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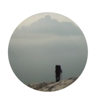

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**Short Note**

Alexandros A. Karamanlidis*, Miguel de Gabriel Hernando, Lazaros Georgiadis and Josip Kusak

# Activity, movement, home range and habitat use of an adult gray wolf in a Mediterranean landscape of northern Greece

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**Abstract:** We present the results of a study on the activity patterns of a wolf in northwestern Greece (2011–2012). The home range of the wolf was 460.5 km$^2$, while the core area was 88.9 km$^2$ and included mainly areas with tree cover and agricultural areas. On three occasions the wolf unsuccessfully tried to cross a highway, highlighting the necessity to identify habitat corridors and effectively mitigate the effects of transportation infrastructure on the species in Greece. Based on these results we propose the increase of research and management actions for the effective protection of wolves in the country.

**Keywords:** *Canis lupus*; highway barrier effect; home range; movement; satellite telemetry.

Large carnivores, including gray wolves (*Canis lupus* Linnaeus, 1758) have made recently significant population recoveries in most of Europe. Such recoveries have been met with enthusiasm (Chapron et al. 2014), but often also with growing concern over potential increases in human-wolf conflicts (Linnell et al. 1999). Effective management and conservation actions, which in turn require the in-depth understanding of a species' biology (Boersma et al. 2001), are necessary to make sure that such population recoveries persist.

Gray wolves are considered vulnerable in Greece and it is estimated that fewer than 700 individuals still survive in the country. Despite a recent increase in distribution, wolves in Greece still face numerous threats, including high human-caused mortality, illegal use of poisoned baits, reduced food availability and ongoing habitat fragmentation (Iliopoulos 2009). Effective wolf conservation in Greece is hampered by the lack of reliable scientific information on the biology and status of the species and the poor enforcement of the existing legal framework.

Telemetry is a useful method in understanding the biology of wild animals and has been used extensively to study gray wolves throughout their range (e.g. Blanco et al. 2005). We present the first wolf telemetry study in Greece, at one of the species' southernmost distributions in Europe and use the results to propose research and management actions that will help protect this poorly-understood and vulnerable wolf population.

The study was carried out in a 1195 km$^2$ study area (40°24′N, 21°33′E) in northwestern Greece, which was delimited by three major, fenced highways and a highly-used national road in the North (Figure 1). Following an unsuccessful attempt on the 15th November 2011 to raid livestock, a wolf was physically restrained and then tranquilized with an initial intramuscular injection of 1 ml xylazine (100 mg/ml) using a jab stick and additionally 5 ml ketamine (100 mg/ml), by hand. We identified the animal as an adult male (approx. 7–8 years of age), named it "Askios" and fitted it with a GPS-GSM collar (Vectronic Aerospace GmbH, Berlin, Germany) programed to attempt a GPS-fix every 2 h, 24-h per day. The wolf was monitored during the winter and early spring season, until 3 May 2012, when the collar signal was abruptly lost. Evidences of a resident wolf pack present in the area were found

