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Research Article

Ecological characteristics of Caracal (*Caracal caracal*) in Türkiye: An isolated Feline population

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Abstract

Caracal is an adaptive and generalist predator with high ecological tolerance on the other hand it has an isolated population in Türkiye. We investigated the ecological characteristics of caracal (*Caracal caracal*) in the Mediterranean ecosystems of Southwestern Anatolia (Türkiye) where its population is isolated from other Asian populations. We used field observations and camera trap methodology across a landscape covering 750 km^2 to determine the population status, morphology, behavioural characteristics, the status of species in the community, diet and habitat preference of caracal in the region. Caracal density was estimated to be 0,18 caracals/km^2. The female home range was estimated to be between 4,1 km^2 and 25 km^2 whereas the male home range was estimated to be between 5 km^2 and 50 km^2 or more. Species' daily activity was determined as cathemeral. Annual activity patterns as well as home range sizes decreased during the dry season. During the wet season, caracal activity as well as home range sizes increased. Vegetation cover was found to be the most important factor affecting habitat use by caracal. A strong negative correlation of 0.7 between caracal occurrence and forest cover indicated that forest cover was the most important factor affecting habitat use by a caracal. Caracal occurrence was also positively correlated with 3 mammal species in the study area, wild boar, European hare and wild goat. Caracal was determined as the dominant carnivore species in the ecosystem. Wild herbivore populations in the study area seem to be influenced by caracal thus resulting in a conspicuous effect on grazing pressures. We conclude that caracal is a keystone species in our ecosystem and plays a vital role in maintaining their integrity. Thus, the conservation of the caracal population is crucial for the conservation of the whole Mediterranean ecosystem.

Keywords: *Caracal caracal*, Mediterranean Ecosystems, Türkiye, camera-trapping, REM

Introduction

Caracal (*Caracal caracal*) is a wild and charismatic cat that has a wide distribution range making it one of the most expansive mammalian species among carnivores. It ranges from the African continent except central parts, north to the Arabian Peninsula, the Middle East, and Türkiye, eastwards to central India and northwards to central Asia, Kazakhstan and Turkmenistan. Its habitat in Turkiye can generally be defined as dry habitats that include arid woodlands, savanna, scrublands, hilly steppes, and arid mountainous regions and Mediterranean woodlands formed by maquis and Turkish Red Pine (Stuart, 1982; Nowell & Jackson, 1996; Sunquist & Sunquist, 2002; Hoath, 2003; İlemin & Gürkan 2010; Veals et al., 2020).

However, knowledge about the caracal in Türkiye is rare despite occurrence records from the early 1960s (Çağlar, 1963). In recent years, studies on the ecology of caracal have been conducted in Southwestern Türkiye (Giannatos et al., 2006; İlemin & Gürkan, 2010; İlemin, 2014, Mengüllüoğlu & Ambarlı 2019, Soyumert et al., 2020, Ünal et al., 2019, İlemin et al., 2020, Ünal et al., 2020, Ünal 2023). A detailed study on caracal ecology was carried out in Muğla Province in Türkiye (İlemin & Gürkan 2010) that found caracal to occur mainly in pine woodlands with high habitat heterogeneity. The study found no caracal records from low scrub (phrygana) vegetation. Caracals are known to be active during both day and night except for late morning and around midnight (İlemin & Gürkan, 2010). A study on temporal activity patterns of caracal and several of its potential prey revealed a habitat segregation between the caracal and the wild goat, while indicating an overlap between caracal and other prey species such as brown hare (*Lepus europaeus*), field mice (*Apodemus spp.*), chukar partridge (*Alectoris chukar*) and wild boar (*Sus scrofa*) (Mengüllüoğlu & Ambarlı, 2019). Caracal have also been shown to avoid habitats visited by humans and feral dogs (Ünal et al., 2020).

