Acta Theriologica 55 (3): 203–209, 2010.
PL ISSN 0001-7051 doi: 10.4098/j.at.0001-7051.085.2008

Evidence of non-hibernation in Cantabrian brown bears

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Nores C., Ballesteros F., Blanco J. C., García-Serrano A., Herrero J. and Palomero G. 2010. Evidence of non-hibernation in Cantabrian brown bears. Acta Theriologica 55: 203–209.

Evidence of non-hibernation in brown bears *Ursus arctos* Linnaeus, 1758 on the Iberian Peninsula has existed since the Middle Ages. We systematically monitored brown bears in the Cantabrian Mountains (Northern Spain) by recording tracks and sightings from 1998 to 2007 to document hibernation behaviour. Our results indicate that females with yearlings and solitary yearlings were more active in winter than bears over two years old. Intensive snow tracking and direct observations of five family groups indicated that they travelled, fed and defecated in winter, which are activities not compatible with the physiological state of hibernation. Also, based on tracking data, the maximum period between two consecutive locations of active family groups in winter was less than that needed by bears to emerge from a state of hibernation (6 days). We conclude that the family groups which we monitored in winter did not hibernate.

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Key words: *Ursus arctos*, hibernation, breeding females, Cantabrian Mountains, Spain

Introduction

Hibernation has been reported in almost all mammal orders. However, some authors consider that there are no true hibernators among large mammals because a large mass and a corresponding low rate of metabolism would require a prolonged and energetically expensive metabolic effort to raise body temperature (Randall *et al*. 2002). Other authors think that shallow and deep torpor form a continuum (Willmer *et al*. 2000), the breakpoint being arbitrary depending on body mass (Withers 1992). Thus, very large mammals with longer entry and arousal times, such as bears, need long minimum torpor durations (about 6 days for a bear) (Withers 1992). Hibernation is generally considered to be a period of winter dormancy in animals living in cold climates, involving lowered body temperature and reduced metabolism to conserve energy stores (Randall *et al*. 2002). However, for a more specific definition for the purposes of this paper, we define hibernation as a drop in biochemical

and physiological parameters (hypofagia, hypodipsia and reduction in urine production) that not rapidly reversed (Nelson *et al*. 1983). Thus, we consider bears to be hibernators.

Several bear species, for example, sloth bear *Melursus ursinus*, spectacled bear *Tremarctos ornatus*, sun bear *Helarctos malayanus*, and giant panda *Ailuropoda melanoleuca*, do not hibernate, only pregnant female Asiatic black bears *Ursus thibetanus*, hibernate in warmer parts of their range whereas in the colder parts, all age and sexes do so (Hwang and Garshelis 2007). Likewise, only pregnant female polar bears *Ursus maritimus* hibernate. It is generally assumed that American black bears *Ursus americanus* and brown bears *Ursus arctos* Linnaeus, 1758 hibernate in winter throughout their range, although winter sleep may occasionally be interrupted by excursions outside the den (Nowak and Paradiso 1983).

All brown bears radiocollared in Scandinavia (> 150) hibernated (Friebe *et al*. 2001, Manchi and Swenson 2005). However, Huber and Roth (1996) concluded from telemetry results, fresh scats and snow tracking that in Croatia (southern Europe) some bears overwinter outside the den. Similarly, some American black bears in southern USA do not hibernate (Hellgren and Vaughan 1987). On Kodiak Island, 8 out of 115 radio-tagged brown bears did not eat, drink, or defecate (consistent with hibernation) even though they spent most of their time in the den, travelling only short distances for brief periods (van Daele *et al*. 1990).

