ARCTIC
VOL. 50, NO. 2 (JUNE 1997) P. 158–166

Distribution, Characteristics, and Use of Earth Dens and Related Excavations by Polar Bears on the Western Hudson Bay Lowlands

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(*Received 17 June 1996; accepted in revised form 7 March 1997*)

ABSTRACT. Polar bears fasting on land along the western coast of Hudson Bay during the open water period, from late July through early November, excavate three different types of structures, which we termed pits, deep dens, and shallow dens. Pits were shallow excavations found on the tops of banks or beach ridges, whereas both deep and shallow dens were dug into frozen peat banks. Pits were used as temporary resting places. The function of shallow dens is less clear, although some bears have been observed resting in them. Deep dens, which have an entrance tunnel and an enlarged inner chamber, are similar in size and structure to maternity dens dug in snow by female polar bears elsewhere in their range. Deep and shallow dens are primarily occupied by lone females, most of which are pregnant, while pits are generally occupied by adult males and are used more during summer than in autumn. Pregnant polar bears in western Hudson Bay give birth between mid-November and mid-December, by which time snowdrifts suitable for the construction of maternity dens have not yet formed in most years. Thus, because earth dens represent the only consistently suitable environment available at the time of parturition, we suggest most cubs in western Hudson Bay are born in them. Consequently, the availability of suitable habitat for the construction and use of earth dens is probably critical to the survival of the polar bear population in Western Hudson Bay. Secondary benefits of earth dens to pregnant females, and to other bears during the warm weather in late summer, are that they help the bears to conserve energy by remaining cool and to avoid insect harassment.

Key words: polar bear, *Ursus maritimus*, den, permafrost, Hudson Bay Lowlands, Manitoba

RÉSUMÉ. Les ours polaires qui jeûnent sur la terre ferme le long de la côte occidentale de la baie d'Hudson durant la période d'eau libre (fin juillet à début novembre), creusent trois types de structures différentes que nous appelons fosses, tanières profondes et tanières peu profondes. Les fosses sont des creux peu profonds que l'on a trouvé en haut des talus ou des crêtes de plage, alors que les tanières profondes et peu profondes étaient creusées dans de la tourbe gelée. Les fosses étaient utilisées comme lieux de repos temporaires. La fonction que remplissaient les tanières peu profondes n'est pas claire, bien qu'on y ait observé des ours qui s'y reposaient. Les tanières profondes, qui ont une entrée en forme de tunnel s'élargissant en une chambre intérieure, sont semblables, par leur dimension et leur forme, aux tanières de mise bas creusées dans la neige par les ourses polaires ailleurs dans leur territoire. Les tanières profondes et peu profondes sont surtout occupées par les femelles solitaires, dont la plupart sont pleines, tandis que les fosses sont en général occupées par des mâles adultes et sont plus utilisées en été qu'en automne. Dans la baie d'Hudson occidentale, les ourses pleines mettent bas entre la mi-novembre et la mi-décembre, date à laquelle, la majorité des années, les bancs de neige propres à la construction de tanières de mise bas ne sont pas encore formés. Par conséquent, vu que les tanières dans la terre représentent le seul milieu convenable régulièrement disponible au moment de la parturition, on suggère que, dans la baie d'Hudson occidentale, la plupart des oursons y naissent. La disponibilité d'un habitat approprié à la construction et l'utilisation des tanières de terre est donc probablement critique à la survie de la population de l'ours polaire dans la baie d'Hudson occidentale. Un autre bénéfice que représentent les tanières de terre pour les femelles pleines, ainsi que pour les autres ours durant la saison chaude à la fin de l'été, est que ces tanières aident les ours à conserver leur énergie en les maintenant au frais et à les mettant à l'abri des insectes.

Mots clés: ours polaire, *Ursus maritimus*, tanière, pergélisol, basses-terres de la baie d'Hudson, Manitoba

Traduit pour la revue *Arctic* par Nésida Loyer.

INTRODUCTION

The polar bear (*Ursus maritimus*) population that inhabits western Hudson Bay spends the period from late July through early November on shore each year because the annual ice melts completely (Stirling et al., 1977). Once on land, bears segregate by age and sex class. Adult males tend to remain along the coast, while adult females, with and without cubs, move 30–50 km inland (Derocher and Stirling, 1990). Subadults are found throughout the coastal and inland areas.

