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Den abandonment and transitional day bed use by black bears *Ursus americanus* in Newfoundland

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The use of day beds for extended periods during the transition into and out of the physiological state of hibernation has been documented in many bear populations, but has never been quantified. Additionally, den abandonment by black bears *Ursus americanus* has rarely been observed at northern latitudes except after den visits by researchers. In three areas on the northern island of Newfoundland, where male and female black bears spent an average of 158 and 178 d denning, respectively, we identified den sites and extended-use day beds (occupied continuously for 6–26 d) remotely using GPS collars, and here provide the first systematic description of the use of these day beds by bears. We documented den abandonment in 6 (9%; 3 F, 3 M) of 67 bear-winters (6 [14%] of 44 radio-collared bears) and the use of extended-use transitional day beds in 16 (24%) of 67 bear-winters (15 [34%] of 44 radio-collared bears, 8 F, 7 M). In 5 of 10 instances bears left their fall day beds on days with >15 mm of rain (mean = 28.2 mm, range = 15.6–63.6 mm), which was more than would be expected by chance (p < 0.01). We had more than one year of denning data for 17 bears, 6 (35%) of which reused den sites in different years. Further, we observed some bears using day bed and den sites interchangeably. Though we hypothesized that environmental (floodling) or anthropogenic disturbance (researcher-, forestry-related, or recreational) may have played a role in den abandonment, we found no such relationships, nor was there a difference in the rate of abandonment or day bed use between male and female bears. We could not assess the effects of microhabitat attributes, condition, or reproductive status, but acknowledge that these factors may have played a role in den changes.

Hibernation is an energy-conserving adaptation of some mammals believed to have evolved as a strategy to cope with periods of food scarcity and severe weather in winter (Humphries et al. 2003). While hibernating, bears reduce their body temperature (Hellgren 1998, Hissa et al. 1998), lower their heart-rate (Nelson et al. 1983, Toien et al. 2011), and slow their metabolism (Toien et al. 2011) to reduce energy requirements. Bear hibernation and denning have been distinguished, with hibernation being characterized as the physiological adaptation that allows bears to survive long periods without food or water, and denning as the physical act of reducing mobility and remaining in a sheltered place (Nelson and Beck 1984, Schwartz et al. 2003). For bears, the availability of food resources in the fall may dictate the timing of den entrance (Van Daele et al. 1990, Schooley et al. 1994), whereas emergence dates may be related to spring snowmelt or increasing temperatures (Schooley et al. 1994, McLoughlin et al. 2002, Manchi and Swenson 2005).

Bears typically remain in one den throughout the hibernation period (Pelton 2003, Schwartz et al. 2003), but den abandonment has been recorded in brown *Ursus arctos* (Swenson et al. 1997), black *Ursus americanus* (Tietje and Ruff 1980), and polar bears *Ursus maritimus* (Amstrup 1993), with most instances of abandonment in the published literature associated with human disturbance (Linnell et al. 2000). In 67% of den abandonment events by brown bears in Sweden and Norway, Swenson et al. (1997) documented hunting, fishing or forestry activity within close proximity of the abandoned den sites. More frequently, however, it is human disturbance associated with researcher activity that has been found to cause den abandonment (Linnell et al. 2000). Natural causes, especially flooding, are also commonly reported to have interrupted hibernation and induced den abandonment (Schwartz et al. 1987, Oli et al. 1997). Den abandonment may negatively impact reproduction and fitness. Both Elowe and Dodge (1989) and McDonald and Fuller (1998) reported cub mortality after researcher-induced den abandonment. Swenson et al. (1997) found that pregnant female brown bears that relocated dens lost young significantly more often than undisturbed pregnant...
females, and Tietje and Ruff (1980) reported that black bears that abandoned dens during the winter experienced greater weight loss than bears that stayed in one den. Bears may transition into the physiological state of hibernation prior to denning in the fall, and may transition out of this state after leaving their dens in the spring (Nelson and Beck 1984). These transitional periods, when bears are entering or exiting a biochemical state of hibernation but are not in their winter dens, have been described as “walking hibernation” (Nelson 1973, Nelson et al. 1975). During this time, bears display marked lethargy, and may remain in one place while occupying “day beds” for days or even weeks at a time (Craighead and Craighead 1972, Hellgren and Vaughan 1989, Beecham and Rohlman 1994). Although there are anecdotal observations of these transitional day beds in the literature, the use of day beds has not been systematically described (e.g. frequency, distance from dens, duration). Black bears display a large degree of plasticity in den site selection, and may even hibernate on the surface of the ground (Nelson and Beck 1984, McDonald and Fuller 1998). Therefore, it may be difficult to differentiate den abandonment events (when a bear abandons a den because of some disturbance and then dens in a new location) from movements between extended-use transitional day beds and dens, as the movement patterns associated with the use of day beds or dens are both accurately described by Nelson and Beck’s (1984) definition of denning as the “...physical act of reducing mobility by crawling into a rock cavern, hollow tree, excavated hole, brush pile, or simply lying down on a bed of leaves”.