Caracal is also a member of a large mammal community in the Mediterranean habitat that is shaped by wildfires (Soyumert et al., 2020). The fires that occurred in Southwestern Türkiye in July and August 2021 were recorded as one of the biggest fires in the history of the Republic. However, the caracal population in the region survived the fires with minimum damage (İlemin, 2021). The aim of this study is to understand the ecological characteristics of caracal (*Caracal caracal*) in Southwestern Türkiye where its population is isolated. To this effect we measured the ecological characteristics of caracal in doing so we hope to highlight the current status of the species, its potential interactions with other wildlife and its conservation importance within Mediterranean ecosystems.

Materıal and methods

Study area

This study was carried out in Muğla Province, Marmaris and Köyceğiz district, located in Southwestern Türkiye (Fig. 1). Our sampling area covered nearly 750 km^2 which included three protected areas; Marmaris National Park, Bördübet and Köyceğiz Wildlife Development Reserves.

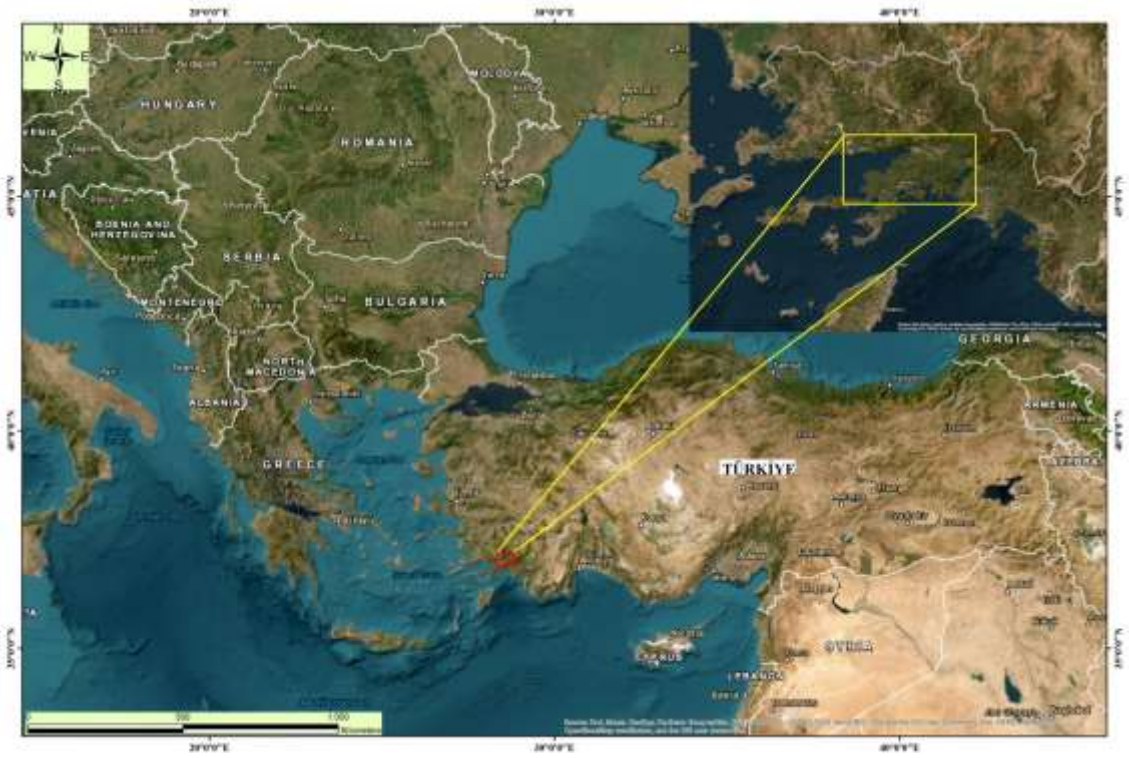

Figure 1: Location of the study site and camera trap stations

The study site has a Mediterranean climate with hot and dry summers and mild and rainy winters. The main vegetation of the region is dominated by Turkish red pine (*Pinus brutia)* forest at different post-fire succession regeneration stages, maquies and mixed stands of red pine and maquies species such as *Arbutus* spp., *Quercus* spp., and *Erica* spp. The altitude ranges between sea level and 1000 m a.s.l.