On the Iberian Peninsula, medieval hunting treatises called into question the idea that brown bears usually hibernate. In the 14th century, Alfonso XI of Castile (Casariego 1976) stated that females with cubs did not hibernate, and in the 15th century, an anonymous author (Duque de Almazán 1936) wrote that not all bears hibernate in winter. More recently, an adult male brown bear radio-tagged for 3 years in the Cantabrian Mountains hibernated every year (mean: 55 days; range: 40–68 days) (Clevenger 1991a), but for less time than that reported for brown bears in Croatia (mean: 86 days; range 6–189 days) (Huber and Roth 1996) and in Scandinavia (mean: 161 days; SD = 13.7; n = 56 for males) (Manchi and Swenson 2005). In the Cantabrian Mountains there are two previously reported cases of family groups with cubs of the year not hibernating. The one described from tracks and sightings between 21 September 1991 and 10 May 1992 (Palomero 1993) involved an average time between consecutive observations of 4 days from January to March and a maximum period of 13 days without being located. The second involved radio-tracking, the longest period of denning being 4 days (Naves *et al*. 2001).

Two brown bear populations (western and eastern) inhabit the Cantabrian Mountains (northwestern Spain) but are genetically separated by a 40–50 km strip of land (García-Garitagoitia *et al*. 2006, Pérez *et al*. 2009). To compare hibernation behaviour in this Iberian brown bears with more northern populations, we monitored winter activity by snow tracking over a 10-year period, differentiating between females with yearlings, solitary juveniles, or older bears by their print size or other characteristics. In addition, we specifically monitored five family groups (adult female with yearlings) to document winter activity.

Material and methods

Study area

We monitored bear activity in the eastern and western brown bear populations (42°50'N) in three different nature parks: Fuentes Carrionas Nature Park (eastern population), Somiedo Nature Park and Fuentes del Narcea Nature Park (both in the western population). The eastern population was located on the southern slope of the Cantabrian Mountains, in Cantabria and Palencia provinces and the western population was mainly located on the northern slope of the Cantabrian Mountains, in Asturias province.

These 2 populations were found in the transition zone between oceanic, montane and Mediterranean climates. In the core of the eastern population, the average annual temperature was 9.3°C, January and July being the coldest and warmest months at 2.1°C and 17.2°C, respectively, and snowfall occurred an average of 26 days a year, usually between December and March (data obtained from the Cervera de Pisuerga station at 1013 m a.s.l.). In the western population, the climate was less continental at similar altitudes, with an average annual temperature of 8.6°C, January and July being the coldest and warmest months at 4.0°C and 15.8°C, respectively. Snowfall occurred an average of 46

days per year (data obtained from the Genestoso station at 1180 m a.s.l.). In the core area of the eastern population, over the last 30 years there has been an annual average of 26 days' snow and an average temperature of 3.6°C between January and March. At the same altitude, the distribution area of the western population has 38 days' snow, and a winter temperature of 4.9°C. In 2003, snowfall in the eastern population range was lower than annual average (13 days) and winter temperature was higher (4.5°C). In 2007, snowfall was similar to the annual average (25 days), but winter temperature was higher (5.0°C). In 2009, snowfall in the western population distribution area was higher than the annual average (56 days) and winter mean temperature was slightly lower (4.5°C) than annual average.

The highest altitude is 2538 m a.s.l. The habitat most used by bears on both areas was a mosaic of deciduous forest, scrub, grassland and rock between 930 and 1903 m a.s.l., with a clear preference for forest (Clevenger 1991b). The forest habitat chiefly was comprised of beech *Fagus sylvatica* and deciduous oaks *Quercus petraea* and *Q. pyrenaica*. The traditional land use was livestock farming, with nature tourism increasing in importance.

Collecting and analysing the data

Since 1989 we have carried out systematic monitoring of both Cantabrian brown bear populations, attempting to detect and characterize all family groups (ie, adult female with cubs of the year). A monitoring team mainly comprised of rangers and technicians from wildlife agencies of the regional governments and the *Fundación Oso Pardo* (Brown Bear Foundation) collected field data throughout the entire study area by means of direct sightings or by locating tracks and other signs, as explained by Palomero *et al*. (2007b). In addition to these survey activities, a team of field technicians from the Brown Bear Foundation conducted systematic monitoring from December to March 1998–2007, involving an average of 324 observer-days per winter. The entire breeding range of the eastern population, especially areas considered most attractive for bears, was surveyed daily for tracks and other signs.

