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Sustainable trophy hunting of Iberian ibex

Por una caza sostenible del trofeo de macho montés

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Selective hunting practices, such as trophy hunting, remove individuals with specific phenotypes (Kuparinen & Festa-Bianchet 2017). For mountain ungulates, trophy hunting involves the selective harvest of males with large horns. Trophy hunters usually pay a substantial fee, which in some cases is proportional to the 'trophy score' of the animal they harvest. Trophy hunting can generate important revenues for the conservation of ungulate populations (Leader-Williams 2009). For example, a conservation program based on limited trophy hunting succeeded in increasing the population of the endangered markhor (*Capra falconeri*) from 200 to 3,500 in Pakistan (U.S. Fish and Wildlife Service 2014). If poorly regulated, however, this activity can adversely affects the population dynamics, genetic diversity and evolution of the target species (Mysterud 2014).

Ibex trophy hunting – What do we know?

Even though research on the ecological, phenotypic and evolutionary effects of trophy harvesting of ungulates is advancing, it is still limited to some key species (*e.g.* bighorn sheep *Ovis canadensis*) in a few regions (*e.g.* Rocky Mountains, Canada), where intense selective hunting has apparently led to an evolutionary decline in horn size (Pigeon *et al.* 2017). In contrast, we know very little about the possible effects of selective harvesting on the iconic Iberian ibex (*Capra pyrenaica*, Fig. 1), which is experiencing increased pressure not only from trophy hunting (Pérez *et al.* 2011), but also from changes in both climate and land-use practices (Carvalho *et al.* 2017).

At least four reasons make ibex particularly susceptible to the impact of trophy hunting: i) males with large horns are easily recognizable by hunters seeking a trophy; ii) males with rapidly growing horns may be harvested before they can breed; iii) there is no compensatory horn growth, *i.e.* young males with slow-growing horns will remain small-horned at maturity; and iv) as the largest-horned males are removed, hunters may progressively shift the baseline of what is considered a "trophy", increasing the selective pressure against males with rapidly growing horns.

Horn growth depends on nutrition, age and genetic background (Monteith *et al.* 2018). We suggest that all three factors must be considered for a sustainable hunting management of the Iberian ibex. Here, we evaluate how hunter selectivity and environmental variability jointly affect horn size of male ibex. We also propose research avenues to elucidate those circumstances that contribute to

Figure 1. Two male ibex (*Capra pyrenaica*) fighting during the mating season. The size and shape of male horns evolved through sexual selection and influences male mating success. The geographical distribution of Iberian ibex populations is presented in the upper left corner (Granados et al. 2007). Presence data refer to grid cells, Universal Transverse Mercator 10x10 km^2. Male ibex drawn by Carlos García Poveda (Poveda & López 2018).

the long-term sustainability of hunted Iberian ibex populations.

Research on how hunting, environment, population density and disease drive the phenotypic traits of Iberian ibex is in its infancy. This investigation requires well-replicated inventories of individual metrics and genetic data because the effects of the above-mentioned factors on horn size, particularly the effects of size-selective harvesting, can take several decades to be detected (Pigeon *et al*. 2016). Currently, most information originates from horn measurements of harvested animals (*e.g*. Büntgen *et al*. 2014, 2018 for examples with Alpine ibex, *Capra ibex*), which can be a biased sample if hunting is selective (Pelletier *et al*. 2012). The suggested impact of trophy hunting on horn size of male Iberian ibex is only correlational (Pérez *et al*. 2011), since no genetic data yet support the contention that selective hunting of large-horned ibex males has led to a reduction in horn size. Fandos (1995) showed that annual horn growth rate is reduced by increasing aridity, Pérez *et al*. (2011) reported that population density has a negative effect on horn size and Carvalho *et al*. (2017) demonstrated that local habitat characteristics foster well-differentiated horn growth patterns. Yet, it remains unclear how environmental conditions and population density interact and affect the possible evolutionary consequences of trophy hunting. This is an important question considering the increase of Mediterranean aridity (Kelley *et al*. 2012) and ongoing landscape changes, including forest encroachment of natural prairies (Peñuelas *et al*. 2017), which could cause a reduction of horn size in male bovids (Iberian ibex, Carvalho *et al*. 2017; Mouflon *Ovis gmelini musimon*, Garel *et al*. 2007).