Camera trapping Survey

We conducted the survey between December 2014 and February 2017, using 29 camera traps (Cuddeback Digital, Wisconsin, USA). The camera traps were placed approximately 5 km away from each other and did not use any baits (Fig. 2). We visited the camera trap stations monthly to download data and renew batteries. The caracal survey extended over 15372 camera trap days.

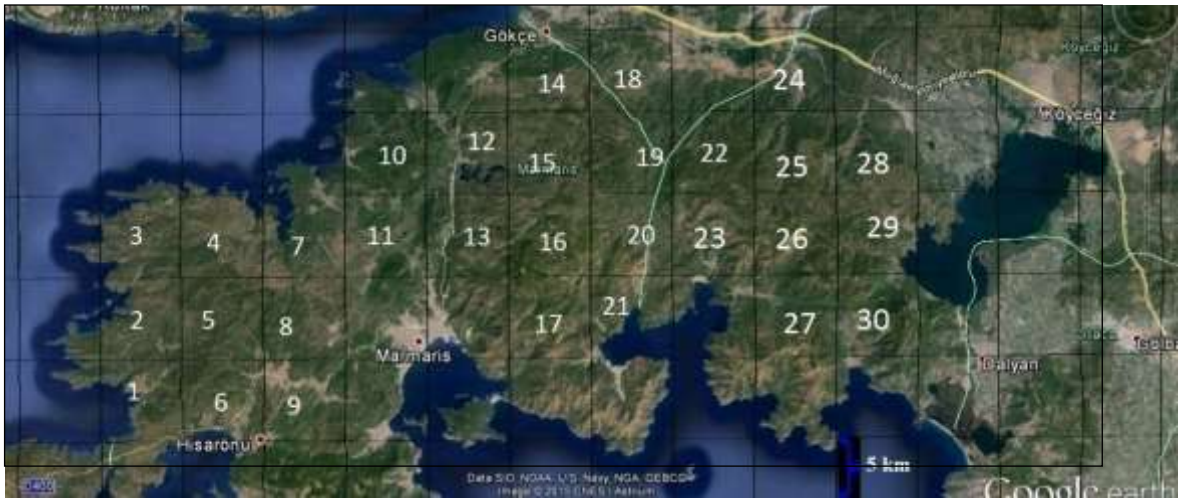

Figure 2: Location and the number of the grid cells. Number 18 was excluded because of the high anthropogenic effects

Data analysis

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 if possible sex, group size and other notes. If more than one record of the same species was obtained on a camera within 10 minutes, we treated them as a single record. The Random Encounter Model (REM) method was used to determine the density of the caracals in the study area and the number of individuals per km^2. 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 (Rowcliffe et al., 2008; Palencia et al., 2022). REM method estimates density as: $D= y/t. \pi/v.r. (2+ \theta)$ 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. R-value is 0,0015; θ value is 0,392; v value is 10 km/day (Ramesh et al., 2017, İlemin, 2017).

Capture rate (Cr)" was calculated to find the relative abundance of caracal and other species in the study area (Rovero et al., 2014; Cusack et al., 2015). Capture rate was estimated as "Cr" = (A*100/B) where Relative abundance index value=Capture rate (Cr), A = number of records of the target species from all stations in the study area, B = total camera-trap days. Cr value was used to compare the caracal abundance of different caracal regions. Correlation analysis (Spearman Correlation Analysis) was performed to determine the relationship of the caracal with other mammalian species and habitat variables. We estimated the area covered by the crown closure classes (percentage coverage of the red pine forest) in the stand compartments for each grid cell using the ArcGIS 10.2 program. We classified crown closure classes as 0, 1, 2 and 3 in each grid cell representing 1-10%, 1: 11%-40%, 2: 41%-70%, and 3: 70%-100% crown closure respectively. Correlation coefficients (Spearman and Kendall'stau) were used to

assess the relationship between caracal and crown closure. In order to calculate the home range size of the species in the study area, a home range was defined as a set of contiguous grid cells with at least three detections per grid cell within 1 month with 3-h interval recording (Douglas-Hamilton et al., 2005).

Results

During our 15372 camera trap days, we recorded 15 different mammalian species (Table 1).

