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Short Communication

Jackals as cleaners: Ecosystem services provided by a mesocarnivore in human-dominated landscapes

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ABSTRACT

Ecosystem services are receiving increasing attention among researchers and managers, due to emerging recognition of their global extent and contribution towards human welfare. Obligatory scavengers have been identified as important providers of these services, namely waste management, but their populations are declining worldwide and mesocarnivores are taking on the role of dominant scavengers in many regions. However, mesocarnivores are rarely appreciated for their services of waste removal, and are mostly cited in negative contexts in the literature. Here we explored the widely neglected potential of mesocarnivores as providers of ecosystem services. We used the golden jackal (*Canis aureus*) as a model species and evaluated its provision of ecosystem services in a developing country in the Balkans, where waste management creates numerous challenges. Based on contents of 606 jackal stomachs, food intake and population size, we estimate that in Serbia jackal population annually removes >3700 t of animal waste and 13.2 million crop pest rodents. We estimate the monetary value of animal waste removal at >0.5 million € per year. We scaled this result up to evaluate ecosystem services at the continental-scale, and these results indicate that jackals remove substantial amounts of discarded animal waste (>13,000 t) as well as potential crop pests (>158 million crop pest rodents) across human-dominated landscapes of Europe. These results are the first to demonstrate the value of ecosystem services provided by mesocarnivores as facultative scavengers, and show that they are of great value for local communities in the modern world. We emphasize the importance of recognizing ecosystem services provided by species with predominantly negative public images, in consideration of their conservation.

1. Introduction

Large mammalian carnivores are regularly recognized as keystone species with important roles in maintaining biodiversity and stability of ecosystems (Estes et al., 2011; Ripple et al., 2014). There is also ample literature documenting their provision of ecosystem services (Brashares et al., 2010; Duffield et al., 2008; Krofel et al., 2014; Ripple et al., 2014). In contrast, mesocarnivores (i.e. carnivores with body weight < 15 kg such as coyotes [*Canis latrans*] and badgers [*Meles meles*]) are rarely appreciated for their ecological role or the ecosystem services they provide (Roemer et al., 2009). In fact, most literature reports only their negative ecological effects, including killing of endangered species or monopolizing vital resources (DeVault et al., 2011; Prugh et al., 2009; Ripple et al., 2014). Due to real or perceived losses caused by mesocarnivores on livestock or valuable hunted species, they are often considered to be vermin or agricultural pests (Roemer et al., 2009). Consequently, the general public and various interest groups often express negative attitudes towards them (Kellert, 1985; Mihelič and Krofel, 2012) and they are subject to intensive lethal control programmes (Berger, 2006). At present, it is difficult to assess whether the deficiency of literature on ecosystem services provided by mesocarnivores is due to a lack of research or if is it a genuine indication that mesocarnivores have a limited role in providing such services.

Ecosystem services are receiving increasing attention among researchers and managers (Millennium Ecosystem Assessment, 2005, Posner et al., 2016) and waste management has been identified as one of the most globally important ecosystem services (Costanza et al., 1997). Every year, human societies discard substantial quantities of livestock carcasses and other animal waste (Mateo-Tomás et al., 2015; Oro et al., 2013). Obligate vertebrate scavengers, such as vultures, have been recognized as important agents of carcass removal and related ecosystem services (Markandya et al., 2008; Moleón et al., 2014b). However, especially in human-dominated landscapes, obligate scavengers have suffered dramatic declines (Ogada et al., 2012). On the other hand, facultative scavengers, including mesocarnivores, have been rarely considered as providers of waste management services, and have even been regarded as detrimental to endangered scavengers through competition for carrion (DeVault et al., 2011; Moleón et al., 2014a). In contrast to vultures, mesocarnivores are highly adaptable to human-caused habitat modifications and often thrive in human-dominated landscapes,

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including urban and rural areas (Šálek et al., 2013). Therefore, there is potential for mesocarnivores to have an important impact by removing animal waste in degraded ecosystems with an impoverished scavenger guild. The need for research on animal waste consumption by scavengers in human-dominated landscapes has been recently recognized (Mateo-Tomás et al., 2015), and the ecosystem services provided by these species could be important for future waste management, as well as for mesocarnivore conservation through improving their often negative image among general public.

Here we explore this so far neglected potential of mesocarnivores as providers of ecosystem services. As a case study, we use the golden jackal (*Canis aureus*) in European human-dominated landscapes. The golden jackal is a typical mesocarnivore with high degree of adaptability and plasticity in its behaviour, which has facilitated its recent expansion throughout South-eastern and part of Central Europe (Šálek et al., 2013; Trouwborst et al., 2015). Opportunistic dietary habits have also enabled jackals to profit from anthropogenic food sources in the area (Lanszki et al., 2015). Studies comparing jackal feeding habits with other mesocarnivores, such as the red fox (*Vulpes vulpes*), suggest that diet and foraging behaviour of the golden jackal are typical for a mesocarnivore in human-dominated landscape (Lanszki et al., 2006).

