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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 (flooding) 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, Tøien et al. 2011), and slow their metabolism (Tøien 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

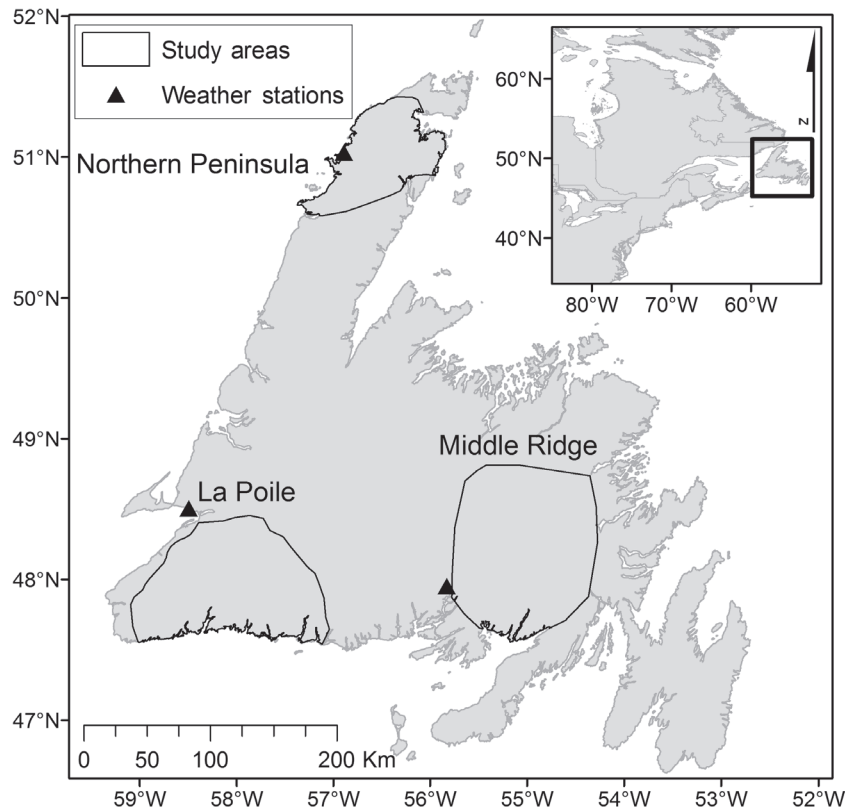


Figure 1. We outfitted black bears with GPS collars in the La Poile (10 916 km²), Middle Ridge (13 243 km²), and Northern Peninsula (5391 km²) study areas, Newfoundland, 2008–2011. Rainfall data were acquired from three weather stations on the island.

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 χ^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-denning 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

