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Optimizing the sampling effort to evaluate body condition in ungulates: A case study on red deer

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ABSTRACT

Body condition is a useful measure of the nutritional status and performance in ungulates. The most widely used indicators of body condition are based on fat reserves, mainly those surrounding the kidneys. To estimate the body condition in large herbivores, researchers often collect and pool the data from both kidneys and their perirenal fat in order to compensate for potential differences between the body condition indicators obtained from the left and right kidneys. Since these differences do not seem to be properly established in wildlife, we checked for the potential differences between the body condition indicators, derived from both kidneys, in wild ungulates. In the present study, we used red deer *Cervus elaphus*, both under experimental and field conditions, as a model to analyse the patterns of response of the body condition indicators, calculated from left and right kidneys, to supplementary feeding, sex, age class and season. By considering two analytical approaches – kidney fat index and fat weight (including kidney weight as a covariate) – we consistently obtained similar statistical results and the same ecological interpretations by using left, right and average indicators for all the factors tested. In the experimental study, supplementary feeding had a significant effect on all the body condition indicators of red deer hinds. Under field circumstances, the condition indicators were statistically higher in females than in males and they increased with age. Sex related differences were significant in the winter. Taking into account our results, we hypothesize that information from only one kidney will be enough to assess the body condition in red deer and probably in other wild ungulates. However, a standardized sample (*i.e.* always using the same kidney and associated fat) should be used, while a better understanding regarding possible asymmetries in the amount of the energy reserves on each side of the animals' bodies has not been reached. Our study has clear implications concerning wildlife monitoring since it represents a considerable reduction of time and effort, both in the field (collecting the samples) and in the laboratory (processing and weighing the samples) when evaluating the body condition of individuals and populations.

1. Introduction

Monitoring body condition is an essential tool in wildlife management to evaluate the nutritional status of both individuals and populations. It can also provide a proxy for habitat quality (Taillon et al., 2011) and population dynamics (Morellet et al., 2007). Moreover, it is a useful means to diagnose potential situations of species overabundance (Caughley, 1981). Body condition can be defined as the amount of animals' energy reserves (Hanks, 1981) and is determined by the net balance between nutritional intake and physiological demands (Hickman et al., 1997; Parker et al., 2009; Schmidt-Nielsen, 1975). Several factors may affect the body condition of large herbivores, which in turn can have effects on survival, performance and reproduction (Cook et al., 2004; Parker et al., 2009). For instance, in seasonally changing environments, the availability and quality of food resources vary within a year (Moen et al., 2006), leading to changes in the seasonal cycle of food intake (Illius, 2006) and inducing nutritional constraints (Parker et al., 2009). Additionally, climatic variation and harsh weather conditions (*e.g.* intense and prolonged rainfall, variation in temperature,

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severe winds) increase the animals' energy demands to maintain thermal homeostasis (Clutton-Brock and Albon, 1989; Garroway and Broders, 2005; Serrano et al., 2011). Hence, the body condition could be greatly influenced by intra- and inter-annual environmental fluctuations. Body condition also depends on population density (Couturier et al., 2009; Gaidet and Gaillard, 2008; Stewart et al., 2005) and may be highly variable depending on individual traits such as sex and age class (Mitchell et al., 1976) and reproductive status (Carrión et al., 2008; Yoccoz et al., 2002). Finally, parasite burdens can negatively affect individual body condition (Irvine et al., 2006; Mulvey et al., 1994; Vicente et al., 2004) and supplementary feeding practices – which are also related to diseases and parasite transmission (Gortázar et al., 2006; Vicente et al., 2007) – may help to maintain or enhance the animals' nutritional status (Putman and Staines, 2004).

Several indicators have been developed to assess body condition in wildlife (for reviews see Franzmann et al., 1995; Kirkpatrick, 1980) and in deer species in particular (see Cook et al., 2005; Kie, 1988). The most commonly used indicators are based on fat reserves and, among them, the kidney fat index (KFI; Riney, 1955) has been the most widely used to estimate ungulates' body condition over the last decades (reviewed by Serrano et al., 2008). Originally, the KFI was proposed to evaluate the nutritional status of wild deer and it was defined as the weight of perirenal fat in relation to the weight of the kidneys, as a percentage (Riney, 1955). The KFI correlates positively with total body fat (Finger et al., 1981) and changes in perirenal fat accompany those in body weight (Mitchell et al., 1977). Despite this evidence regarding its physiological significance, the KFI has been questioned as a measure of condition across seasons due to variations in kidney weight that could affect the index values (Batcheler and Clarke, 1970; Dauphiné, 1975). Instead of KFI, Warren and Kirkpatrick (1982) recommended the use of absolute perirenal fat to assess nutritional status, however Waid and Warren (1984) showed a strong correlation between perirenal fat and KFI. Moreover, these authors argued that KFI can be as accurate and reliable as absolute perirenal fat to determine nutritional condition. More recently, Serrano et al. (2008) pointed out some potential problems associated with the use of KFI – a ratio – when performing analysis of variance (ANOVA) and they suggested the analysis of the perirenal fat weight (with kidney weight as a covariate; named here as KCOV) as an alternative method to analyse the variations in the body condition of wild ungulates.