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Because they cannot hunt seals during this period and little feeding occurs on shore (Russell, 1975; Knudsen, 1978; Lunn and Stirling, 1985; Ramsay and Hobson, 1991; Derocher et al., 1993), bears are mostly inactive and subsist on their stored fat reserves (Nelson et al., 1983; Derocher et al., 1990; Ramsay et al., 1991, 1992).

Over the years, polar bears have dug hundreds, if not thousands, of dens and simple shallow pits in the earth of the study area. During the late summer and fall, the bears occupy some of these dens and pits (Jonkel et al., 1972; Stirling et al., 1977). Jonkel et al. (1972) speculated that these excavations were used by adult bears for temporary resting and cooling during the relatively warm ice-free season. Other possible explanations for their use include escape from insect harassment and maternity denning. This paper describes the types of structures dug, quantifies the age and sex classes of bears using them, and evaluates possible hypotheses to explain their function.

METHODS

The study area is the western coast of Hudson Bay near Churchill, Manitoba, from latitude 57˚00′ to 58˚50′ N and from longitude 92˚40′ to 94˚00′ W (Fig. 1). Elevation is less than 200 m, and the entire area has little relief. It contains numerous lakes, rivers, and creeks and is underlain by continuous permafrost (Dredge and Nixon, 1992). The geobotany of the region, a transition zone between boreal forest and low arctic tundra, was described by Ritchie (1962). Details of the terrestrial habitats used by polar bears are given by Clark (1996) and Clark and Stirling (in press). To generalize, however, the study area is an open patchwork of treeless expanses (mainly tundra, old beach ridges, and wetlands) interspersed with generally low-lying shrub vegetation, and treed along the rivers and most streams (Jonkel et al., 1972; Stirling et al., 1977; Ramsay and Stirling, 1990). The inland beach ridges are characterized by Dredge and Nixon (1992) as unsorted deposits 1 – 2 m deep and underlain by clay. Dens were dug into frozen peat along stream or lake banks or beneath permafrost hummocks, usually beneath black spruce (*Picea mariana*). With few exceptions, dens were readily visible from the air. The numerous pits, located on beach ridges or near the edges of lakes, were easy to see because of the open habitat.

During August and September of 1992 and 1993, we used a Bell 206B helicopter to search for polar bears in all habitat types throughout the study area, and then captured them as part of a long-term population study. During this period, we selected a sample of active (occupied by a bear) and inactive (unoccupied) dens and pits for study. Some active dens were found by tracking radio-collared adult female bears to them. Bears in dens usually exited when approached by a helicopter and then were immobilized, allowing the den to be measured. If a female did not leave her den promptly, she was not further harassed, and we resumed searching. Attempting to measure all the old dens or pits seen in a typical day was not practical, because there were too many. One or more (usually inactive) excavations were often within a few hundred metres of a selected den or pit. These were usually noted from the helicopter, and checked to ensure they were unoccupied, before we landed and entered them. We tried to measure all the excavations seen at each site after we landed, because it enabled us to enlarge the sample size without the expense of additional flying. In this way, both active and inactive deep dens were chosen nonrandomly, but nonselectively.

In the field we recognized three different types of excavations made by polar bears: shallow, round-to-oblong pits on the tops of banks or beach ridges (Fig. 2); deep dens in peat banks, with an elliptical entrance and a narrow entrance tunnel, often running parallel to the bank, leading to a larger inner chamber (Fig. 3); and intermediate structures that were simple, shallow, semicircular excavations into peat banks, without an entrance tunnel (Fig. 4). We treat each of these types individually, and refer to them as pits, deep dens, and shallow dens, respectively. The dryness of excavated peat and the condition of vegetation in and adjacent to the den or pit were used to classify these structures as either fresh (evidence of digging during the current field season) or old (one or more years since they had been occupied).

