hare was main prey for caracals as indicated in literature [38–40]. The density of the European hare is directly proportional to the increase in human footprint in an area, especially size of the agricultural land [41]. High European density in our study might be explained by high human footprint (croplands). Red fox is the main predator of European hare in Europe [42]. Abundant prey options (including European hare) due to human influence and the absence of an apex predator such as caracal may explain the high density of red foxes in İzmir/Seferihisar.

Conclusion

Results of this study showed that REM method is reliable monitoring tool for mammal populations. Mammalian wildlife is dramatically affected by an increasing number of anthropogenic impacts to ecosystems which is referred to as the "human footprint" [43]. Conversely, species that have a cosmopolitan distribution such as rodents, red foxes and hare may benefit from human footprint [44]. Findings of this research are in parallel with the literature mentioned above. On the other hand this study revealed that caracal might be a serious suppressor on red fox population in Anatolian Mediterranean forest ecosystem. Caracal also stands out as a species that regulates carnivora mammal wildlife in ecosystems where human footprint is relatively low. As a result, it can be said that the wildlife community of Mediterranean ecosystems could be shaped by both human footprint and apex carnivore

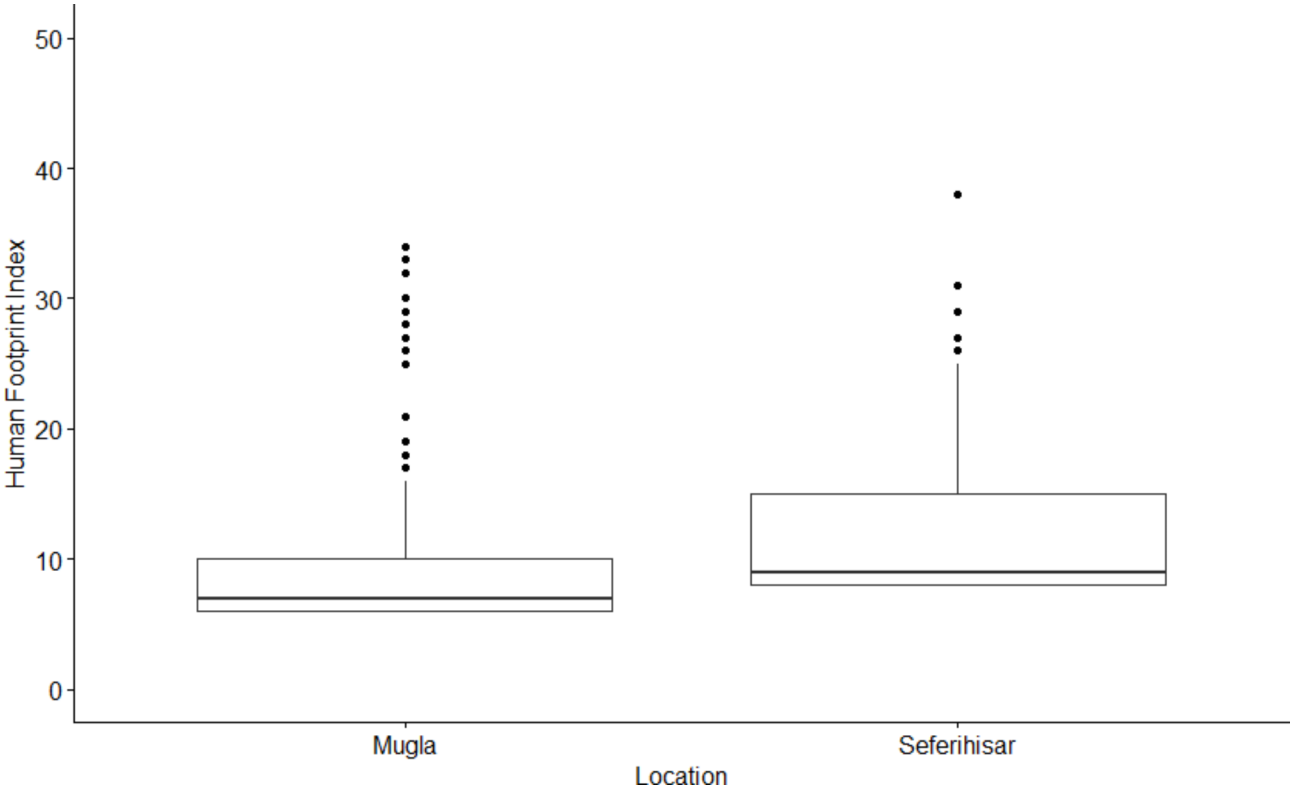

Fig. 3 Human Footprint Index (HFI) in the two study areas; Muğla/Marmaris and Izmir/Seferihisar

Table 3 Densities of five mammals in two study area; Izmir/Seferihisar and Muğla/Marmaris using the same methodology (REM or random encounter model) in Mediterranean Ecosystem

		REM density (n/km^2 ± SE)				
Literature	**Location**	**Red fox**	**Wild boar**	**European hare**	**Beech marten**	**Golden jackal**
This study	İzmir (Seferihisar)	7,89	4,36	15,33	0,99	0,50
İlemin (2017)	Muğla (Marmaris-Köyceğiz)	0,54	4,95	2,9		

species like caracal. Maintaining caracal suppressor effect and decreasing human footprint index might be crucial for the conservation of the whole Mediterranean ecosystem.