Independently of the indicator or analytical technique used, it is a common procedure to use both kidneys and their associated fat to evaluate ungulates' body condition. According to Anderson et al. (1972), there are important differences between KFI values – both kidney weights and perirenal fat – derived from left and right kidneys, therefore comparisons between them must be avoided. In order to balance these differences, researchers frequently pool the data from the left and right kidneys to perform their analyses. Thus, to date, the use of the two kidneys is the most widely used form of quantifying body condition (*e.g.* Cook et al., 2005; Dauphiné, 1975; Serrano et al., 2008), but differences between kidneys are not well established in wildlife and deserve further investigation.

The optimization of sampling procedures to monitor ungulates is an important issue for wildlife ecologists and managers (see Tayce et al., 2008). In this context, the purpose of this paper is to revisit the topic started by Anderson et al. (1972) on the use of one or two kidneys to evaluate body condition in large herbivores. Here, by using red deer *Cervus elaphus* as a model, we investigate the potential differences between body condition indicators derived from left and right kidneys, by focusing our attention on the response of those indicators to a series of ecological and biological factors that could affect the nutritional condition of the species. Specifically, we aimed at analysing the sensitivity (*i.e.* ability to detect changes) of body condition indicators derived from left and right kidneys to supplementary feeding, sex, age class and season. In this sense, we simultaneously assessed two approaches – KFI (Riney, 1955) and KCOV (Serrano et al., 2008) – to verify whether there are differences in the outcomes of the analyses and subsequent interpretations when quantifying body condition by using the left and right kidneys separately, and their perirenal fat, in relation to pooling the information from both kidneys.

2. Materials and methods

2.1. Study area

Our study was carried out in a 900 ha fenced private hunting estate located in the province of Ciudad Real (south-central Spain, UTM 30S 387400 E – 4308561 N; 600–850 m.a.s.l.). This area is characterized by a Mediterranean climate, with hot and dry summers and mild winters, and a mesomediterranean bioclimate (Rivas-Martínez, 1987). During 2000–2008, the average annual rainfall was 469 ± 47 mm and the average maximum and minimum temperatures were 34 °C and −1 °C, respectively. The vegetation is mainly composed of evergreen oak (*Quercus ilex*) scrubland, but large patches of savannah-like grasslands (*dehesas*) – mostly formed by pastures and scattered trees – are also found throughout the hunting estate. Red deer in the study area live in sympatry with Eurasian wild boar *Sus scrofa* and Barbary sheep *Ammotragus lervia* and Mouflon *Ovis aries*, the latter two species are rarely present. Red deer density is medium-to-high for this region (38 ± 2 deer/km^2 between 2000 and 2008; for a range of densities in the study region see Acevedo et al., 2008) and is maintained by supplementary feeding throughout the whole year, particularly at the end of summer when natural food resources are limited. Under these circumstances, density-dependent effects on body condition are less evident than in natural conditions (Rodriguez-Hidalgo et al., 2010).

2.2. Study design

The analyses of the factors affecting the body condition indicators were carried out using two complementary studies. On the one hand, the effect of the supplementary feeding was assessed in two experimental homogeneous groups of hinds. One group had supplementary food – non-commercial pellets – whereas the other group only had naturally available food sources, obviously also available for the former. After four years in contrasted nutritional conditions, their body condition was assessed. On the other hand, the effects of sex, age class and season were evaluated in a food-supplemented population that is managed for hunting, using the data available from nine years of monitoring.

2.2.1. Experimental study

To investigate the effect of supplementary feeding on the body condition of red deer the hunting estate managers performed a controlled experiment between September 2003 and November 2007. Thirty-six females were divided into two matched age groups and placed into two 14 ha contiguous experimental fenced areas with similar habitat composition, each comprising 1/3 of Mediterranean scrubland and 2/3 of *dehesa* (Fig. 1), and without other ungulate species. All animals used in the experiment came from a single wild non-supplemented population about 50 km from our study area. Prior to release in the experimental fenced area, blood and faecal samples were collected to monitor their physiological and parasitological status. In addition, they were weighed (±0.5 kg) and total body length was measured (±0.5 cm). No differences between supplemented and non-supplemented hinds for