In mild climatic conditions bears may be more likely to abandon dens (Linnell et al. 2000). Records of den abandonment from northern latitudes in areas with long-term winter snow cover, however, are almost exclusively associated with human disturbance (Tietje and Ruff 1980, Evans et al. 2012, but see Schwartz et al. 1987). In three study areas in Newfoundland where median winter snow cover lasts 100–180 d (Potter 1965), and mean annual snowfall is 200–350 cm (Ullah 1992), we observed several instances of den abandonment among radio-collared black bears and also documented frequent use of extended-use transitional day beds in both the fall and the spring. Our objectives were to quantify the rate of den abandonment, systematically describe the use of extended-use transitional day beds, and investigate potential causes for den abandonment and departure from day beds in the fall. We looked for differences in denning behavior by comparing rates of abandonment and day bed use between males and females and evaluated two hypothesized circumstances under which bears abandon dens or depart from fall day beds: 1) bears are disturbed by human activity; 2) bears are disturbed by flooding events associated with rainfall.

Material and methods

Study areas

Our research was conducted in the La Poile (10 916 km²), Middle Ridge (13 243 km²), and Northern Peninsula (5 391 km²) study areas in Newfoundland (Fig. 1). These areas are lightly populated, with most human settlements on the coast (Statistics Canada 2001). The study areas are a mixture of bogs, heaths, barrens and coniferous and mixed forests of balsam fir *Abies balsamea*, black spruce *Picea mariana*, tamarack *Larix laricina*, mountain maple *Acer spicatum*, birch *Betula* spp. and alder *Alnus* spp. Most of the La Poile and Middle Ridge areas are roadless, but in the Northern Peninsula study area active forest management has created an extensive road system.

Bear capture and telemetry

We captured black bears using Aldrich foot snares or by aerial darting from a helicopter in the three study areas during May–October 2008–2011, and monitored them from 2008–2012. We immobilized bears with a mixture of tiletamine-zolazepam administered intramuscularly with a CO₂-powered pistol at a dosage of 4–7 mg kg⁻¹. Animal capture and handling procedures conformed to guidelines established by the American Society of Mammalogists (Sikes et al. 2011) and were approved by the Univ. of Massachusetts Amherst Institutional Animal Care and Use Committee (Protocol no. 2009-0047). We outfitted 79 bears > 2 years of age with releasable GPS radiocollars from 2008–2011. Each collar was programmed to take a location every 1-, 2-, 4- or 12 h depending on model and time of year. Because of a high failure rate of the collars (24 of 58 collars failed < 2 months, and 48 of 58 failed < 1 year), we were only able to identify dens for 44 bears during 67 bear-winters. We included bear-winters in our analyses only where we could identify an initial entrance and final emergence (i.e. when a collar failed during hibernation we did not use data from that winter). Occasionally we changed bear collars in winter dens (we visited nine bears in their dens [2 M in 2010, 3 M and 4 F in 2011]), but we primarily recollared bears by targeting individuals for recapture and darting them from the air, or opportunistically when we recaptured bears in foot snares. To improve the precision of acquired locations we screened successful fixes and removed 2-D locations with HDOP > 5 (Lewis et al. 2007).

Identifying den sites, day beds and den abandonment events

Using Monte Carlo simulation, Jerde and Visscher (2005) demonstrated that when the step length between consecutive locations in a GPS data set is < 5 error standard deviations it is not possible to distinguish a stationary animal from a slowly moving animal. Previously, we identified the average error standard deviation of the bear collars as 6.98 m (Rayl 2012). Accordingly, we considered bears to be stationary when ‘movements’ were < 35 m, and we identified den sites and extended-use day beds remotely, classifying a bear as either denning (Evans et al. 2012) or in an extended-use day bed if it was stationary > 5 d. We calculated the geographic mean center of all locations when a bear was stationary and used this location as the den site or day bed. Although previous research has found that most abandonment events occur early or late in the denning period (Tietje and Ruff 1980, Swenson et al. 1997, Evans et al. 2012), we conservatively chose to avoid the possibility of misidentifying extended-use
Figure 1. We outfitted black bears with GPS collars in the La Poile (10,916 km²), Middle Ridge (13,243 km²), and Northern Peninsula (5,391 km²) study areas, Newfoundland, 2008–2011. Rainfall data were acquired from three weather stations on the island.

