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Authors: Swenson, Jon E., Sandegren, Finn, Brunberg, Sven, and Wabakken, Petter

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SHORT COMMUNICATION

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Winter den abandonment by brown bears *Ursus arctos*: causes and consequences

Jon E. Swenson, Finn Sandegren, Sven Brunberg & Petter Wabakken

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Winter den abandonment by brown bears *Ursus arctos* in south-central Sweden and southeastern Norway was found to occur in 9% of 194 bear-winters, based on 68 radio-marked bears almost two years old and older. There was no statistical difference between the sexes, between adults and subadults, nor did protection from military or timber-harvesting activities reduce the rate of abandonment. Although anecdotal, observations suggest that human disturbance was a major cause of den abandonment. Most abandonment occurred early in the denning period, before mid-winter. Bears moved up to 30 km before denning again. Distance was not related to sex, age, or time of abandonment. Apparently for the first time, a fitness cost of den abandonment is documented: pregnant females that changed dens prior to parturition lost young in or near the den significantly more often than those that did not move.

Key words: brown bear, den abandonment, disturbance, Ursus arctos

Jon E. Swenson, Norwegian Institute for Nature Research, Tungasletta 2, N-7005 Trondheim, Norway
Finn Sandegren, Research Division, Swedish Hunters' Association, Box 7002, S-750 07 Uppsala, Sweden
Sven Brunberg, Noppikoski 158, S-794 98 Orsa, Sweden
Petter Wabakken, Environmental Protection Division, Country Governor's Office, Fylkeshuset, N-2300 Hamar, Norway

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Brown bears *Ursus arctos* hibernate during the winter to conserve energy, with metabolism reduced by about 70% (Watts & Jonkel 1988). Bears neither eat nor drink, and young are born in the den in late December/early January (Danilov, Tumanov & Rusakov 1993). Weight loss during the winter may be large, 22% for male brown bears and up to 40% for females, the loss increasing with age (Kingsley, Nagy & Russell 1983). We have recorded a weight loss of 53% for a lone 2-year-old female in northern Sweden (unpubl. data). Lactating females lose about twice as much weight per day during hibernation as non-lactating females (Farley & Robbins 1995).

This implies that bears are vulnerable to disturb-

ance during this sensitive period. However, little documentation exists about the consequences of changing dens during the winter (Linnell, Barnes, Swenson & Anderson 1996). Tietje & Ruff (1980) found that black bears *Ursus americanus* that changed dens had a greater weight loss (25%) than those that did not (16%). There are also reports of black bear females that have abandoned their young in the den after human disturbance, but most of the available literature concerning this in black bears is related to the effects of entering the dens to remark radio-collared bears as part of research projects (Linnell et al. 1996).

Here we report the rate of den abandonment by brown bears in south-central Sweden and southeastern Norway. We document a direct fitness cost of den abandonment and provide observations of possible causes of the abandonment.

Methods

The present study was conducted in the southern part of the study area of the Scandinavian Brown Bear Research Project; northern Kopparberg and western Gävleborg counties in Sweden and eastern Hedmark County in Norway. The study area is dominated by forest, primarily Scots pine *Pinus sylvestris* and Norway spruce *Picea abies*, with some deciduous trees, mostly birches *Betula pubescens* and *B. pendula*. Other important landscape elements are bogs and lakes. The terrain is generally flat to rolling, with about 40% of the area sloping less than 3° and only 1.5% of the area sloping more than 15°. Elevations vary from 160 m a.s.l. in the southeast to 1,040 m a.s.l. in the west, but about 70% of the area is between 300 and 700 m a.s.l. During the vegetation period, when temperatures exceed 5°C, there is 350-450 mm precipitation and 800-1,100 degree-days. Snow cover lasts from about November to April/early May (Swenson, Heggberget, Sandström, Sandegren, Wabakken, Bjärvall, Söderberg, Franzén, Linnell & Andersen 1996).

We monitored 68 different radio-collared brown bears during 194 bear-winters from winter 1986-87 through winter 1995-96. In our study, bears were not marked until they left the dens as yearlings, and almost all (97%, N = 31) separated from their mothers during the spring of their yearling year. Thus, all bears in our study were at least coming two-year-olds. The bears were located weekly prior to denning, and at least once a month while they were in their dens, usually from roads, but sometimes from an airplane. We were careful not to disturb denning bears ourselves. We define winter den abandonment as leaving a den and entering another; this does not include leaving a den in spring without showing further hibernation behaviour. Whenever a bear had changed den sites, project personnel inspected the abandoned den sites to try to identify possible reasons for the move. After females had left their dens in the spring, and usually while there was still snow present, project personnel inspected the den sites and surrounding areas to determine if any dead young were present. Protection from disturbance was afforded radio-marked bears denning in the Älvdalen Military Shooting Range. Also, many radio-marked bears denning on the properties of Orsa Communal Forest were protected from timber harvesting activities near the den.

Frequency data were generally tested for homogeneity by χ^2-independence tests, corrected for continuity and Fisher's exact test if the requirements for a χ^2 were not fulfilled, with one exception. The exception was a test of den abandonment frequency among individuals, which has 13×2 cells, most with fewer than five observations. Here, we used a χ^2-test, but estimated the P-value using an exact test of homogeneity and 10,000 simulations (software developed by S. Engen, Norwegian University of Science & Technology, Trondheim). Differences in ages of bears in different groups were tested using the t-test, and differences in distances moved by bears in different groups were tested using the Mann-Whitney U test. All tests were two-tailed unless otherwise stated. All tests were run with SPSS software, except the exact test of homogeneity.