Abbreviations

CMR Capture Marking-Recapture
REM Random encounter model
HFI Human footprint index

Acknowledgements
I thank Berna Yalçınkaya, Hakan Gür, Deniz Mengüllüoğlu and Henrik Andren for their contributions to statistical analysis. I thank to two anonymus reviewers for their comments on the earlier version of the manuscript. I am grateful to the Doğa Derneği (NGO) and Ministry of Agriculture and Forestry for supporting this work.

Author contributions
Y.I. wrote the main text, did to analysis and all works in article.

Funding
Not applicable.

Data availability
All relevant data are within the paper.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 7 November 2023 / Accepted: 8 August 2024
Published online: 16 August 2024

References

1. Noack J, Heyns L, Rodenwoldt D, Edwards S. Leopard density estimation within an enclosed reserve, Namibia using spatially explicit capture-recapture models. Animals. 2019;9(10):724.
2. Kumbhojkar S, Yosef R, Mehta A, Rakholia S. A camera-trap home-range analysis of the Indian leopard (Panthera pardus fusca) in Jaipur, India. Animals. 2020;10(9):1600.
3. Palencia P, Fernández-López J, Vicente J, Acevedo P. Innovations in movement and behavioural ecology from camera traps: Day range as model parameter. Methods Ecol Evol. 2021;12(7):1201–12.