Direct sightings and signs of activity (snow tracks, fresh scats) were quantified as the number of signs per unit of effort (number of days' fieldwork per team). We regarded signs as independent if they were located in adjacent areas greater than four days apart, which is the average time that tracks are recognizable. Signs located on a specific day were considered to be from different bears if supported by differences in track size, a direct sighting, or if the distance between location sites was too great to have been made by a single animal. When a family group was monitored continuously, only the initial detection was recorded so that those data could be compared with the general survey data.

Our analysis was based on the assumption that reduced activity levels as evidenced by bear signs should accompany periods of hibernation during winter. Data frequency for all years grouped in bi-weekly units was analysed using a χ^2 test, differences of $p < 0.05$ being regarded as significant. Differences in bear activity during the eight bi-weekly periods were studied for all observations and for three categories distinguishable by group composition and/or track size, ie females with yearlings (litter born the previous winter, 11–14 months old during the study winter), young bears (solitary juveniles after family break-up, 23–26 months old during the study winter) and other bears over two years old (≥ 34–38 months old). We assigned all signs from mixed-age groups of an adult bear and one or more smaller bears to the "female with yearlings" category; signs from single or paired bears with a track width under 95 mm to "1 year old bears"; and to all signs from single bears with a track width over 100 mm to the "≥ 2 years old bears" category. Unmeasurable or intermediate tracks were grouped into a heterogeneous class (≥ 1 year-old bears).

To determine whether the solitary young bears exhibited winter activity similar to that of females with yearlings or that of the remaining bears > 2 years old, we pooled data for months of non-hibernation (December and March) and hibernation (January and February) and compared them using the Fisher exact probability test (Sokal and Rohlf 1995).

We monitored family groups in 2003, 2007 and 2009 whenever weather conditions permitted and the means were available (roughly 50% of days in the study periods), in accordance with a work protocol. Direct sightings were made at over 500 m using telescopes so as to avoid altering bear behaviour. Tracks and signs were recorded when the group was not visually observed. The small number of family groups present every year in the eastern population (between 0 and 3 per year during study period), together with records of group composition and specific physical characteristics of some individual bears, simultaneous observations and distance to other observations enabled us to differentiate between family groups as described in Palomero *et al*. (2007b). Inconclusive observations were not included in the analysis.

Results

Monitoring all age and sex groupings

The number of days of observation per two-week period during the ten-year period (Table 1) did not differ ($\chi^2 = 5.52$, df = 7, $p = 0.61$), so we considered observation effort to be distributed homogeneously during winter. Temporal distribution of bear signs in winter was not uniform ($\chi^2 = 51.75$, df = 7, $p < 0.001$) suggesting a decrease in activity. In general, activity decreased beginning in the second fortnight of December and increased again at the end of March, corresponding with the suspected start and end of hibernation (Clevenger 1991a, Huber and Roth 1996) (Table 1). Bears over two years old were significantly less active in mid-winter (($\chi^2 = 84.91$, df = 7, $p < 0.001$). In contrast, family groups ($\chi^2 = 2.72$, df = 7, $p = 0.91$) and solitary

Table 1. Temporal distribution of brown bear *Ursus arctos* winter activity signs in the Cantabrian Mountains (1998–2007, $n = 630$). Monitoring effort was measured as number of field work days by team in the first (1st) and the second (2nd) fortnight of the month.

	December		January		February		March		
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	Total
Monitoring effort in days	152	162	143	157	147	128	147	155	1191
Females with yearlings	25	26	28	24	27	32	23	22	207
1 year old	8	6	6	5	14	6	8	11	64
≥ 1 year old	14	13	9	7	8	5	2	12	70
≥ 2 years old	77	50	25	18	16	17	33	53	289
Total signs	124	95	68	54	65	60	66	98	630

yearlings ($\chi^2 = 9.25$, df = 7, $p = 0.25$) were not less active in mid-winter. Differences between the winter activity of family groups and that of solitary yearlings were not detected (Fisher exact probability test = 0.4779) but activity levels differed between solitary yearlings and those > 2 years old (Fisher exact probability test = 0.00065).