We measured the length, width, and depth of pits and deep and shallow dens to the nearest 5 cm with a steel tape (Fig. 5). For pits, depth refers to the maximum vertical depth below the rim of the pit. Permafrost depths adjacent to and within dens were measured with a steel probe graduated at 1 cm intervals. We did not measure the slopes of banks containing dens, since they were abrupt, many were rounded from slumping, and the open den entrance was often a large portion of the bank's height. Vegetation and physical features above and immediately adjacent to dens were qualitatively described at each site. The habitat types are those described by Ritchie (1962) and Clark and Stirling (in press). The locations of dens were determined using a global positioning system receiver (Garmin GPS-100, Lenexa, Kansas). We tested aspect measurements for significance with a modified Rayleigh's Z-test, and compared the aspects of deep and shallow dens using the Watson-Williams test (Zar, 1984).

All observed use of dens or pits recorded for polar bears captured during population studies conducted between 1966 and 1994 was stored in a central database maintained by the Canadian Wildlife Service. In years prior to the present study, most shallow and deep dens were recorded simply as dens, which prevents us from separately tabulating the age and sex classes of the bears using the two types of dens. Thus, observations of bears of different age, sex, and reproductive status using dens of both types are pooled. Females with young were divided into two groups: those with cubs-of-the-year (COYs), and those with yearling cubs.

RESULTS

We examined 41 deep dens, 43 shallow dens and 48 pits in 1992 and 1993 (Fig. 1). Of 18 fresh, deep dens, 15 (83%) were occupied, while none of 23 old dens was. Of 34 fresh, shallow