4. Baldwin RW, Beaver JT, Messinger M, Muday J, Windsor M, Larsen GD, Anderson TM. Camera trap methods and drone thermal surveillance provide reliable, comparable density estimates of large, free-ranging ungulates. Animals. 2023;13(11):1884.
5. Montalvo VH, Sáenz-Bolaños C, Cruz-Díaz JC, Carrillo E, Fuller TK. The Use of Camera traps and Auxiliary Satellite Telemetry to Estimate Jaguar Population Density in Northwestern Costa Rica. Animals. 2022;12(19):2544.
6. Vinitpornsawan S, Fuller TK. A camera-trap survey of mammals in Thung Yai Naresuan (East) Wildlife Sanctuary in Western Thailand. Animals. 2023;13(8):1286.
7. Krebs CJ. (1999) Ecological Methodology, Addison-Welsey Educational Publishers Inc., Menlo Park, CA, 620 s.
8. Karanth KU, Nichols JD. Estimation of tiger densities in India using photographic captures and recaptures. Ecology. 1998;79(8):2852–62.
9. Maffei L, Cuéllar E, Noss A. One thousand jaguars (Panthera onca) in Bolivia's Chaco? Camera trapping in the Kaa-Iya National Park. J Zool. 2004;262(3):295–304.
10. Weckel M, Giuliano W, Silver S. Jaguar (*Panthera onca*) feeding ecology: distribution of predator and prey through time and space. J Zool. 2006;270(1):25–30.
11. Can ÖE, Kandemïr İ, Togan İ. The wildcat *Felis silvestris* in northern Turkey: assessment of status using camera trapping. Oryx. 2011;45(1):112–8.
12. O'Brien TG, Kinnaird MF, Wibisono HT. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. Anim Conserv. 2003;6:131–9.
13. Jennelle CS, Runge MC, Mackenzie DI. The use of photographicrates to estimate densities of tigers and other cryptic mammals: a comment on misleading conclusions. Anim Conserv. 2002;5:119–20.
14. Garrote G, de Ayala RP, Álvarez A, Martín JM, Ruiz M, de Lillo S, Simón MA. Improving the random encounter model method to estimate Carnivore densities using data generated by conventional camera-trap design. Oryx. 2021;55(1):99–104.
15. Zero VH, Sundaresan SR, O'Brien TG, Kinnaird MF. (2013) Monitoring an endangered savannah ungulate, Grevy's zebra *Equus Grevyi*: choosing a method for estimating population densities. Oryx, 47(3).
16. Bellan SE, Gimenez O, Choquet R, Getz WM. A hierarchical distance sampling approach to estimating mortality rates from opportunistic carcass surveillance data. Methods Ecol Evol. 2013;4(4):361–9.
17. Pettigrew P, Sigouin D, St-Laurent MH. Testing the precision and sensitivity of density estimates obtained with a camera-trap method revealed limitations and opportunities. Ecol Evol. 2021;11(12):7879–89.
18. P Gibbs J. Monitoring populations. Res Techniques Anim Ecol. 2000;213:252.
19. Rowcliffe JM, Field J, Turvey ST, Carbone C. Estimating animal density using camera traps without the need for individual recognition. J Appl Ecol. 2008;45(4):1228–36.
20. Palencia P, Barroso P, Vicente J, Hofmeester TR, Ferreres J, Acevedo P. Random encounter model is a reliable method for estimating population density of multiple species using camera traps. Remote Sens Ecol Conserv. 2022;8(5):670–82.
21. Ilemin Y. (2017). Some ecological characteristics of caracal *Caracal caracal* (Schreber, 1776) population in Marmaris and Köyceğiz region, Ph.D. Thesis, Muğla Sıtkı Koçman University, Türkiye.
22. Carbajal-Borges JP, Godínez-Gómez O, Mendoza E. Density, abundance and activity patterns of the endangered Tapirus bairdii in one of its last strongholds in southern Mexico. Trop Conserv Sci. 2014;7(1):100–14.
23. Meia JS, Weber JM. Home ranges and movements of red foxes in central Europe: stability despite environmental changes. Can J Zool. 1995;73(10):1960–6.
24. Spitz F, Janeau G. Spatial strategies: an attempt to classify daily movements of wild boar. Acta Theriol. 1990;35(1–2):129–49.
25. Schai-Braun SC, Rödel HG, Hackländer K. The influence of daylight regime on diurnal locomotor activity patterns of the European hare (*Lepus europaeus*) during summer. Mammalian Biology; 2012.
26. Zalewski A, Jedrzejewski W, Jedrzejewski B. Mobility and home range use by pine martens (*Martes martes*) in a Polish primeval forest. Écoscience. (2004).
27. Rotem G, Berger H, King R, Saltz D. The effect of anthropogenic resources on the space-use patterns of golden jackals. J Wildl Manag. 2011;75(1):132–6.
28. Venter O, Sanderson EW, Magrach A, Allan JR, Beher J, Jones KR, Possingham HP, Laurance WF, Wood P, Fekete BM, Levy MA, Watson JE. Sixteen years of change in the global Terrestrial Human footprint and implications for Biodiversity Conservation. Nat Commun. 2016;7:12558. https://doi.org/10.1038/ncomms12558.
29. Venter O, Sanderson EW, Magrach A, Allan JR, Beher J, Jones KR, Possingham HP, Laurance WF, Wood P, Fekete BM, Levy MA. and J. E. Watson. 2018. Last of the Wild Project, Version 3 (LWP-3): 2009 Human Footprint, 2018 Release. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H46T0JQ4
30. Soe E, Davison J, Süld K, Valdmann H, Laurimaa L, Saarma U. Europe-wide biogeographical patterns in the diet of an ecologically and epidemiologically important mesopredator, the red fox Vulpes vulpes: a quantitative review. Mammal Rev. 2017;47(3):198–211.
31. Ghoshal A, Bhatnagar YV, Mishra C, Suryawanshi K. Response of the red fox to expansion of human habitation in the Trans-Himalayan mountains. Eur J Wildl Res. 2016;62:131–6.
32. Bateman PW, Fleming PA. Big city life: carnivores in urban environments. J Zool. 2012;287(1):1–23.
33. Macdonald D. Running with the fox. London: Unwin Hyman; 1987.
34. Helldin JO, Liberg O, Glöersen G. Lynx (*Lynx lynx*) killing red foxes (*Vulpes vulpes*) in boreal Sweden–frequency and population effects. J Zool. 2006;270(4):657–63.
35. İlemin Y, Koç H, Yenisey Kaynaş B. Ecological characteristics of Caracal (Caracal caracal) in Türkiye: an isolated feline population. J Wildl Biodivers. 2024;9X(X–X). https://doi.org/10.5281/zenodo.8225067.
36. Helldin JO, Danielsson AV. Changes in red fox *Vulpes vulpes* diet due to colonisation by lynx Lynx lynx. Wildl Biology. 2007;13(4):475–80.
37. Melville HIAS, Bothma JDP, Mills MGL. Prey selection by caracal in the Kgalagadi Transfrontier Park. South Afr J Wildl Research-24-month Delayed open Access. 2004;34(1):67–75.
38. Ünal Y, Pekin BK, Oğurlu İ, Süel H, Koca A. Human, domestic animal, Caracal (*Caracal caracal*), and other wildlife species interactions in a Mediterranean forest landscape. Eur J Wildl Res. 2020;66(1):5.
39. Mengüllüoğlu D, Ambarlı H. Assessing caracal-prey interactions by spatial and temporal analyses. Eur J Wildl Res. 2019;65:1–10.
40. Mori E, Carbone R, Viviano A, Calosi M, Fattorini N. Factors affecting spatio-temporal behaviour in the European brown hare Lepus europaeus: a meta-analysis. Mammal Rev. 2022;52(3):454–70.
41. Demirbaş Y. Density of European hare and red fox in different habitats of Kırıkkale Province (Central Anatolia), with a low level in hare number and an expected correlation in Spring. Acta Zool Bulg. 2015;67(4):515–20.
42. Toews M, Juanes F, Burton AC. Mammal responses to the human footprint vary across species and stressors. J Environ Manage. 2018;217:690–9.
43. Hill JE, DeVault TL, Wang G, Belant JL. Anthropogenic mortality in mammals increases with the human footprint. Front Ecol Environ. 2020;18(1):13–8.
44. Gilby BL, Henderson CJ, Olds AD, Ballantyne JA, Cooper TKA, Schlacher TA. Cross-ecosystem effects of coastal urbanisation on vertebrate assemblages and ecological function. Anim Conserv. 2023;26(1):126–36.

Publisher's Note