day beds as dens and thereby artificially inflating the number of den abandonments by only classifying clusters that included > 5 d of stationary locations > 30 d from either the initial cessation of movement or the final return to activity as dens. We classified all other > 5 d stationary clusters as extended-use transitional day beds. We considered a den to be abandoned when a bear moved > 35 m from its den site and denned again. We did not classify occasional activity bouts (Bridges et al. 2004), when a bear exited a den for a period of time and then reentered the same den, as abandonment. We used the first location outside of a den after the last location in that den as the date of abandonment.

Analyses

We used \( \chi^2 \) and Fisher’s tests to compare rates of abandonment and rates of extended-use day beds between males and females. We compared the dates of abandonment events to the dates of den work to see if there was any relationship between den work and abandonment events. We compared the distance to publicly maintained roads and the distance to linear features (forestry roads, utility lines, and snowmobile trails commonly used as travel corridors by snowmobiles and all-terrain vehicles) between abandoned dens and successfully used dens and between fall day beds and successfully used dens using non-parametric Mann–Whitney tests. We used weather data from the Meteorological Service of Canada (Environment Canada 2013; Fig. 1) to compare the frequency of abandonment or fall day bed departure on days when it rained > 15 mm to the frequency of abandonment or fall day bed departure on days when it rained < 15 mm using Fisher’s test. We compared the location of each den and day bed to all other dens and day beds to see if dens or day beds were reused. We used program R ver. 3.0.2 for all analyses, relying on the packages adehabitatLT (Calenge 2006), rgdal (Keitt et al. 2013), rgeos (Bivand and Rundel 2013), sp (Bivand et al. 2008), spatstat (Baddeley and Turner 2005) and maptools (Bivand and Lewin-Koh 2013).

Results

Male and female black bears spent an average of 158 and 178 d denning, respectively. We documented den abandonment in six (9%; 3 F, 3 M) of 67 bear-winters (6 [14%] of 44 radio-collared bears, Fig. 2), with bears re-denned following abandonment in five of six instances after traveling an average of 3.2 km (median = 110 m, range = 57–8,521 m) in < 1 d (median = 0 d, range = 0–1 d). We detected no difference in rates of abandonment between males and females (\( p = 1.0 \)). One male bear that abandoned his den on 20 March, remained active for over a month, traveling 39 km before occupying a day bed for nine days (28 April–7 May). We found no instances of researcher-induced den abandonment; we did not visit any abandoned dens during den work, and bears did not emerge until spring from all dens we visited in the late winter. We found no difference in the distance to...
Denning and day bed timeline for 17 black bears (9 F, 8 M) that either abandoned dens or used extended-use day beds in Newfoundland, 2008–2011. We classified sites that included >5 days of stationary locations >30 days from either the initial cessation of movement or the final return to activity as dens. We classified all other clusters of >5 days stationary locations as extended-use transitional day beds. Vertical hash marks represent entrances and emergences to day beds or dens, and numbers above horizontal lines indicate the number of days dens or day beds were occupied. When a bear emerged from a den or day bed and reentered a new den or day bed on the same day only 1 hash mark is displayed. Den abandonment events (n = 6) are indicated by an “A” above den emergence hash marks.

Figure 2. Denning and day bed timeline for 17 black bears (9 F, 8 M) that either abandoned dens or used extended-use day beds in Newfoundland, 2008–2011. We classified sites that included >5 days of stationary locations >30 days from either the initial cessation of movement or the final return to activity as dens. We classified all other clusters of >5 days stationary locations as extended-use transitional day beds. Vertical hash marks represent entrances and emergences to day beds or dens, and numbers above horizontal lines indicate the number of days dens or day beds were occupied. When a bear emerged from a den or day bed and reentered a new den or day bed on the same day only 1 hash mark is displayed. Den abandonment events (n = 6) are indicated by an “A” above den emergence hash marks.

Roads (mean = 17,824 m, range = 609–39,828 m) or the distance to linear features (mean = 4126 m, range = 27–25,872 m) between abandoned and successfully used dens (both p > 0.20). It did not rain on the day of the 6 abandonment events. We knew the reproductive status of two of the three females that abandoned dens: LP1001 was accompanied by yearlings when she abandoned her den, and LP1006 was pregnant when she abandoned her den (Fig. 2).