Monitoring specific family groups

2003: One family group (female with two yearlings in the eastern population)

Between 4 January and 12 March 2003 we located tracks in the snow or saw these bears on 15 occasions, with a maximum interval between two consecutive locations of 10 days (Table 2). At the end of this period the three bears were seen to be fully active, showing no signs of lethargy. The 15 locations were recorded in an oak forest with an abundant yield of *Quercus* acorns. On 8 January and 3 February, they foraged for acorns under snow. On 7 March, 50 fresh and old scat samples containing acorn remains (in two cases mixed with deer hair) were found.

2007: One family group (female with two yearlings in the eastern population)

This group was monitored between 4 January and 14 March 2007, being located active 21 times, the longest period without locations being 9 days (Table 2). In February (most typical month for hibernation), the group was classified as active during 11 out of 12 location attempts. The family foraged intensively, and on 2 and 12 February, members were seen scraping away snow while foraging for beech mast and acorns. The yearlings played and engaged in mock fighting, and female and yearlings intentionally slid across the snow. Track monitoring on 7, 10, 16, 20 and 22 February revealed signs of foraging for acorns and beech mast under snow as well as consumption of roe deer *Capreolus capreolus* Linnaeus, 1758 carrion.

2009: Three family groups (one female with one yearling in the eastern population and two females with two and three yearlings, respectively, in the western population)

The eastern group was monitored between 6 January and 16 March 2009, being classified as active 15 times. The longest period without locations of this family group was 14 days (Table 2). The female and yearling were always seen foraging, scraping snow and searching for acorns, even in heavy rain or snow. The yearling was observed playing and eating the remains of a roe deer carcass.

The two groups in the western population were monitored between 6 January and 31 March (Table 2) in different areas (20 km apart). The group with two yearlings was located active 14 times; the longest period without locations up to 20 February was 4 days. The group with three yearlings was classified as active 13 times, the longest period without an active fix being 13 days. Two other family groups (easily recogniz-

Table 2. Characteristics, survey period, number of active locations (sightings and tracks) and intervals between active fixes of five family groups (female bear with dependent yearlings) in the winters of 2003, 2007 and 2009.

	Group				
	1	2	3	4	5
Year	2003	2007	2009	2009	2009
Number of yearlings	2	2	1	2	3
Population	Eastern	Eastern	Eastern	Western (Somiedo)	Western (Alto Narcea)
Period of winter survey	4 Jan–12 Mar	4 Jan–14 Mar	6 Jan–16 Mar	21 Jan–9 Mar	6 Jan–31 Mar
Total number of days with winter survey	16	24	28	20	45
Total number of days with active fixes (direct sightings and fresh tracks)	15	21	16	14	15
Number of days with active fixes in January	4	7	10	7	5
Maximum interval of days between active fixes in January	8	9	12	2	10
Number of days with active fixes in February	6	11	4	7	7
Maximum interval of days between active fixes in February	10	5	12	4	4
Number of days with active fixes in the first fortnight of March	5	3	2	0	3
Maximum interval of days between active fixes in the first fortnight in March	5	5	9	9	8

able because they had one and two yearlings) were seen in the same area that winter on 1 and 5 days, respectively. They also foraged on acorns and suckled, sometimes up to 100 m from the monitored group. We also sighted two young siblings and the footprints of another solitary young bear.

Discussion

Our data indicate that not all bears in the Cantabrian Mountains hibernate. A similar phenomenon was described for another southern European population by Huber and Roth (1996), who wrote: "Based on telemetry results, fresh bear scats and tracks in snow found in all winter months, we conclude that many bears in Croatia do not hibernate for the entire winter, and some may even spend the entire winter out of den". In addition, our results indicate that the continued winter activity of females with yearlings and of solitary yearlings is a regular phenomenon in the Cantabrian Mountains.