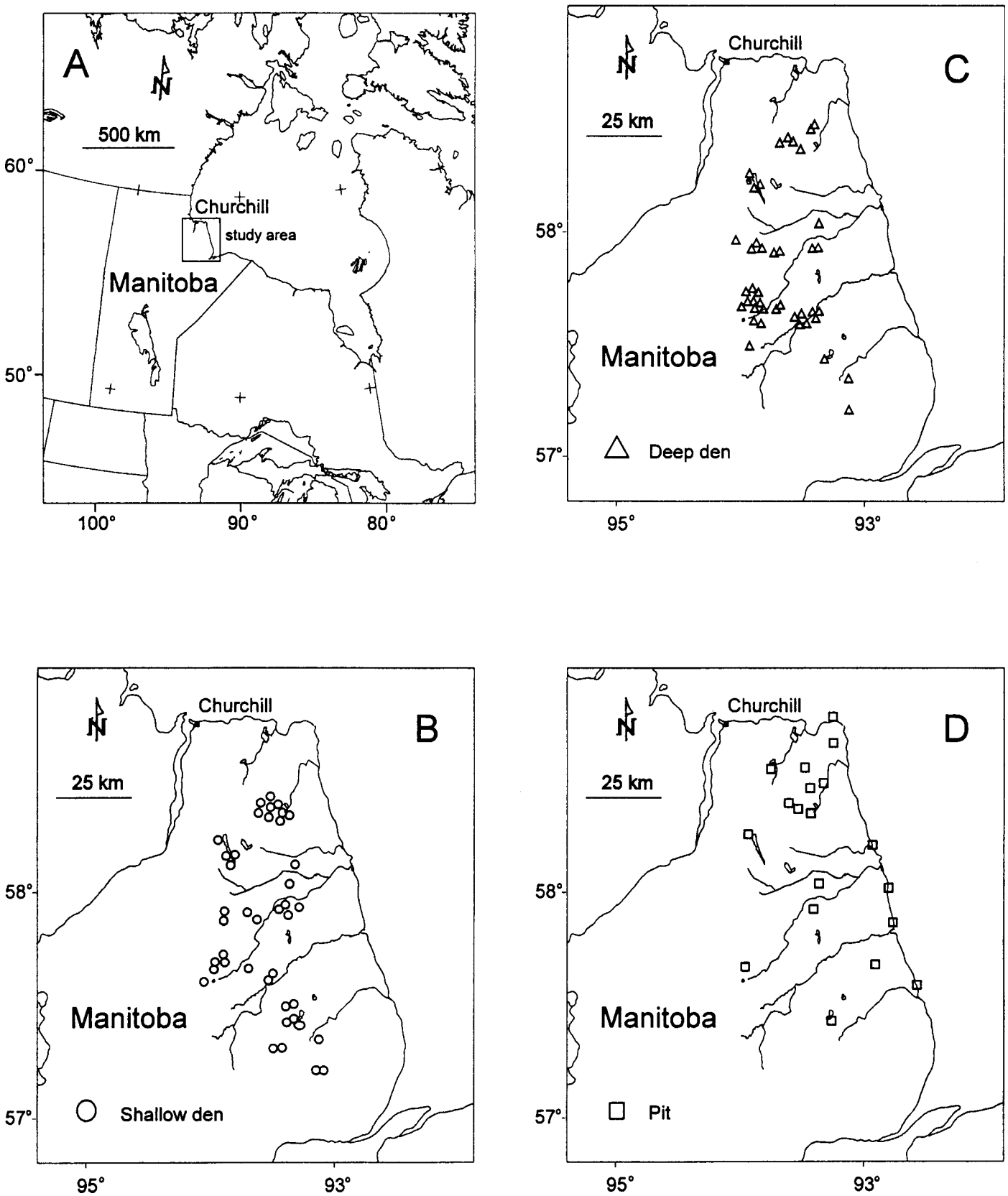

FIG. 1. Maps showing: (A) the location of the study area, (B) locations of 43 shallow dens, (C) 41 deep dens, and (D) 48 pits.

dens, 19 (56%) were occupied, but none of the 9 old shallow dens was. Bears also occupied 22 (69%) of 32 fresh pits and 1 (6%) of 16 old pits. The bear lying in the old pit had made no new excavations.

FIG. 2. A typical pit.

FIG. 3. Entrance to a typical deep den. Note the presence of spruce trees along the top of the bank over the den.

FIG. 4. A typical shallow den. Shallow dens may or may not have vegetation above them.

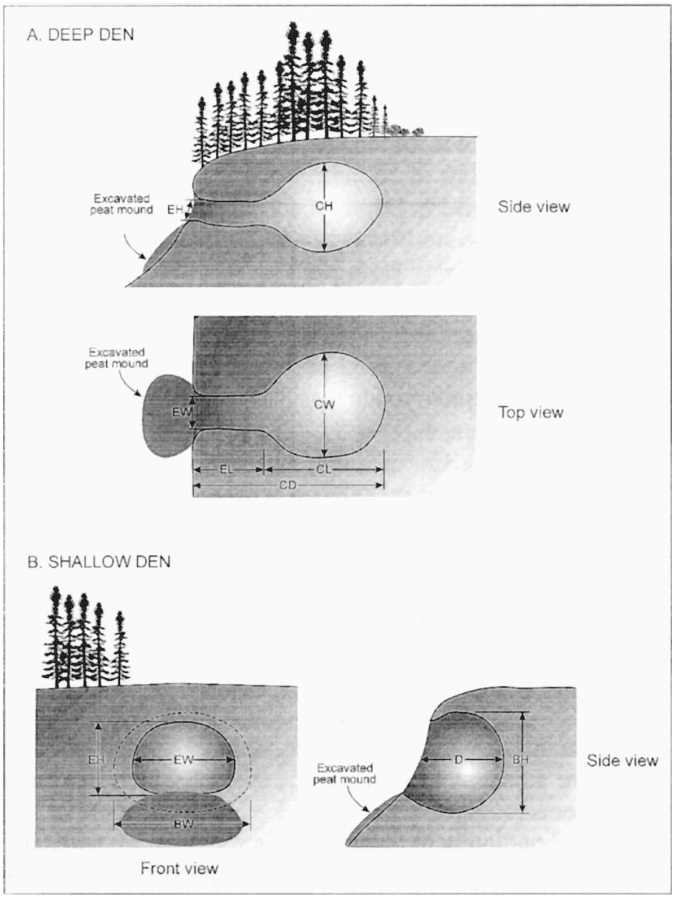

FIG. 5. Schematic diagrams of deep and shallow dens, showing the locations of measurements taken. Note that the entrance tunnels to deep dens may either go straight into the bank or curve to either side, parallel to the bank. (BH = back height; BW = back width; CD = chamber depth; CH = chamber height; CW = chamber width; D = depth from entrance; EH = entrance height; EL = entrance length; EW = entrance width.)