Table 1. Total number of events in 15372 camera trap days

Species	Total number of events in 15372 trap days
Sus scrofa	1457
Capra aegagrus	1263
Lepus europaeus	1020
Vulpes vulpes	576
Caracal caracal	320
Meles meles	229
Ursus arctos	53
Felis silvestris	17
Martes foina	15
Canis lupus	11
Erinaceus concolor	10
Canis aureus	7
Dama dama	2
Lutra lutra	1
Mustela nivalis	1

Caracals were detected on twenty-five camera trap stations totalling 320 encounters.

Density and daily activity

According to the REM calculations, the population density was found to be 0.18 caracal/km^2 (D = 0.18 +/- 0.58; 95%CI = [0.11 -- 0.49]). Caracal records were obtained mostly during the day between 06:00 and 08:00. During the noon, between 12:00 and 14:00, and late around midnight (22:00-00:00) we recorded the minimum number of detections of caracal (Figure 3).

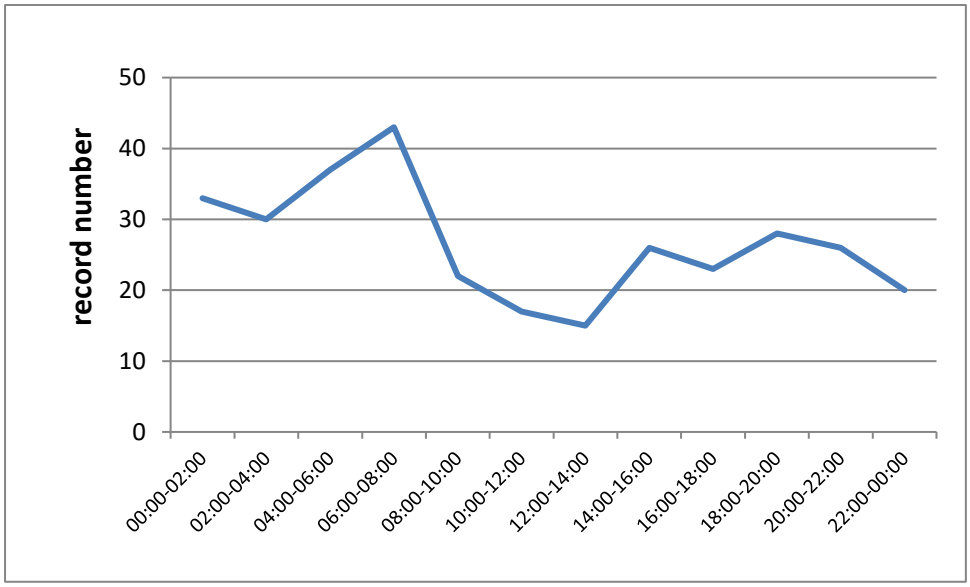

Figure 3. The daily activity of Caracal

Annual activity

The lowest activity during the year was observed in October (Fig. 4).

