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Original investigation

The influence of human disturbance on occupancy and activity patterns of mammals in the Italian Alps from systematic camera trapping

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ABSTRACT

As human activities increase in natural areas, so do threats to wildlife, potentially leading to immediate and long-term impacts on species distribution, activity, reproduction and survival. This is particularly relevant for large-bodied vertebrates that are especially sensitive to human presence and human-driven habitat changes. Assessing the impact of anthropogenic disturbance requires data on distribution and activity patterns of target species in relation to human presence and infrastructures. Here, we used camera trap data to study the influence of anthropogenic disturbance on the community of medium-to-large mammals in a mountainous area in the eastern Italian Alps, with emphasis on the local population of brown bear (*Ursus arctos*). In 2015, we sampled a study area of 220 km^2 with 60 camera trap locations adopting a systematic grid. Such design was inspired by the terrestrial vertebrate monitoring protocol developed by the TEAM Network, a pan-tropical biodiversity programme. Camera traps run for 30 days in each site and cumulated 1978 camera trapping days, yielding 1514 detection events of 12 species of mammals. For the 8 most recorded species, we used detection/non-detection data to model estimated occupancy and detection probability in relation to a suite of environmental and disturbance covariates. Our analysis revealed that human disturbance plays a significant role in influencing species-specific detection probability, while we found little evidence of significant relationship between occupancy and anthropogenic disturbance. For example, we found that brown bear's detectability was negatively correlated with capture rate of humans at sampling sites, and positively correlated with distance from settlements. We also assessed species-specific daily activity patterns and found that, for all species, the overlap with human diel pattern decreased significantly at sites with higher human presence. We also discuss the potential of our approach for cost-efficient and long-term monitoring of mammals.

Introduction

In human-dominated landscapes, increased habitat fragmentation and accessibility to natural areas are bringing humans in closer contact with wild populations (Preisler et al., 2006). Outdoor recreation is typically assumed to be compatible with biodiversity conservation and permitted in most protected areas worldwide, but its effect is still a relatively unknown topic in the conservation science literature (Taylor and Knight, 2003; Blumstein et al., 2005; Sutherland, 2007). Human recreation and diversification of outdoor activities have become of major conservation concern as tourism expands into natural parks (Margules and Pressey, 2000). Recreation is important for maintaining public support for protected areas and connecting people with nature (Kays et al., 2016), but at the same time it could also be a major disturbance to wildlife (Baker, 1992; Hobbs and Huenneke, 1992; Larson et al., 2016). In addition to habitat degradation resulting from the development of recreational facilities and infrastructure, which can cause an array of impacts on the distribution, reproduction and survival of wildlife (George and Crooks, 2006; Reed and Merenlender, 2008), human disturbance can elicit costly behavioral responses such as flight (Arlettaz et al., 2007; Thiel et al., 2007), feeding disruption (Fernandez-Juricic and Tellería, 2000) or changes in spatial/temporal habitat use (Rogala et al., 2011). Species with large spatial requirements

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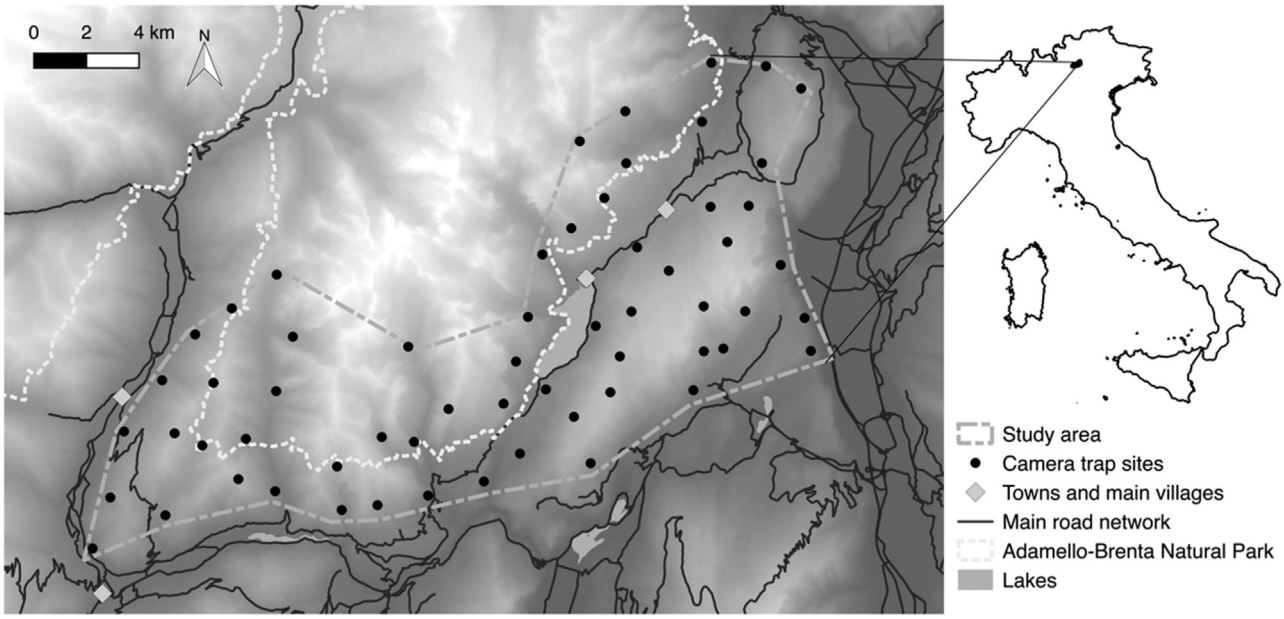