Characteristics

In general, our observations on the structure of earth dens and pits are similar to the preliminary, unquantified descriptions of excavations by polar bears in the study area, given by Jonkel et al. (1972).

Deep dens had elliptical entrances, which typically led through a tunnel into a larger inner chamber (Figs. 3 and 5). Thirty-five deep dens had a single chamber, and six had two or more chambers. Eleven deep dens and their entrances were at right angles to the bank face, twenty-two curved either left or right, parallel to the bank, and two single den entrances, after entering the bank, had separate tunnels and dens extending in both directions. The direction of entrance tunnels was not recorded for six dens. Mean aspect of the deep dens was not significantly different from random ($\bar{x}$ = 119°, circular SD 150°, $r = 0.033$, $p > 0.5$, n = 41).

Shallow dens are simpler structures than deep dens, typically being just semicircular excavations (Figs. 4 and 5). Of those dens for which the direction of the entrance tunnel was recorded, 24 were symmetrical and 10 curved either to the right or left, parallel to the bank. Nine were either collapsing

TABLE 1. Average dimensions of earth dens (cm). Standard deviations are in parentheses.

Deep Dens Age	Entrance Length	Entrance Width	Entrance Height	Chamber Length	Chamber Width	Chamber Depth	Chamber Height
Fresh	137 (50)	101 (27)	68 (17)	129 (17)	142 (32)	203 (81)	90 (13)
n	7	17	17	7	17	17	16
Old	154 (72)	132 (58)	60 (11)	169 (66)	159 (59)	300 (151)	84 (21)
n	7	13	8	7	19	22	17

Shallow Dens Age	Entrance Width	Entrance Height	Back Width	Depth	Back Height
Fresh	104 (23)	76 (21)	133 (49)	124 (52)	88 (24)
n	24	23	34	34	31
Old	114 (37)	75 (15)	107 (39)	125 (67)	67 (15)
n	6	6	9	9	8

or too shallow to determine if they were curved or straight. The dimensions of fresh and old earth dens are presented in Table 1. Mean aspect of shallow dens was not significantly different from random ($\bar{x}$ = 135°, circular SD 89°, r = 0.0299, $p > 0.2$, n = 43). The mean aspects of deep and shallow dens were significantly different (F = 13.446, $p < 0.001$, df = 83).

Figure 2 illustrates a typical pit. Average dimensions (and SD) in cm of 32 fresh pits were length 155 (76) and width 140 (65). Mean depth was 16 cm (20) for 28 measured fresh pits. Average dimensions of 16 old pits were 133 (49) for length and 121 (46) for width. Depth of 15 old pits was 35 cm (27). Mean aspect of the landforms in which pits were situated did not differ significantly from random ($\bar{x}$ = 52°, circular SD 102°, r = 0.207, $p > 0.1$, n = 48).

Mean depth to permafrost inside fresh structures (18 deep dens, 34 shallow dens and 32 pits) was 12.5 cm (SD = 25.6 cm), and mean depth outside was 37.8 cm (SD = 21.1 cm): a significant difference (F = 72.708, $p < 0.001$). Depths to permafrost among the different types of structure did not differ significantly (F = 0.807, $p > 0.4$), and there was no interaction effect between structure type and permafrost depth differences (F = 0.516, $p > 0.5$).

Spruce (mainly *Picea mariana*) was on top of the bank above 33 of 41 deep dens and 32 of 43 shallow dens, but only 5 of 26 inland pits. Estimated mean tree height above all types of excavations did not vary and averaged 2.1 m (SD = 1.0 m, n = 70). The proportion of shallow dens with trees above them may be overestimated, as several were examined because they were adjacent to deep dens, most of which had trees above them.

In or immediately in front of nine structures, we noted dry vegetation, apparently cut by bears, that may have been bedding material. This included *Carex* sp. (4), *Elymus arenarius* (3), *Sphagnum* sp. (2), *Ledum groenlandicum* (2), *Potentilla palustris* (1), and *Salix* sp. (1).