We documented the use of extended-use transitional day beds in 16 (24%) of 67 bear-winters (15 [34%] of 44 radio-collared bears, 8 F, 7 M, Fig. 2). We observed three male bears using multiple day beds in one season (two in fall, one in spring). We detected no difference in rates of day bed use between males and females ($\chi^2 = 0.23$, DF = 1, p = 0.63). During the fall, female bears using day beds spent an average of 13.3 days in them, while male bears using day beds spent an average of 9.4 days in them. After emerging from their dens in the spring, bears using spring day beds traveled an average of 2.8 km (median = 829 m, range = 36–13,529 m) in 2.8 days (median = 1 day, range = 0–12 days) to their day bed. We knew the reproductive status of 5 of 8 females that used day beds: LP0809 and MR1004 used spring day beds when they were alone; MR1106 shared a fall day bed with cubs of the year and then a spring day bed with those same individuals as yearlings; LP1006 used a spring day bed with cubs of the year; and LP1001 shared a spring day bed with yearlings (Fig. 2).

We observed a high frequency of den reuse, with 6 of 17 (35%) bears for which we had multiple years of denning data reusing den sites in different years. In La Poile, two (2 F) of four (3 F, 1 M) bears with multiple years of
denning data reused dens from previous winters. In the
winter of 2010–2011, one of these female bears returned to
her 2008 den to hibernate, and then left this den in the spring
and used her 2009 den site as a day bed for 20 days (Fig. 2,
LP0809). In Middle Ridge, four (44%; 2 F, 2 M) of nine
(3 F, 6 M) bears with multiple years of denning data reused
dens from previous winters, with one female using the same
den in three consecutive winters (data associated with the
3rd year in this den were not included in our other analyses
because we could not identify an initial den entrance date as
the GPS portion of her collar failed in August of that year,
and we did not recollar her until later in the winter during
den work). Additionally, in Middle Ridge, two males used
the same den in separate winters (2008 and 2011), and one
female returned to her spring day bed (Fig. 2, MR0807) the
next fall to den. We had multiple years of denning data for
four (2 F, 2 M) bears in the Northern Peninsula study area,
but did not observe any den reuse there.

Discussion

Although we hypothesized that flooding or anthropogenic
disturbance played a role in den abandonment, we found
no such relationships. The small sample sizes in our study,
as well as our reliance on indirect measures (with the excep-
tion of our examination of researcher effects) to assess our
hypotheses may have hindered our ability to detect differ-
ences (but see Elfström and Swenson 2009, who also used
sequences, e.g., reduced cub survival, Swenson et al. 1997);
and even reasonable to assume, that at least some of the day
beds we identified were actually dens (especially those occup-
ied for >15 d). Without biochemical monitoring, it may
be difficult or impossible to differentiate between these two
forms of sedentary behavior, although in the absence of any
evidence of disturbance, the more parsimonious explana-
tion may be that sedentary bears near the start or end of the
denning season are occupying day beds rather than dens.

Den abandonment by bears has been used as an indicator
of anthropogenic disturbance with potential population con-
sequences (e.g., reduced cub survival, Swenson et al. 1997);
however, baseline information on this behavior is scarce. We
found no evidence of anthropogenic disturbance influencing
abandonment rates in our study areas, albeit using indirect
measures with very small sample sizes. Thus, our results may
provide preliminary background rates for a northern and
relatively remote ecosystem. Natural rates of abandonment
appear to range widely from populations where abandon-
ment is not observed (e.g., multiple papers that do not report
abandonment), to areas where up to 26% of bears may
abandon dens (Evans et al. 2012). To acquire more accurate
estimates of background abandonment rates, however, GPS
data would need to be downloaded and examined frequently
throughout the denning period, with ground investigations
to inspect abandoned dens and the surrounding areas com-
mencing immediately whenever abandonment events were
detected. Without accurate knowledge about the natural
rate of abandonment in bear populations it may be difficult
to assess the impact of human disturbance on hibernating
bears. Furthermore, increased rates of den abandonment may
be another consequence of climate change (cf. Rodríguez
et al. 2007, Hunter et al. 2010) and thus in need of
future monitoring. As the climate warms, events that are
typically associated with den abandonment in southern bear
populations (e.g. flooded dens; Oli et al. 1997) may become more common in the north. In addition to the demographic ramifications associated with abandonment, more time outside dens in winter may increase human-bear conflict (Servheen and Cross 2010) and the negative consequences for population dynamics that these interactions typically entail.

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