Our monitoring protocols did not enable us to ascertain whether the active bears experience winter lethargy for short time spans, as females with yearlings might undergo brief periods of non-synchronous hibernation which would go undetected by track surveys. However, the cases described by Palomero (1993) and Naves *et al*. (2001) suggest that the period required to enter and emerge from hibernation is greater than the maximum time between successive observations that we recorded (a maximum of 13 and 4 days without observations and 4 without emerging from the den, respectively). Our data indicate that some females with yearlings did not initiate hibernation at any time during winter.

The behaviour of captive bears provided with food *ad libitum* all year round in large enclosures on the northern slope was different than what we observed in the wild. For example, two Cantabrian females that have never bred, kept in a 4-ha enclosure in Proaza (Asturias) at an altitude of 200 m, were observed hibernating for 70–96 days in 2006–2007, one animal occasionally moving short distances around the enclo-

sure (R. García, pers. comm.). In Cabárceno Zoological Park (Cantabria), near the coast (< 200 m above sea level), unsystematic observations of 60 bears from European zoos and circuses living in a 35-ha enclosure indicate that although most hibernate in winter, some remain slightly active, but do not eat. Outside this normal pattern, males from circuses and females with yearlings remain active and feed throughout winter albeit less often than during the rest of the year (S. Borragán, pers. comm.). These observations in semi-captivity support the interpretation that Cantabrian brown bears, including non-breeding females, normally hibernate. The mechanism that induces hibernation appears to be adaptable enough that even males could maintain non-hibernation when some circumstances obliged them to remain active in the past.

Non-hibernation in Cantabrian brown bears resembles that sometimes observed in black bears in the southern USA (Hellgren and Vaughan 1987), but differs from that described on Kodiak Island (van Daele *et al*. 1990) for brown bears. The latter mainly involves males in a stage known as "walking hibernation" in which they do not feed, have a lower than normal metabolic rate and spend most time resting amongst vegetation, occasionally travelling short distances (Nelson *et al*. 1983, van Daele *et al*. 1990). In contrast, some male and female black bears in the southern USA were active and foraged throughout winter. Our observations of foraging and play behaviour of the bears that we studied appeared to be more characteristic of the black bears studied by Hellgren and Vaughan (1987) and are not consistent with the concept of walking hibernation.

Other data on yearling Cantabrian bears after separation from their mother are consistent with our findings. For example, two 2-year-old siblings in the eastern population were found to be active on 24 days between January and mid-March 1993, with an interval of 4.4 days between observations. Also, two orphaned siblings monitored from 9 February to 6 April 2007 in Somiedo Nature Park (western population) were observed for 52 days eating almost daily, occasionally playing and always returning to the den, where they gathered vegetation (Palomero *et al*. 1993, 2007a).

Non-hibernation at this latitude does not appear to be related with the harshness of weather conditions as it has been recorded when snowfall is below and above average.

In conclusion, a decade of track monitoring of the eastern population of Cantabrian brown bears and monitoring of seven family groups in both Cantabrian populations and of two solitary pairs of siblings in western population reveals that females with yearlings and solitary young are regularly active in winter. On the other hand, other adults and the same females in the winter that give birth appear to hibernate in accordance with the typical model for this species at other latitudes.

Acknowledgements: This study would not have been possible without the efforts of the *Fundación Oso Pardo* wardens. Winter monitoring was conducted in the framework of joint working agreements with the Castilla y León Regional Government and the Cantabria Regional Government, which met the monitoring costs. Financial support was also provided through LIFE PROJECT BA/3200/98/461/. Our thanks to R. García, the keeper responsible for the captive Cantabrian bears in Proaza, and to S. Borragán, Chief Veterinarian at Cabárceno Zoological Park. P. Ciucci, D. Huber and E. Can provided unpublished data on hibernation in Italy, Croatia and Turkey, respectively. J. Swenson and an anonymous reviewer significantly improved the first manuscript with their comments. L. Ashcroft improved the English of the original manuscript.

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Received 17 October 2008, accepted 5 February 2010.

Associate editor was Matt Hayward.