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Running Head: Brown bear aggregation during hyperphagia

**Characterization of a brown bear aggregation during the hyperphagia
period in the Cantabrian Mountains, NW Spain**

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Abstract: We characterized a bear feeding aggregation that occurred in an oak forest in the Cantabrian Mountains (NW Spain), during the hyperphagia period 2017 (September to December), which was an atypical year in terms of low fructification success, due to late frost events and drought. We described: 1) number, sex and age class of aggregated

bears; 2) temporal use of the area; and 3) bear interactions. We identified a minimum of 31 individuals, representing 10% of the estimated Cantabrian bear population. The number of adults increased during the study period, whereas the number of subadults decreased, which could be related to a displacement of subadults by dominant adults. The proximity of the aggregation site to a public road attracted numerous people to observe the bears. To minimize adverse bear-human interactions, we recommend providing educational material on best bear viewing practices as well as on-site staffing.

Resumen: Caracterizamos una concentración de osos por recursos alimenticios ocurrida en un robledal de la Cordillera Cantábrica (NO España), durante el periodo de hiperfagia de 2017 (Septiembre a Diciembre), que fue un año atípico en cuanto a baja producción de frutos debido a heladas tardías y sequía. Describimos: 1) número, sexo y edad de los osos congregados; 2) uso temporal del área por los osos; e 3) interacciones entre osos. Identificamos un mínimo de 31 individuos, i.e. el 10% de la población estimada de oso pardo cantábrico. El número de adultos aumentó durante el estudio mientras que el de subadultos disminuyó, lo cual podría relacionarse con un desplazamiento de subadultos por parte de adultos dominantes. La cercanía del lugar de concentración de osos a una carretera, atrajo multitud de personas con el fin de observar osos. Para minimizar las interacciones adversas entre humanos y osos, recomendamos proporcionar material educativo sobre buenas prácticas de observación así como presencia de personal cualificado en la zona.

Key words: bear interactions, brown bear, *Cantabrian Mountains*, feeding aggregation, hyperphagia, *Ursus arctos*

Ursus (): – ()

Solitary animals can aggregate temporarily for various biological reasons, including mating (Sadovy et al. 2008), nesting (Bass et al. 2006), migrating (Taylor and Taylor 1977), and feeding (Peirce and Van Daele 2006). Feeding aggregations of solitary animals generally occur as a response to natural events, such as predictable seasonal peaks in the availability of food resources, as observed in whales (Penry et al. 2011) and large vertebrates (Shardlow and Hyatt 2013). However, there has been an increase in the frequency of feeding aggregations produced by anthropogenic food resources, e.g., garden birds (Robb et al. 2008), and food shortages derived from climate change, e.g., polar bears (*Ursus maritimus*) (Schliebe et al. 2008).

The brown bear (*Ursus arctos*) is a solitary species, but aggregations may occur in areas where food is abundant, profitable, and reliable, because bears generally use the most productive foraging habitats to maximize nutrition (Schoen 1990). Bear congregations around feeding resources have been reported primarily in North America, e.g., in garbage dumps (Peirce and Van Daele 2006), insect aggregation sites (White et al. 1998), salmon spawning sites (Egbert and Stokes 1976, Ben-David et al. 2004), and whale carcasses (Lewis and Lafferty 2014), as well as in Eastern Europe (Eastern Carpathians) around supplementary food sites (Štofik et al. 2016).

The Cantabrian Mountains (northwestern Spain) are inhabited by a small, isolated and endangered population of brown bears, which is distributed in two partly connected subpopulations (Gonzalez et al. 2016), with ca. 200 individuals in the western subpopulation (CI95% = 168–260 individuals) and 20 individuals in the eastern subpopulation (CI95% = 12–40 individuals; (Pérez et al. 2014)). Bear aggregations are rare in this population and the few available records are related to the mating period,

when several males and/or females stay together for some hours engaging in multiple mating episodes (Fernández-Gil et al. 2006).

Bears belonging to the Cantabrian population have a well-defined seasonal diet consisting mainly of plants and fruits available during different times of the year (Fernández-Gil 2013). During the hyperphagia period (July – December (Martínez Cano et al. 2016)), acorns (*Quercus pyrenaica*, *Quercus robur* and *Quercus ilex*) are prevalent items in their diet (Fernández-Gil 2013). However, the combination of atypical weather conditions, such as high temperatures at the end of winter, late snowfall and frost, and low rainfall affect fructification success of several plant species, including oaks (Inouye 2000, Sanchez-Humanes and Espelta 2011). The effect of frost on food availability and its impact on fruit consumer populations has been studied for several mammal species (e.g., montane voles (*Microtus montanus*) (Murray 1965) and grey squirrels (*Sciurus carolinesis*) (Nixon and McClain 1969)) and it has been suggested for other acorn consumers, including bears (Inouye 2000).