Results

All brown bears in our study denned during the winter, entering the den in September-November and leaving it in March-May (rarely June). An analysis of den abandonment by 13 bears followed five or more winters showed no significant individual variation ($\chi^2 = 13.23$, df = 12, P = 0.31). There was no statistical difference between rates of den abandonment for males (10%, N = 108) and females (8%, N = 86, $\chi^2 = 0.06$, df = 1, P = 0.81). All the data were therefore combined for further analyses. We also found no statistical difference between rates of den abandonment for adults (5 years and older; 8%, N = 100) and subadults (11%, N = 83, $\chi^2 = 0.03$, df = 1, P = 0.86).

The rate of den abandonment for all bears combined was 9% (N = 194).

Protection was expected to reduce the rate of den abandonment, but no statistically significant difference was found in relation to the protection afforded some bears from military and timber harvesting activities (protected bears moved in 5% of the bear-winters, N = 22, not protected bears moved in 10%, N = 172, Fisher's exact test, one-tailed P = 0.37). Still, it appeared that human disturbance was an important factor promoting changing of dens. Project personnel visited all 18 dens after abandonment had been documented. Human activity was found at 12 (67%) of them. No human activity was found at the other six, but tracks could have been obliterated, e.g. by snowfall and wind, so human activity at 67% of the dens that were abandoned is most likely a minimum estimate. The following activities near the dens were suspected to contribute to their abandonment: hare hunting (twice), forestry survey activity at the den site (twice), a bird hunter shot a bird at the den site, a roe deer hunter 50 m from the den site, moose and dog tracks 10 m from the den, ski tracks 80-90 m from the den, ice fishermen 100 m from the den with a dog that had been at the den site, an excavation machine working 75 m from the den, and 'people present' (twice). We were careful not to disturb denning bears ourselves, so we have no estimate of the frequency of human activity at or near dens that were not abandoned.

After abandoning a den, the bears either dug a new den, or made a bed of branches and lay on the ground. Movements to new sites varied from 100 m to 30 km, but one bear returned to the original den. Mean distance of movement was 5.1 km, and 56% moved two kilometres or less. Distance moved was not related to sex (Mann-Whitney U = 26.5, N = 18, P = 0.26), age (U = 26.5, N = 18, P = 0.26), or period, i.e. before or after 1 January (U = 33.0, N = 18, P = 0.61). Bears changed dens more often early in the winter. The distribution was: five in November, six in December, two in late December/early January, three in January, one in late January/early February, and one in April.

Den abandonment had a negative effect on reproductive success. Of five pregnant females that moved during the winter prior to giving birth, three (60%) lost at least one young in or near the second den, but only 6% (N = 36) of those that did not move lost a young in or near their dens (Fisher's exact test, P = 0.009). The age of adult females that abandoned dens (7.1 ± 0.7 years (SE), N = 7) did not differ from the age of those that did not abandon dens (8.8 ± 0.5 years, N = 48, t = 1.25, df = 53, P = 0.22), nor was the age of females that lost young in the den (5.0 ± 0.7 years; N = 5) significantly different from the age of those that did not loose young (7.2 ± 0.6 years, N = 35, t = 1.37, df = 38, P = 0.18). Using an ANOVA that incorporated loss of young as the dependent variable, den abandonment as a independent variable, and female age as a covariable, also showed an effect of den abandonment (F = 14.62, df = 1, P < 0.0001), but not of female age (t = 1.01, df = 38, P = 0.28). One female moved her young-of-the-year in April and stayed in a new den with them for 2-3 weeks prior to leaving it. She was not included in the above analyses, which only considered pregnant females. If she had been included (she did not lose any young), the difference would still be statistically significant (Fisher's exact test, P = 0.015).

Discussion

Our results showed that den abandonment had a fitness cost, with a higher loss of young during the denning period and at emergence in the group of pregnant females that moved prior to parturition. Although our sample size of pregnant females that abandoned their dens was small, the finding of a fitness effect of abandonment is not surprising considering the cost of lactation in the den (Farley & Robbins 1995) and the documented increased weight loss associated with den abandonment (Tietje & Ruff 1980). This is apparently the first time a negative effect of den abandonment on reproduction has been documented in brown bears (Linnell et al. 1996).

Although our observations of human activity near the abandoned dens are anecdotal, they do suggest that human activity is an important factor causing the bears to abandon their dens. This has also been found elsewhere. Linnell et al. (1996) concluded from a literature review that brown bears showed a tolerance for industrial activity as long as the source of the noise was some kilometres from the den, but dens visited directly by people were often abandoned. The efforts to protect dens from disturbance on our study area were not measurably successful, but there was a tendency towards reduced abandonment. Perhaps there was enough unregulated human activity in the den areas protected from military and timber-harvesting activities to confound our results.

Most of the den abandonments occurred early; only

5 of 18 occurred after mid-winter. Brown bears may be less tolerant to disturbance early in the denning period, as has been suggested for black bears and polar bears *Ursus maritimus* (Linnell et al. 1996), or perhaps there are just more people out in the forest at this time. An important disturbance activity seems to be hunting, which occurs early in the denning period.

It is difficult to predict where bears will den and thereby steer activity away from these areas. However, areas with a definite concentration of brown bear dens have been identified in many areas, such as Norway (Swenson et al. 1996), European Russia (Danilov et al. 1993), Spain (Naves & Palomero 1993), the Caucasus Mountains (Kudaktin & Chestin 1993), and Alaska (van Daele, Barnes & Smith 1990). To minimise den abandonment, we recommend that an area around known active bear dens be avoided by humans. Our limited data suggest that this distance should be over 100 m, perhaps up to 1 km. In addition, potentially disturbing activity be minimised in areas that traditionally have dense concentrations of dens.

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