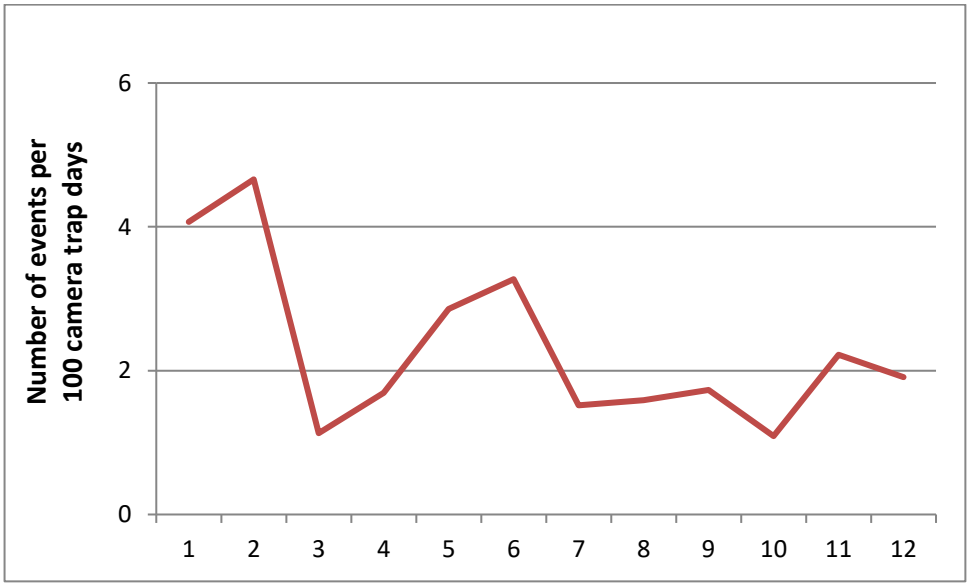

Figure 4: Annual activity of Caracal, Number of caracal records per 100 camera trap days for each month

Habitat preference

According to the results of habitat preference analysis, a negative correlation was found between the presence of caracal and crown closure 3 (Spearman'srho=- 0.398, p=0.029). The caracals did not prefer areas with a red pine crown closure higher than 70%. It was figured out that caracal records are not related to altitude. Although the statistical result obtained (Spearman'srho= 0.356, p=0.058) did not indicate a significant relationship, the abundance of the species tends to increase with altitude.

Interaction with other mammal species

Correlation analyses revealed a positive relationship between the presence of Caracal and the presence of Brown hare (Spearman'srho=0.413, p=0.021) as well as between caracal and wild boar (Spearman'srho=0.487, p=0.006). There was also a positive relationship between the presence of Wild goats and the Caracals in the area (Spearman'srho=0.375, p=0.038).

Other records (Morphological and behavioural characteristics, Diet)

We observed no sexual dimorphism in terms of fur colouration. However, in some males, a dark colouration was seen in the form of a thin line along the spine. Its coat colour varied from red or dark brick colour to yellowish grey tones and white bellies (Fig. 5, 6).

Figure 5. A male caracal recorded by a camera trap in Köyceğiz, 06.12.2015

Figure 6. A camouflaged caracal

Dark patterns in the form of lines and spots were detected on the inner parts of the front legs of caracals. These patterns show different features in each individual. In this way, individuals were diagnosed by examining the photographs (Fig. 7).