Distribution

Most deep and shallow dens were located on banks, with lichen tundra above and water or wetland below. In contrast, pits were located on banks and beach ridges throughout most habitat types except spruce forest, and had a variety of habitat types above and below them. Lichen tundra was above 36 deep dens and 31 shallow dens, and below 4 deep dens, 1 shallow den, and 1 pit. It was also the habitat surrounding 12 pits. Wetlands were above 5 deep dens and 9 shallow dens and surrounded 6 pits. Wetlands were below 36 deep dens, 37 shallow dens, and 16 pits. The only other habitat types associated with denning excavations were beach ridges surrounding 19 pits, and intertidal wetlands below 3 pits. The banks and ridges on which deep dens (n = 41) and shallow dens (n = 40) were located were significantly higher than those with pits (n = 47) (p = 0.0009, F = 7.421, df = 124): average heights were 2.5 m, 3.0 m, and 1.8 m respectively. Average heights above the bases of banks were 1.5 m for deep dens, 1.8 m for shallow dens, and 1.5 m for pits.

Twenty-five deep dens (61%) were on lakeshores, 4 (10%) were on the banks of rivers and creeks, and 12 (29%) were not adjacent to water. Similarly, 22 shallow dens (51%) were on lakeshores, 11 (26%) were along the banks of rivers and creeks, and 10 (23%) were not near water. In contrast, 19 pits (40%) were on lakeshores, 1 (2%) was on a riverbank, 22 (46%) were on beach ridges just above or nearly at high-tide line, and 6 (12%) were not associated with water. The average distance from water, if water was adjacent, was 10.2 m (SD = 12.6 m) and did not differ among types of excavations (F = 0.175, p = 0.840). Three pits, two of which were occupied by adult males, were located in the intertidal zone, on a bed of wave-deposited kelp approximately 0.5 m thick. Such a location could be occupied only intermittently.

Use by Polar Bears

During 1992 and 1993 (when data from deep and shallow dens were segregated), of the 14 bears that were occupying deep dens when captured, 11 (79%) were lone females, two (14%) were subadult males, and 1 (7%) was an adult male. Of 17 bears occupying shallow dens, 15 (88%) were lone females, 1 (6%) was a subadult male, and 1 (6%) was an adult male. Of 15 bears occupying pits, 2 (13%) were lone females, 2 were females with cubs of the year, 1 (7%) was a subadult male, and 10 (67%) were adult males.

The age and sex classes of bears captured each month from 1966 through 1994, in shallow and deep dens pooled, in

TABLE 2. Age, sex, and reproductive status of polar bears in earth dens and pits for each month from 1966 through 1994.

Polar Bears in Deep and Shallow Dens Month	Lone Female	Female w. COY	Female w. Yrlg	Subadult Female	Adult Male	Subadult Male	Σ
July	0	0	0	0	0	0	0
August	9	0	0	1	3	1	14
September	100	2	1	3	16	5	127
October	36	2	1	3	1	0	43
November	9	0	0	2	0	0	11
Σ	154	4	2	9	20	6	195
Polar Bears in Pits							
July	1	0	0	2	9	0	12
August	3	5	1	2	20	4	35
September	0	2	0	1	10	0	13
October	0	0	0	0	3	0	3
November	0	0	0	0	1	0	1
Σ	4	7	1	5	43	4	64

comparison to pits, are summarized in Table 2. (Prior to 1992, shallow dens were distinguished from deep dens in only six cases in the capture database: one adult male in July, two lone females and one subadult female in September, one female with yearlings in October, and one subadult female in November.) Of all bears caught while using a pit or den in August, 71% (35/49) were in pits; while of those caught in September, 91% (127/140) were in dens. Use of pits declines by late September as the weather cools, and later, in October, even many of the large adult males retreat from the beach ridges to dense patches of willows to escape direct exposure to strong, cold wind.

DISCUSSION

Functions of Dens and Pits

Hypotheses that have been advanced to explain the function of earth dens and pits on land in the study area include cooling, resting, escape from insect harassment, and maternity denning. These explanations need not be mutually exclusive, nor are the functions of each type of excavation necessarily the same.