Sustainable hunting of Iberian ibex – What should we do?

A long-term approach will be required to test whether or not current hunting practices are sustainable. It is important to identify the sources of trait variation, as directional changes caused by environmental or climate change could be erroneously attributed to hunting selection (Festa-Bianchet & Mysterud, *in press*). Studies of multiple populations are needed, because responses to selective hunting and to environmental changes are likely to vary among populations under different management regimes and environmental conditions. For instance, Hedrick (2011) suggested that winter drought is the major driver of horn size reduction of desert bighorn sheep rams in Aravaipa Canyon, Arizona, USA, but analyses of 42 years of data on male bighorn sheep at Ram Mountain (Alberta, Canada) revealed that warmer springs had positive effects on horn growth, which was reduced by high population density and by the evolutionary effects of trophy hunting (Douhard *et al*. 2017). We call for a coordinated research effort to monitor individual growth and genetic data from hunted and unhunted populations sharing the same environmental regime. This will allow to assess the comparative influence of hunting and environment on trends and extremes in horn size. The best approach would be individual-based monitoring, as establishing a pedigree and assigning paternity will allow to quantify the role of horn size in male reproductive success and to determine to what extent horn size is affected by genetic variability. Because ibex horns form distinct growth rings each year (Fig. 2), analyses of males harvested or found dead in protected areas would allow a test of whether early growth affects age at harvesting.

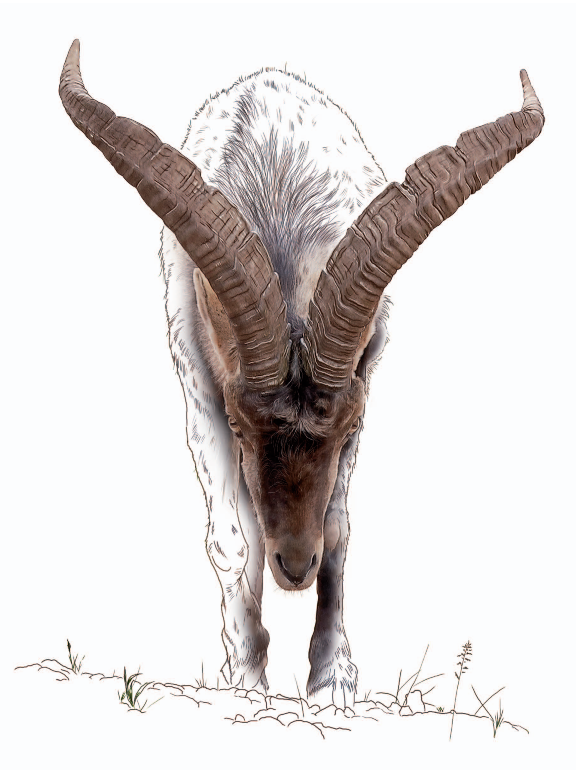

Figure 2. The horn growth segments of male ibex (*Capra pyrenaica*) are not only a mirror of males' age, but also a repository of past environmental conditions and genetic information. Drawn by Carlos García Poveda (Poveda & López 2018).

Comparative studies, however, require a commitment from policy makers, game managers and wildlife researchers. Standardized procedures are essential to perform controlled quasi-experiments and evaluate their results. A good example comes from the Swiss canton of Grisons, where horn growth segments of each ibex harvested since 1977 have been measured (Büntgen *et al*. 2014). Analyses of 44,088 annual horn growth increments from 8,355 male Alpine ibex over 36 years (1977-2013) revealed that the harvesting criteria implemented in this area limit the potential phenotypic and evolutionary effects of selective hunting (Büntgen *et al*. 2018). The Els Ports de Tortosa i Beseit National Hunting Reserve, northeastern Spain, has also measured each annual horn growth segment. Between 1995 and 2017, 31,813 measurements from 2,815 male ibex were recorded. These data are currently being analysed to evaluate how hunting strategy, environment conditions, particularly climate and habitat changes, and population density influence horn growth trends.

The creation of an Iberian research program and network that extends over multiple populations and beyond artificial management units will be a necessary step to assess the impact of intense selective harvesting and environmental change on Iberian ibex, a charismatic species that become an icon for conservation of mountainous ecosystems in the peninsula.

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