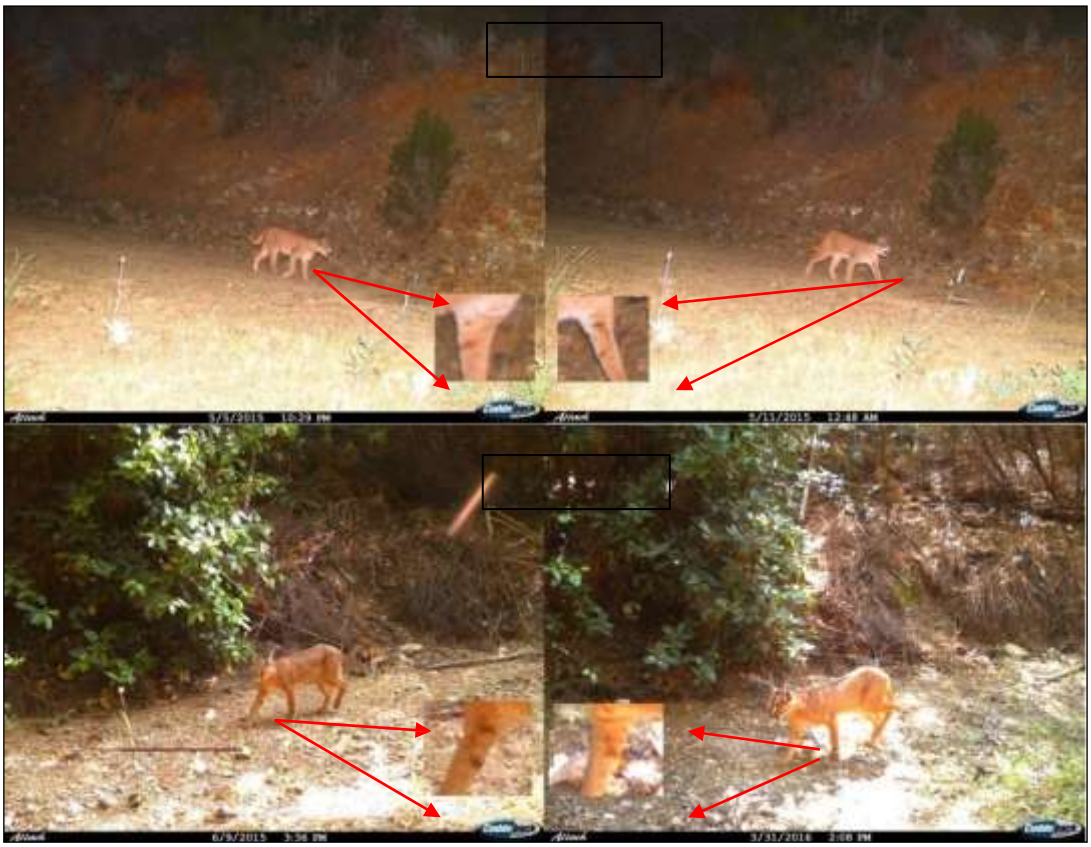

Figure 7. Four different caracals at two different camera trap stations (station numbers: 28, 14)

Some of our camera traps recorded chukar partridge, common blackbird, Eurasian jay and green lizard (Fig. 8).

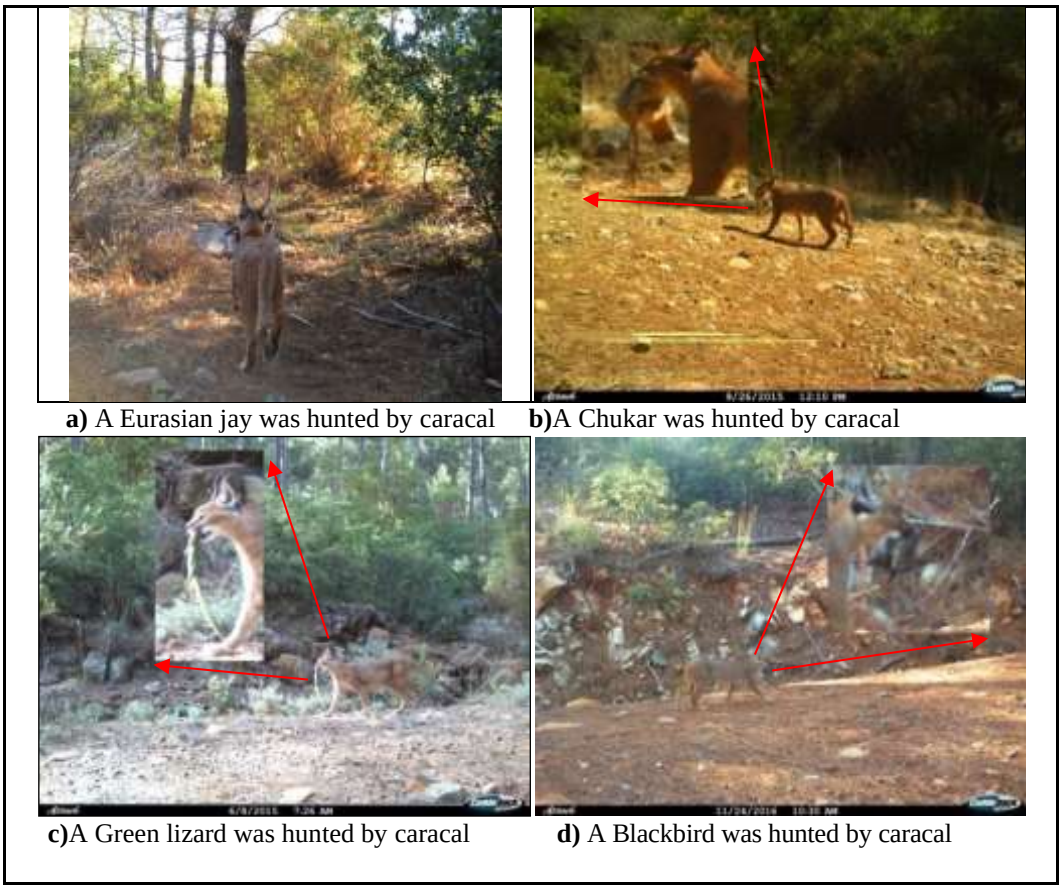

Figure 8: Caracal and preys were taken by camera trap, station numbers: a) 23, b) 13, c) 22, d) 25