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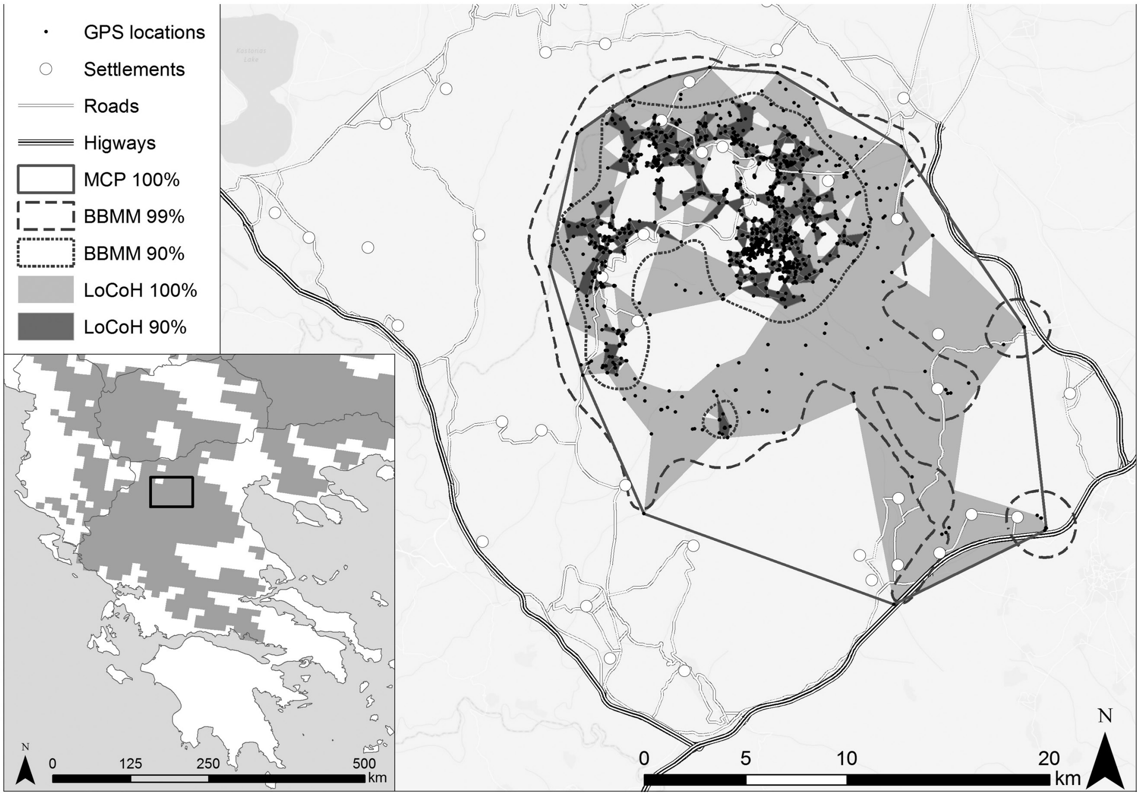


**Figure 1:** Map showing GPS-fixes and home ranges of a resident adult male wolf tracked using GPS telemetry in Northern Greece (15 November 2011–3 May 2012).
The shaded areas in the inset map of Greece indicate the approximate range of wolves in Greece according to Chapron et al. 2014.

during the entire study period, so we concluded that this individual was a member of the resident pack.

We calculated home range size by the traditional 100% minimum convex polygon (MCP) method and by calculating Brownian bridge movement models (BBMMs) (Bullard 1999) and local convex hulls (LoCoHs). Latter approaches are known to be more appropriate for studying highly mobile species (Walter et al. 2011) and identifying hard boundaries, such as roads (Getz et al. 2007). Calculations for σ1 in BBMMs were based on algorithms suggested by Horne et al. 2007, using a value of σ2=10.6 based on the average error obtained by 40 trials with the collar placed in a known location. We plotted cumulative home-range sizes against the BBMM and LoCoH contour levels in 5% intervals, identifying the "core area" as the isopleth levels with the outermost slope discontinuity (Harris et al. 1990). All analysis were performed using the packages adehabitatHR and adehabitatLT for program R 3.0.1 (Calenge 2006, R Core Team 2013). For each valid GPS-fix we calculated its distance to roads and human settlements and compared it (t-test) with the expected values obtained from 2000 random points within the study area (ArcGIS v.10.1). We also evaluated human-wolf interactions, by assessing the proximity of each GPS-fix to a human construction: Each GPS-fix <50 m to either a house or a livestock enclosure was considered an active attempt to feed from garbage and/or from livestock. Finally, activity patterns were calculated based on the distances between successive GPS-fixes; the wolf was considered to be stationary when successive fixes were closer than twice the GPS average error distance (i.e. 21.2 m), once all 2-D locations with dilution of precision >5 were excluded (Lewis et al. 2007).