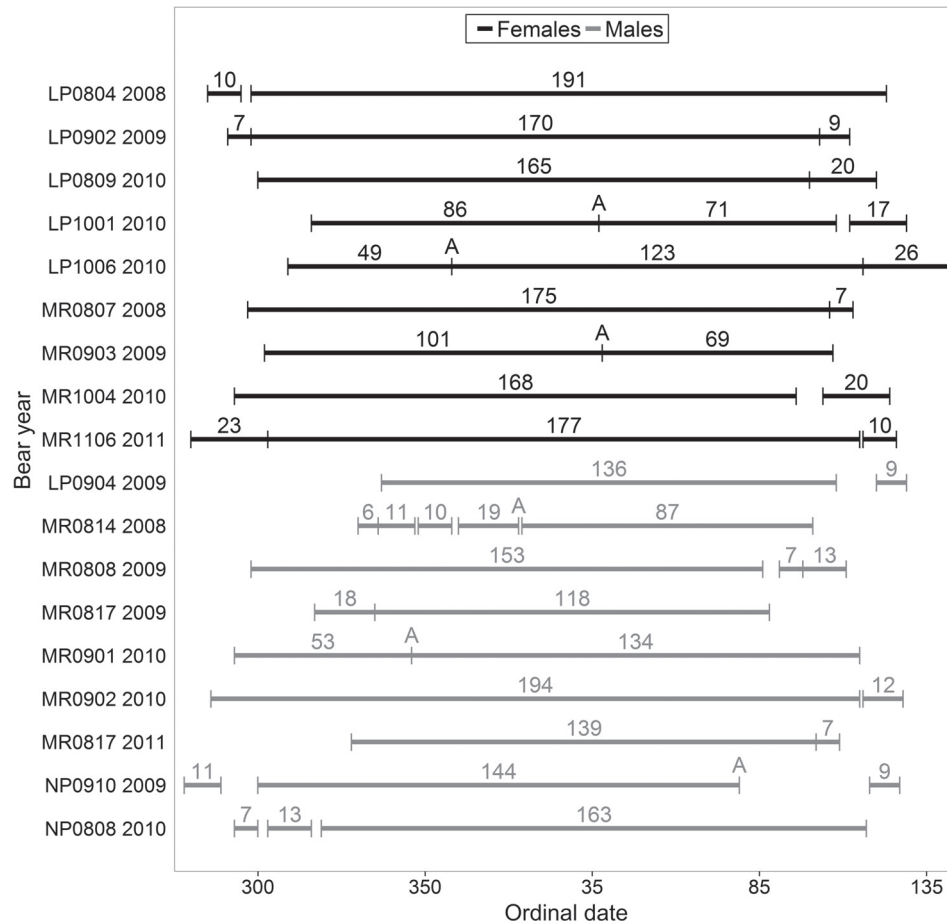


Figure 2. Denning and day bed timeline for 17 black bears (9 F, 8 M) that either abandoned dens or used extended-use day beds in Newfoundland, 2008–2011. We classified sites that included > 5 d of stationary locations > 30 d from either the initial cessation of movement or the final return to activity as dens. We classified all other clusters of > 5 d 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 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 d in them, while male bears using day beds spent an average of 12 d in them. 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 ($p < 0.01$). After leaving their final fall day bed, bears traveled an average of 2.4 km (median = 959 m, range = 57–5960 m) in 2.7 d

(median = 2 d, range = 0–11 d) before denning. We found no difference in the distance to roads (mean = 18 697 m, range = 609–39 828 m) or the distance to linear features (mean = 4415 m, range = 27–25 872 m) between fall day beds and successfully used dens (both $p > 0.26$). During the spring, female bears using day beds spent an average of 15.6 d in them, while male bears using day beds spent an average of 9.4 d 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 d (median = 1 d, range = 0–12 d) 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 exception of our examination of researcher effects) to assess our hypotheses may have hindered our ability to detect differences (but see Elfström and Swenson 2009, who also used surrogates for human disturbance (distance to plowed roads), and found significant differences between abandoned and successfully used dens). Because we did not visit most dens, we could not evaluate the effects of microhabitat attributes, relative bear mass (i.e. condition), or reproductive status of females, but acknowledge that these factors could certainly have played a role in abandonment.

We documented the use of fall and spring day beds by both male and female black bears in Newfoundland, and, for the first time that we are aware, systematically described the use of these sites for a bear population. We observed female bears using day beds in all combinations of season and reproductive status except for unaccompanied females in the fall. We did not see any evidence of lactation, however, nor any cubs with LP0804 in August of 2008 or LP0902 in July of 2009 when we captured them in snares, which suggested that they may have been alone when they used day beds in the fall of those years (Fig. 2). The significant effect of rain > 15 mm on the timing of fall day bed departure suggested that weather played a role in the termination of occupancy of some of these day beds.

It has been reported that bears may reuse dens because there is a scarcity of suitable den sites available, because a site was used successfully in the past, or for both reasons (Davis et al. 2012). Given the large degree of variability we observed in den site selection during our limited den work (including dens on the surface of the ground), we doubt that there was a scarcity of suitable den sites available in our study areas, but instead suggest that the high frequency of den reuse we observed (35% of collared bears with multiple years of data reused dens at least once during the monitoring period), indicated that bears in our areas displayed a propensity to

choose familiar places to den. The reuse of den sites was not limited to an individual bear, nor to consecutive years; two adult males used the same den in separate winters (2008 and 2011), and the behavior of an adult female demonstrated that a bear's memory of previously used dens extends beyond the preceding winter when she returned to her 2008 den to hibernate in 2010 (see description of LP0809's movements in Results).

We also observed bears using den sites from previous years as day beds and day beds from previous years as dens, and documented instances of rainfall influencing day bed departure in the fall. Considered together, these results suggest both that we need to carefully consider the distinction between day beds and dens, and further reinforce the idea (Introduction) that it may be difficult to differentiate between them, because the same sites can serve both roles and departure from these sites may be induced by similar circumstances (e.g. den abandonment after flooding, Schwartz et al. 1987, Oli et al. 1997). Although the literature is replete with research on bear denning, few studies provide parameters that can be used to identify when a bear is denning. This may be because in most study systems bears unambiguously enter a den in the fall and remain in that den until the spring, or because it is assumed that this is the pattern that bears follow, and data to demonstrate otherwise are unexamined or unavailable. We established criteria to distinguish day beds from dens, but it is quite possible, and even reasonable to assume, that at least some of the day beds we identified were actually dens (especially those occupied 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 explanation 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 consequences (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 abandonment 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 commencing 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. Rodriguez 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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