We first analysed jackal diet in rural areas of Serbia, where waste management faces numerous challenges, including the incapacity to process large quantities of domestic animal carcasses and widespread unregulated disposal of slaughter remains (Gvozdenac, 2015; Slamnig, 2015). Despite being under strong hunting pressure, the jackal population is increasing in the country (Appendix A, Fig. A1). We evaluated the amount of animal waste (remains from slaughtering and hunting) and rodents removed by jackals at the individual and population levels. For animal waste removal we also estimated annual monetary value of this service. We also reviewed the literature to gain a general understanding of ecosystem services provided by this mesocarnivore throughout Europe. To put these services in perspective, we also provide data to evaluate potential costs that are associated with the presence of jackals. We then call attention to the importance of recognizing ecosystem services provided by species with predominantly negative public images for their conservation, as well as the importance of facultative scavengers for waste management in developing countries (Appendix A, Fig. A2).

2. Material and methods

2.1. Sample collection and diet analysis

Stomachs of shot animals and road kill were collected during 2004–2014 in all seasons, throughout the jackal distribution in Serbia (Appendix A, Fig. A3). All jackals were sexed, weighed and measured before the stomachs were removed. Stomach content (Appendix A, Fig. A4) was processed and analysed according to standard procedures (Ćirović et al., 2014a). Only samples from adult animals with food remains in the stomach were used for further analysis (N = 606). Bones, teeth, hairs, and feathers were identified using identification keys (e.g. Teerink, 1991) and our own reference collections of wild and domestic animals. Food items were classified into 12 categories (Table 1) and for each category percentage of biomass consumed (%B) and relative frequency of occurrence (%O) were calculated. For animal remains found in stomachs it is generally difficult to differentiate between predation in scavenging. In our case, absence of muscles from livestock in the jackal stomachs and no reported livestock losses attributed to jackals according to the questionnaires made among livestock owners in the study area suggests that at least vast majority of livestock remains found in stomachs come from scavenging and not predation. Similarly, most of wild ungulate remains found in jackals stomachs were limited to hide, bones and intestines (i.e. parts that hunters discard in the field after dressing shot game), although we acknowledge that some of the wild ungulates consumed might have originate from predation.

Table 1
Stomach content of jackals in Serbia (N = 606). %B — proportion of consumed biomass; %O — relative frequency of occurrence.

Food categories	%B	%O
Domestic animals	71.82	49.69
Crop pest rodents	6.45	17.06
Other rodents	3.61	5.4
Wild ungulates	7.99	5.84
European brown hare	2.65	2.74
Birds	2.63	4.16
Plants	2.38	7.96
Medium size carnivores	1.86	1.06
Invertebrates	0.32	1.50
Indigestible	0.24	3.63
Amphibians and reptiles	0.03	0.53
Insectivores	0.03	0.27
Fish	0.01	0.27

2.2. Diet composition at the continental level

In order to evaluate consumption of the three food categories concerned (domestic animals, rodents and wild ungulates) at the European level, we reviewed all available literature on jackal diet in Europe. The primary search for references was carried out on Web on Science and Google Scholar using various combinations of keywords: golden jackal, *C. aureus*, feeding, diet, and Europe. We also searched in the literature-cited sections of all retrieved articles. We retained those studies where food items were categorized in a way that enabled evaluation of the consumed biomass of categories concerned. Data from 13 references were considered (Appendix A, Table A3). For studies where consumed biomass was not reported we calculated conversion factors from our data from Serbia and estimated these values based on reported frequencies of occurrence (Appendix, Table A1). We estimated average diet composition of jackals in Europe by first calculating mean values from all studies for each country. Then we used country averages to calculate overall average diet at the continental level. In this way we reduced bias due to variable number of diet studies in individual countries. Because not all studies reported species composition among rodent species consumed by jackals, we first estimated overall proportion of rodents in jackal diet across Europe and then applied average proportion of crop pest taxa among the rodents (85.7%B) from studies (N = 6) that reported rodent species composition.

2.3. Evaluation of ecosystem services

We estimated consumed biomass of domestic animals (presumably from illegal dumps or road kills), wild ungulates (presumably from hunting remains) and rodents, which are often regarded as major crop pests (Brown et al., 2003). Most of the damage in agriculture caused by rodents in the study area in Serbia is caused by the species from genera *Microtus*, *Apodemus* and *Cricetus* (Jokić, 2012). We evaluated ecosystem services based on jackal consumption of rodents from these taxa (termed “crop pest rodents”).

Estimation of biomass removed from environment was based on dietary data (see above), daily food intake rate, and estimated number of jackals. According to previous dietary studies on jackals (Klare et al., 2010; Mukherjee et al., 2004) we used 850 g for mean daily food intake, which corresponds also to information obtained from feeding of captive jackals at five zoos (800–1000 g; M. Heltai, M.T. Cortez García and K. Ovari, pers. comm.) and general estimate of 7–10% of body weight for carnivores (Mukherjee et al., 2004) and a mean body weight of 11.3 ± 1.5 kg for adult jackals in Serbia (N = 769; own unpublished data), which corresponds to 777–1111 g.

For evaluation of ecosystem services on the continental scale we reviewed available literature or contacted local jackal experts to obtain current estimates of jackal numbers in European countries and thus