"Askios" was tracked for 170 days and 1766 valid GPS-fixes were obtained. The total 100% MCP home range was 460.5 km$^2$, the 99% BBMM home range was 341.9 km$^2$ and the BBMM core area was 88.9 km$^2$ (Figure 1 and Table 1). Wolf home range included mainly open pastures, grasslands and agricultural areas. Forested and areas with shrubs were less represented in the total home range, but relatively increased within the core area (Table 1).

During the study the wolf actively avoided proximity to roads (t=-3.20, p=0.001) and human settlements (t=-11.06, p<0.001). However, we documented at least 46 approaches to human settlements: these approaches occurred on average every 3.5 days and always during

**Table 1:** Home range and core area size, habitat composition (CORINE land-cover) and road density of a resident adult male wolf tracked with GPS telemetry during the winter and early spring of 2011–2012 in northwestern Greece.

| | Study Area | Home range | | | Core area | |
|---|---|---|---|---|---|---|
| | | MCP[a] 100% | LoCoH[b] 100% | BBMM[c] 99% | LoCoH 90% | BBMM 90% |
| Size ($km^2$) | 1195.0 | 460.5 | 279.4 | 341.9 | 39.6 | 133.9 |
| Land cover type use (%) | | | | | | |
| Broad-leaved forest | 11.1 | 11.7 | 11.7 | 17.7 | 18.1 | 24.7 |
| Mixed forest | 1.5 | 2.0 | 1.0 | 2.4 | 1.5 | 4.2 |
| Coniferous forest | 0.4 | 0.3 | 0.1 | 0.2 | 0.3 | 0.4 |
| Shrub | 13.1 | 15.9 | 15.1 | 15.3 | 25.0 | 19.2 |
| Pasture and grassland | 30.4 | 43.9 | 40.4 | 34.5 | 13.9 | 14.8 |
| Agricultural | 39.4 | 25.0 | 30.5 | 28.3 | 41.0 | 35.1 |
| Settlements | 4.1 | 1.2 | 1.2 | 1.5 | 0.2 | 1.5 |
| Road density ($km/km^2$) | 0.422 | 0.196 | 0.237 | 0.206 | 0.197 | 0.277 |

[a]MCP, Minimum convex polygon.
[b]LoCoH, Local convex hulls.
[c]BBMM, Brownian bridge movement models.

nighttime (i.e. 19:00–05:00). Most approaches (78%) were within the 90% BBMM core area.

"Askios" traveled a total distance of 2463 km throughout the study area. On three occasions in February 2012 he unsuccessfully attempted to cross a 4-lane, fenced highway (Figure 1). We believe that these were active attempts to move beyond the highway, because the potential highway crossing points were at least 5 km outside the 90% LoCoH and BBMM core areas of the animal, <170 m from the highway fence and the animal traveled in a >5 km straight line towards them. However, "Askios" did manage on at least 426 occasions to cross secondary roads. The average distance traveled daily was 14.7±6.7 km; the shortest and longest distance traveled in a single day was 1.1 and 36.6 km, respectively. "Askios" was active during 68% of the day and activity levels were highest during night hours when the distance traveled was higher. Whereas in the core area the wolf was active 65% of the time (GPS-fixes, n=1533), he increased the average activity levels up to 86% when going outside the core area (GPS-fixes, n=233).