Home Range

89 different individuals were identified across all camera traps. The average home range of the two females identified was determined to the 25 km^2 (Min.:1, Max.:6). This indicates that the size of the home range for females can vary between 4.1 km^2 and 25 km^2. In some grid cells of the study area, while female individuals were detected, male individuals were not detected which means a male caracal has a home range size of covering at least two grid cells. In some grid cells, there may be more than one male individual (Max: 5). This indicates that the size of the home range for males can vary between 5 km^2 and 50 km^2.

Discussion

In this study, we reveal the main ecological characteristics of caracals with the most intensive study ever performed in Türkiye. The caracal population in Türkiye is one of the most fragile populations due to its isolated situation from the other populations in Asia (Avgan et al, 2016; İlemin et al., 2020). The results indicate that our study area has the second-highest caracal abundance and density in Anatolia (Table 2).

Table 2: Comparison of Abundance (Cr)* and Density (REM) of Caracal in Anatolia and Asia

Literature	Location	Caracal Abundance (Cr)/Density (REM)
İlemin, 2014	Türkiye, Muğla (Marmaris-Bördübet)	4 / 0.36
This study	***Türkiye, Muğla (Marmaris-Köyceğiz)***	***2.08 / 0.18***
Mengüllüoğlu&Ambarlı, 2019	Türkiye, Muğla (Köyceğiz)	1.96 /-
İlemin&Gürkan, 2010	Türkiye, Muğla (Datça)	0.67 / 0.06
İlemin et al., 2020	Türkiye, Burdur (Altınyayla)	0.62 / 0.05
Ünal et al., 2019	Türkiye, Antalya (Düzlerçamı)	0.19 /-
Giannatos et al., 2006	Türkiye, Antalya (Düzlerçamı)	0.29*/-
Smith, 2012	South Africa	7.9/-
Khorozyan et al., 2014	Yemen	4.18/-
Gubiani et al., 2020	Abu Dhabi Emirate	5.4/-
Singh et al., 2014	Western India	0.14/-
Moqanaki et al., 2016	Iran	0.30/-
Hamidan et al., 2019	Jordan	0.11/-

(Cr)*: Capture rate, was calculated as the independent number of events of a target species per 100 camera-trap days.
0.29*: sampling was made by baiting a camera-trap station

The high density of caracals in the Muğla region (Marmaris, Bördübet and Köyceğiz) as evidenced by our study and others (Table 2) is likely the result of abundant prey availability (rodents and chukar) and the existence of early succession post-fire habitat patches. The Marmaris-Bördübet region, in particular, has a diverse fire regime and the landscape displays a variety of different post-fire successional stages which means abundant prey for caracals and other carnivores (Soyumert et al., 2020; İlemin, 2021). According to our data caracal has a remarkable abundance in Türkiye and is only rivalled by South Africa and the Southern parts of the Arabian Peninsula (Yemen and Abu Dhabi).

Daily/Annual activity

Table 3. Daily activity patterns of Caracal

Activity range	Nocturnal		Crepuscular		Diurnal				Crepuscular		Nocturnal
Time	00:00-01:59	02:00-03:59	04:00-05:59	06:00-07:59	08:00-09:59	10:00-11:59	12:00-13:59	14:00-15:59	16:00-17:59	18:00-19:59	20:00-21:59
Records	33	30	37	41	22	17	15	26	23	28	26
Total records	**63**		**78**		**80**				**51**		**46**

Activity	Records	Ratio (%)	Activity description*
Nocturnal	109	**34.27**	Nocturnal: starts with sunset ends with sunrise
Crepuscular	129	**40.56**	Crepuscular: active at dawn and dusk (twilight)
Diurnal	80	**25.15**	Diurnal: starts with sunrise ends with sunset