During 2017, the Cantabrian Mountains suffered the weather conditions mentioned above, which affected the fruiting process of multiple plant species used by brown bears during summer and autumn (Servicio de Aplicaciones Agrícolas e Hidrológicas de la Agencia Estatal de Meteorología 2017). However, areas at low altitudes are usually less affected by frost and fructification is generally successful (Dittmar et al. 2006).

This scenario may have precipitated the occurrence of an unusual situation of bears congregating in a *Quercus* spp. forest at low altitude in order to exploit a locally abundant food resource. To our knowledge, the guards of the local Administration, who have been working in the area during the last 20 years, have not experienced or heard of

such an event in the Cantabrian Mountains. The bear aggregation occurred in a relatively open area at a distance of 150 m of a main road, which caused many people, attracted by the real possibility of observing bears, to gather nearby, sometimes adopting inappropriate behaviors. These kinds of situations may lead to bear disturbance and human-bear conflicts (Penteriani et al. 2017). Therefore, it is important to understand the causes and consequences of these aggregations, which may occur again in future years with similar atypical weather conditions. Indeed, by being able to predict these situations, we could better manage human activities in order to avoid human-bear conflicts in a human-modified landscape (Penteriani et al. 2018, Penteriani et al. *submitted*).

The objectives of this paper were to describe: 1) number, sex and age class of the bears using the aggregation area; 2) temporal use of the area by bears; and 3) interactions among the bears. Finally, we recommend actions for minimizing adverse bear-human interactions when aggregations occur.

Study Area

The study area is located in the western part of the Cantabrian Mountains (León Province), in northern Spain (Fig. 1), near the Eurosiberian-Mediterranean climatic boundary (Moreno et al. 1990). Predominant vegetation is characterized by common oaks (*Quercus robur*), Pyrenean oaks (*Quercus pyrenaica*), common broom (*Cytisus scoparius*), and *Genista florida* subsp. *polygaliphylla* (Moreno et al. 1990, García and Jimenez Mejías 2009). The area consists of a ca. 44-ha wooded siliceous rocky mountain slope with open zones composed of rock deposits, with an altitude range from 800 to 1264 m a.s.l. A main road is at the bottom of the frequented slope, 150 m across from the aggregation area.

Methods

Data collection

We opportunistically visited the area to observe bears at least two times per week from 16 September 2017, coinciding with the start of the bear aggregation, to 4 December 2017. We conducted observation sessions from 1 h before to 30 min after sunset, when bears are generally more active, especially in human-modified landscapes, such as the Cantabrian Mountains (Ordiz et al. 2014). We used telescopes (Swarovski ATS 80 HD) and binoculars (Swarovski Habicht 10x40) to locate the individuals, always from the same spot, at an average distance of 400 m from the area frequented by bears. We used a Canon sx540 camera and a Swarovski telescope coupled with a Nikon D7000 camera to record videos of the sightings, with the aim of individually recognizing the different bears in the aggregation area.

Bear number, sex and age class estimation

To individually recognize all the bears, we compared all the video footage we recorded. Specific characters of each animal, such as fur marks and body morphology, allowed individual identification (Fagen and Fagen 1996, Higashide et al. 2012). This made it possible to estimate the minimum number of individuals that congregated in this area (O'Brien and Lindzey 1995). Video analyses also allowed confirming, when possible, field estimations of the age and sex of observed bears. We adapted the age classification system described by Peirce and Van Daele (2006) for a bear aggregation in a garbage dump in Alaska as follows: adults (males and single females), females with cubs (both females with cubs-of-the-year and with yearlings), and subadults (2-4 year-old individuals). We estimated the age of bears by observing body size and morphology (Herrero 1983). For all analyses we considered family units as one individual given

their spatial requirements, as mothers and cubs forage close to each other whereas solitary bears need more space to forage (Peirce and Van Daele 2006). Field observations did not allow sex identification, except when females were accompanied by cubs.

Determination of the temporal use of the aggregation site

We assessed temporal patterns of bear use of the aggregation area by examining: 1) variation in the number of bears observed during each session over the sampling period; and 2) individual bear presence or absence each session over the sampling period.

We determined the temporal use of the area by all the observed bears by summing the minimum number of different individuals that used the area in each session during the study period. We fitted two Poisson generalized linear models to analyze the effect of successive observation sessions (hereafter referred to as time) over the study period on the number of adult (including females with cubs) and subadult bears observed per session. Sample days when age class determination was not possible for all the individuals observed per session, because of poor light, bad weather conditions, or short length of the sighting, were excluded from the analysis. We conducted statistical analyses in R 3.4.2 statistical software (R Core Team 2017). Statistical significance levels were set at $\alpha < 0.05$. We performed the statistical models and tested autocorrelation to ensure that model residuals were independent of each other with the package ‘stats’ (R Core Team 2017).