Fig. 1. Map of the study area (left) in western Trentino province, Northern Italy. The 60 camera trap locations are shown as black dots and the border of the Adamello-Brenta Natural Park is also shown. The background is a Digital Terrain Model, with brighter tones corresponding to higher elevation. The geographic location of the study area in Italy is shown in the map on the right.

and low population densities, typically the large carnivores, are especially sensitive to human infrastructure and activities (Crooks, 2002). Stankowich (2008) indicates that experience with humans and their recreational activities also has a significant impact on ungulate behaviour. For these reasons, larger mammals are considered a proxy of ecosystem health and habitat connectivity (Crooks et al., 2011; e.g. Peters et al., 2015); hence, understanding how their spatio-temporal patterns of habitat use are locally affected by human disturbance becomes an increasingly important research question (Larson et al., 2016).

Here, we examined habitat preferences and the influence of human disturbance on spatial and temporal patterns of medium-to-large terrestrial mammals in a human-disturbed mountainous area in the eastern Italian Alps. The Alps represent a priority area for conservation globally (Olson and Dinerstein, 2002), being one of the richest biodiversity hot spots of Europe and at the same time one of the most intensively exploited mountain ecosystems in the world (Lassen and Savoia, 2005). This mountain range, despite the natural fragility of its ecosystems, is the first destination for outdoor winter sports in the world, which is emblematic of the anthropogenic pressure (Elsasser and Messerli, 2001). The study area is partially inside a protected mountain area (Adamello Brenta Natural Park, PNAB) of particular faunal importance for the historical presence of the last alpine population of brown bear (*Ursus arctos*) that was recently reintroduced (Preatoni et al., 2005), as well as for the current recolonization of the wolf (*Canis lupus*; Ražen et al., 2015).

The on-going expansion of tourism and recreation into wildlife habitats calls for measures to mitigate the negative effects of anthropogenic disturbance (Sutherland, 2007). Mitigating such disturbance requires knowledge on how humans impact wildlife occurrence and activity patterns. We aimed to study the potential influence of human disturbance on spatial (i.e. occupancy and detectability) and temporal (daily activity) patterns of wildlife in the study area, especially in relation to the high presence of tourism in the summer. Our specific objectives were: (1) to assess species' probability of occurrence by estimating occupancy and detection probability, (*sensu* MacKenzie et al. (2002)), (2) to determine anthropogenic and habitat drivers of variations in these metrics, and (3) to assess daily activity patterns of the species in the study area and investigate the relationship between these and human presence.

Material and methods

Study area

We conducted the camera trap survey between June and August 2015 in an area of about 220 km^2 within Trento Province, NE Italy (centred on 46°06′45"N and 10°55′50"E; Fig. 1). This mountainous area encompasses the southern part of Brenta, the westernmost Dolomite group, and its adjacent valleys, which are partially included within the PNAB. While this is formally a protected area, not being a National Park its regulations allow for activities such as hunting, logging and road building, and therefore we assumed that human disturbance does not differ inside and outside the protected area. Therefore, the most relevant feature for our study aims was that some of the sampling sites within the PNAB were more distant from settlements and trafficked roads, and at relatively higher elevation. The sampling area holds part of the core area of the brown bear population (Groff et al., 2015) and represents a large variation in both habitat type and altitudinal range (300–2800 m a.s.l.), with a dominant mountainous terrain. The vegetation composition ranges from mixed broad-leaved and coniferous forest, dominated by common beech (*Fagus sylvatica*), European larch (*Larix decidua*) and pine (*Pinus* spp.), to subalpine forest communities dominated by pine, spruce (*Picea excelsa*) and silver fir (*Abies alba*). Above the treeline (at about 1800 m) vegetation is dominated by mountain pine (*Pinus mugo*) and open habitats comprised of alpine herbaceous species. The climate of the study area varies from continental to alpine, in relation to altitude. The average resident population density is of 32.2/km^2 (http://www.urbistat.it/AdminStat/it/) and occurs along the main valleys to the west, south and east of the core study area, with intense tourism presence in the summer. Tourists contribute largely to human activity in summer across the study area.

Data collection: camera trapping

We designed our sampling protocol by adapting the one developed by the Tropical Ecology Assessment and Monitoring (TEAM)