Activity description/literature*: It has been calculated according to local time zone / Gomez et al., 2005; Jimenes et al., 2010; Soyumert et al., 2020; Dendup et al., 2023

Although there was no sharp distinction between activity time categories, we observed that caracals tended to be more active around twilight (crepuscular), especially at dawn (Table 3). These results were consistent with previous studies (İlemin & Gürkan, 2010; Mengüllüoğlu & Ambarlı, 2019). This activity pattern could be explained by caracals' adaptive and generalist character as a predator with a wide ecological tolerance (Avenant & Nel, 2002; Jansen, 2016; Mengüllüoğlu & Ambarlı 2019). The easiest time to hunt especially bird species such as the chukar was in the early morning and early hours of the night. This situation explains the crepuscular activity of caracal (n= 129). The daily activity of rodents, hares were nocturnal and overlapped with the caracal activity. This period was indicated as the second active period for caracals (n=109). A pregnant individual preying on a large green lizard in the early morning (see Fig. 8c) suggests that the species employs opportunistic strategies for hunting since lizards as poikilotherm vertebrates are inactive in the colder temperatures of early morning and is thus easy prey.

Our study revealed cathemeral activity for caracals in Anatolia which means that random intervals of activity during the day or night in which food is acquired. Despite African caracals not exhibiting this trait another Asian caracal population in Yemen also showed cathemeral activity (Avenant & Nel 1998, Khorozyan et al., 2014). Our study also indicated that caracals were more active in the rainy period (52%) than in the dry period (48%). In Iran, caracals are found in the areas with permanent water sources located in the middle desert region of the country (Adibi et al., 2014).

Similar to our study, it is an expected result that permanent water resources are in the center of the home range size of the species in the dry season (Sapozhenkov, 1962; Avenant & Nel, 1998; Marker & Dickman, 2005). According to our results, caracals do not prefer forested areas with more than 70% crown closure. Productivity and therefore hunting options are low in high crown closure areas (Şişli, 1999; Kaynas & Gürkan 2008; Soyumert el al., 2020). Our findings of a positive correlation between caracal, brown hare, wild boar occupancy patterns are also consistent with previous studies (Mengüllüoğlu & Ambarlı, 2019; Ünal et al., 2019). However the positive relationship between caracal and wild goat presence we observed is unusual (Mengüllüoğlu & Ambarlı, 2019; Ünal et al., 2019). Future studies supported by GPS telemetry and scat-based diet data may help reveal whether this occupancy overlapp is indicative of a prey-predator interaction or not. Our findings nontheless do suggest a preference of caracal for chukar and other birds as prey species which is in parallel with the literature (Palmer, 1988; Melville et al., 2004). We found that the home range of males (5 km^2- 50 km^2) was larger than females (4.1 km^2- 25 km^2), which is similar to caracal home range (males: 5 km^2- 15 km2, females: 2.5 km2- 10 km^2) in İsrael (Weisbein & Mendelssohn, 1990). Generally, regions with low vegetation productivity will support less prey and as a result home range size is larger in arid areas (van Heezik & Seddon 1998). In South Africa, males have a home range size of 26-65 km^2, while females have an average home range size of 7 km^2 (Norton & Lawson 1985, Avenant & Nel 1998). On the other hand, a home range size of 1116 km^2 was recorded in Saudi Arabia during the winter months, which coincides with the dry season (van Heezik et al., 1998). Several records and sightings were taken where caracals focused and sticking to permanent water sources for the purpose of drinking or hunting in the summer days which may be the explanation for our results indicating low activity and less home range patrolling in summer (İlemin, unpublished data).

Caracals in Türkiye are on the decline due to continuous habitat loss, fragmentation, and human persecution. Caracal was determined as the dominant carnivore species in the ecosystem. Wild herbivore/ omnivore populations in the study area seem to be influenced by caracal thus resulting in a conspicuous effect on grazing pressures. Conservation of the local caracal population is crucial for the conservation of the whole Mediterranean ecosystem. This study may be a good guide for the conservation actions of Anatolian Caracals. Because caracal is an indicator species of Mediterranean ecosystems of Southwestern Türkiye.

Acknowledgements

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