We classified individuals from each age class (categorical variable ‘age class’: adults, females with cubs, and subadults) according to the number of observation days

that they were spotted (categorical variable ‘number of sightings’: 1 sighting vs. 2-3 sightings vs. >3 sightings) over the study period.

Bear interaction analysis

We recorded all the interactions that occurred between all age classes. We classified the interactions as aggressive vs. nonaggressive; and following the classification of Peirce and Van Daele (2006), we considered lunges, direct stares, chases, and charges as aggressive interactions. We classified bears involved in aggressive interactions as winners vs. losers; winners caused another bear (the loser) to move away from the disputed area (Herrero 1983). We considered play-fight and seen-ignored as nonaggressive interactions.

Results

We visited the study area a total of 22 days and recorded 33 hours of observations. We collected 85 bear sightings during the sample period and recorded at least one video for 69 of them, with an average length of 2 min. We did not record the individuals for 16 sightings, because of the poor light, bad weather conditions, or short length of the sighting.

We identified a minimum of 31 bears: 14 adults, 6 subadults, and 5 females with 6 cubs. Three family groups contained cubs-of-the-year (1, 1 and 2 cubs), and two females were accompanied by one yearling each. We recorded a total of 63 sightings of identified individuals and 22 sightings of unidentified individuals. Considering that these 22 sightings could belong to 22 different individuals, there could have been a maximum of 53 individual bears using the study area.

The number of bears that used the study area each evening varied from 1 to 7 individuals and showed no clear trends (Fig. 2). There was a fire event on the area from

12 to 18 October 2017, which burned ca. 350 ha. Immediately after the fire started, we observed a fall in the number of individuals observed per session (5 individuals on 11 October to 2 individuals on 14 October). However, the numbers recovered quickly (5 individuals on 25 October), after the fire had been put out.

The number of adult and subadult bears that used the area varied with time over the study period (Table 1; Fig. 3). The number of adult bears increased with time (estimate = 0.0178, $p = 0.0071$; Fig. 3), whereas the number of subadults decreased (estimate = -0.0531, $p = 0.0002$; Fig. 3).

Adult bears showed the greatest proportion of individuals (4 adults out of 14) observed in more than 3 sessions (Table 2). Subadults comprised the greatest proportion of individuals (3 subadults out of 6) observed in either 2 to 3 sessions, and females with cubs showed the greatest proportion of individuals (3 females with cubs of 5) observed in only 1 session and none of them was observed in more than 3 sessions (Table 2).

We recorded 7 aggressive interactions: 5 adult *vs.* adult and 2 adult *vs.* subadult, which were all won by adults. We also recorded 5 nonaggressive interactions: 1 adult *vs.* subadult, 1 adult *vs.* female with cubs, 1 subadult *vs.* female with cubs and 2 adult *vs.* adult.

Number of observers in the area was usually low from Monday to Friday (<10 people). But during weekends and public holidays, up to 50 people were present. People were generally on the road and its surroundings, at a distance of 150 m from the bear area. However, the distance was considerably shorter under some situations, which implied potential conflicts with bears. For instance, one evening one bear came down to the river to drink and around 30 people crossed the guardrails to get closer and take pictures of it at a distance of ~ 40 m. The bear stared at the people and walked along the

riverside away from them. On a different occasion, 12 people stood on the road 20 m away from a subadult bear that was trying to cross it (<https://www.youtube.com/watch?v=jRi1Ql-w4as>, last accessed in May 2018).

Discussion

Bear number, sex and age class estimation

A remarkable number of bears (31-53) congregated at this site, especially when considering the estimated size of this bear population. Indeed, the minimum number of bears we were able to identify represents 10% of the entire Cantabrian population, which is estimated to be a maximum of 300 individuals (Pérez et al. 2014). This aggregation occurred during the hyperphagia period, a critical period for bears, when individuals spend most of their active time foraging to store fat, which is essential for successful hibernation and cub production (Farley and Robbins 1995, Fernández-Gil 2013). Acorns are their main food item in the Cantabrian Mountains during this period (Fernández-Gil 2013) and its production locally may have been low in 2017. The damage caused by a late snowfall and frost event on prematurely developed flower buds derived from a mild winter, as well as a severe drought, may have affected fructification success in this and several other species (Servicio de Aplicaciones Agrícolas e Hidrológicas de la Agencia Estatal de Meteorología 2017). Acorn production has been recorded to decrease under similar conditions in other parts of the world (Inouye 2000, Sanchez-Humanes and Espelta 2011). A localized abundance of acorns in a low-altitude oak forest, where plants are generally less affected by extreme weather (Dittmar et al. 2006), could have promoted this bear aggregation. Even though brown bears are known to aggregate at concentrated food resources (White et al. 1998, Peirce and Van Daele 2006), this is the first time that a feeding aggregation has been recorded

for the Cantabrian brown bear population. This small and isolated population is located in the southwestern periphery of the European distribution of the brown bear, making it especially vulnerable to unpredictable meteorological events derived from climate change (Vucetich and Waite 2003).