Studying spatial requirements and activity patterns is essential in understanding wolf biology and GPS telemetry is a useful tool in achieving this. We present the results of the first GPS telemetry study of an adult male member of a wolf pack in northern Greece. Considering the fact that our study animal was tracked only for half a year our results regarding the assessment of its home range should be interpreted with caution (Okarma et al. 1998). However, since our tracking efforts included the entire winter, when wolves roam the most (Mech 1970) our home range estimation should not differ significantly from the actual annual home range. The 100% MCP home range of the tracked wolf was considerably smaller than home ranges of resident wolves in northern Europe (Kaartinen et al. 2005), but in general accordance to home ranges recorded throughout the human-dominated landscape of the Mediterranean (Ciucci et al. 1997, Kusak et al. 2005). The core area comprised only a small percentage (26%) of the entire home range and consisted mainly of areas with some type of tree cover and agricultural areas. The use of this type of habitat is characteristic for wolves occupying a Mediterranean landscape and appears to be influenced by the necessity to hide from humans and find at the same time enough food (Ciucci et al. 1997, Kusak et al. 2005).

Within his home range "Askios" actively avoided human settlements and roads. Similar behaviors have been recorded throughout the Mediterranean and in northern Europe (Ciucci et al. 1997, Kaartinen et al. 2005, Kusak et al. 2005). Such avoidance behaviors are most likely associated with active efforts of wolves to avoid humans (Merrill 2000). Despite this, the studied wolf crossed on several occasions secondary paved roads, which is consistent with the recorded efforts of wolves in areas with limited human activity to use roads in order to travel faster (James and Stuart-Smith 2000).

Despite his overall attempts to avoid humans, "Askios" approached in numerous occasions human settlements in, presumably, an attempt to feed from anthropogenic food sources. Such potential human-wolf conflicts are a serious conservation problem for wolves throughout the European continent (Boitani 2000) and might have led ultimately to the loss of our study animal through poaching.

The general activity patterns of the wolf "Askios" indicated high nocturnal activity. This is consistent with wolf activity patterns throughout the Mediterranean (Vilà et al. 1995, Ciucci et al. 1997, Blanco et al. 2005, Kusak et al. 2005), but also northern Europe (Theuerkauf et al. 2003). It is unclear however, whether the nocturnal activity of wolves is influenced and determined by the intensity of human activity. This has been suggested for wolves living in the Mediterranean (Ciucci et al. 1997, Kusak et al. 2005), but could not be verified for wolves in Poland (Theuerkauf et al. 2007).

Considering the results of our study we believe that our tracked wolf and his pack-mates actively attempted to make the best out of the available food resources within their home range, while avoiding at the same time humans. This concurs with observations from throughout the Mediterranean (Ciucci et al. 1997, Kusak et al. 2005).

The use of GPS tracking to study wolves has provided valuable new insights into the biology and behavior of the species in Greece. Considering this, the limited amount of information on wolves in Greece and the usefulness of this methodology in wolf research (White and Garrott 2012), we suggest that efforts to study the species using this methodology should be intensified.

During this study we collected circumstantial proof of a highway acting as a barrier to wolf movement. Similar observations have been made in Banff National Park where the importance of highway crossing structures to mitigate such barrier effects has been emphasized (Clevenger and Waltho 2000, Kusak et al. 2009). Concurrent genetic studies in Greece indicate that the existence of highways has not yet had an effect on wolf population structure in Greece (Karamanlidis, unpublished data); considering however, the documented barrier effect and the fact that on occasion, fenced highways may add to wolf mortality through vehicle collisions (Clevenger et al. 2001), we recommend intensifying monitoring efforts in the area in order to identify suitable locations for the construction of effective wildlife crossings.

The results of our study indicate that our study area offers suitable habitat for wolves in the region. The study area is currently not included in the ecological network of protected areas NATURA 2000 of the European Union and no protection and management measures are in place. On a national level, efforts should intensify that will identify suitable habitat for wolves in the country and ultimately lead to the establishment of a functional network of protected areas that will secure the survival of the species (Apollonio et al. 2004). All new information on the biology and behavior of the species, should ultimately lead to the formulation of a Wolf Management Plan for Greece, similar to the one formulated for wolves in Europe (Boitani 2000), that will guide and coordinate conservation actions for the species in the country.

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**Conflicts of interest:** The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in the study.

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