Determination of the temporal use of the aggregation site

Subadults decreased and adults increased in the area over time, suggesting that they avoided conflicts with adults. In other brown bear aggregations, subadults were the least dominant individuals and actively avoided encounters with adult individuals to reduce risk of aggressive fights and predation (Egbert and Stokes 1976, Peirce and Van Daele 2006). Therefore, adults may have progressively increased in numbers over the course of the study period, displacing subadults, which may have either left the area or remained in peripheral areas.

When analyzing individual frequency in adults vs. subadults vs. females with cubs, adults showed a greater proportion of frequent visitors than subadults, which could be due to dominance of adult bears over subadults explained above. However, females with cubs had the lowest proportion of frequent visitors, perhaps because females with cubs of the year usually avoid encounters with adult males.

Management Implications

Bear viewing practices have been shown to cause both negative and positive impacts on bears, people, and ecosystems and are highly context dependent and thus each situation should be managed at a local scale (Penteriani et al. 2017). In the case of the bear aggregation site in the Cantabrian Mountains, its location close to a public road facilitated the presence of many people who were attracted by the strong possibility of observing bears. Several of these people did not behave in an appropriate way while

observing the bears, e.g., closely approaching the bears to take photos or speaking loudly. It is well known that these behaviors can induce bears to leave the area (Nevin and Gilbert 2005) or to become habituated to human presence, which may represent a serious source of human-bear conflict (Herrero et al. 2005, Smith et al. 2005).

Therefore, we recommend providing bear viewers with educational material on bear behavior and best bear viewing practices to minimize adverse bear and human interactions in future similar situations. It would also be valuable to have on-site staff available to provide instruction and enforcement of guidelines for safe viewing. Finally, specific research should be done to detect areas with similar environmental and vegetation characteristics as the bear aggregation spot, in order to predict potential bear feeding aggregation areas in years with low fructification success. The location of such areas may also help limit human activities that may affect these potential food reservoirs for brown bears.

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Table 1. Details of the two Poisson generalized linear models investigating the effect of time (i.e., successive observation sessions) over the number of adult (modelAd) and subadult (modelSubAd) individual brown bears observed per session in the Cantabrian Mountains in Spain. Sample size for both models is 17 after excluding the sample days when age class determination was not possible for all the individuals observed per session. RV = response variable; EV = explanatory variable; EST = model estimate; SE = standard error of model estimate; Z = test statistic for assessing the significance of the model curve (i.e., slope); P-VAL = p-value for the null hypotheses that the curve is zero; DEV (%) = proportion of explained deviance, i.e., proportion of the variation in the response variable that is explained by the explanatory variable.

Model	RV	EV	EST	SE	Z	P-VAL	DEV (%)
ModelAd	Number of adults	Time	0.0178	0.0066	2.694	0.0071	37.6
ModelSubAd	Number of subadults	Time	-0.0531	0.0143	-3.711	0.0002	47.5

Table 2. Number, age class and frequency of sightings of individually identified brown bears in the Cantabrian Mountains in Spain during 16 September to 4 December 2017.

Age class	1 sighting	2-3 sightings	>3 sightings	Total
Adults	6	4	4	14
Subadults	2	3	1	6
Females + cubs	3	2	0	5
Total	11	9	5	25

Figure legends

Figure 1. Study area location of the brown bear aggregation in the western Cantabrian Mountains (León Province, Spain).

Figure 2. Variation in the number of brown bears at the study area from 16 September to 4 December (n = 22), western Cantabrian Mountains (Spain), 2017. The arrow indicates a fire event that occurred in the study area.

Figure 3. Scatterplot of the number of adult and subadult brown bears (response variables; circles and triangles respectively) observed in the Cantabrian Mountains in Spain during 16 September to 4 December (explanatory variable) and the fitted curve for each Poisson GLM model (broken and solid line for models with number of adults and subadults, respectively, as response variables). Sample size for the estimation of both curves is 17 after excluding the sample days when age class determination was not possible for all the individuals observed per session.

438 **Figure 1.**

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440 **Figure 2.**

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442 **Figure 3.**

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