Jonkel et al. (1972) proposed that temperature regulation was the principal function of all three types of structures and that all other functions were secondary. During August and early September, temperatures regularly reach 20–25˚C (Maxwell, 1986). The easiest places to cool off would appear to be the coastal beach ridges, where water is easily available and breezes from the bay are cooler than over the land. In addition, the coastal ridges require minimal travel, making it easier for bears that remain there until freeze-up to conserve energy. Adult males, the most dominant age and sex class in the population, predominate on the coastal areas, while lone females and females with cubs go inland, probably to avoid adult males (Derocher and Stirling, 1990). Subadults are found in all habitats, but they also avoid the males. Thus, if dens were the best place to remain cool in the inland areas during the hot weather, one would predict that bears of all age and sex classes would be found in them, in rough proportion to their frequency of occurrence in the inland areas. But they are not: by an overwhelming majority, the bears in dens are lone females (Table 2). Thus, it appears that, although the coolness of deep dens probably aids thermoregulation for bears inside them, it is not sufficient to explain why lone females use them more than bears of other age and sex classes.

The hypothesis that use of deep dens by bears would provide relief from biting insects, which are abundant during summer and early fall in the inland areas, would not apply to shallow dens or pits. If avoidance of insects were a significant factor, the benefit should apply equally to bears of other age and sex classes. However, because the use of deep dens by bears other than adult females is infrequent, escape from insects appears to be a coincidental benefit, but not an important factor determining den use.

The deep dens described in this study are similar in conformation and internal dimensions to maternity dens dug in snow by adult female polar bears in other areas (Harington, 1968; Lentfer and Hensel, 1980). Since adult female polar bears are about half the size of adult males, the similarity in size of maternity dens in snow elsewhere in the Arctic to deep dens in the study area indicates the latter are probably mostly dug by adult females. If subadult males of a similar size to adult females often dug such dens, we would have found them in dens more often; however, we did not (Table 2).

Harington (1968) made a distinction between maternity dens in snow, which resemble deep earth dens, and temporary dens in snow, which resemble shallow dens. Temporary snow dens were also recognized by Uspenski and Kistchinski (1972), Belikov (1980), and Hansson and Thomassen (1983). Male and female polar bears fasting during the open water period in the High Arctic also made dens and pits in permanent snowfields that appear similar in structure to dens and pits in the study area (Schweinsburg, 1979).

The great majority of bears using deep and shallow dens were lone adult females, most of which were pregnant (Derocher et al., 1993), although small numbers of bears of other age and sex classes used them as well (Table 2). The similarity between the structure of maternity dens in snow and the deep dens in peat, dug and occupied mainly by lone females, suggests that maternity denning warrants investigation as an explanatory hypothesis. Progesterone levels recorded by Derocher et al. (1992) from lone females showed that implantation of the embryo occurs between mid-September and mid-October; thus parturition takes place between mid-November and mid-December. By mid-November, bears of all other age and sex classes have returned to the sea ice to hunt seals. In many, perhaps most, years, snowdrifts suitable for construction of maternity dens like those used in other parts of polar bear range have not yet developed by the time the young are born on the western coast of Hudson Bay. Although the females may burrow out into the overlying snowdrifts later in the winter, earth dens probably represent the only reliable shelter available for neonate cubs in most years and, consequently, are probably critical to their survival. Thus, we suggest the primary function of deep earth dens to polar bears in the western Hudson Bay population is for maternity denning. This also explains why so few bears of other age and sex classes are found in them. Pregnant female bears probably dig maternity dens during summer, rather than waiting until autumn, because it would be harder to dig into the peat once it freezes. Craighead and Craighead (1972) found that grizzly bears digging in unfrozen soil took at least three to seven days to excavate a den similar in size to those we observed, which indicates that a significant effort must be involved in digging these dens.

Judging by the presence of both freshly dug and old dry peat outside established deep dens, polar bears appear to re-excavate dens, and extend many of them over several years. Given that the energy required to excavate a den into permafrost is probably high, it would seem logical to reuse an old den whenever possible rather than always construct a new one. However, since polar bears exhibit fidelity only to general areas and apparently not to specific dens (Derocher and Stirling, 1990; Ramsay and Stirling, 1990; Amstrup and Gardner, 1994), it is unlikely that digging at specific sites in different years represents continued efforts by the same bear.

The functions of shallow dens and pits during the ice-free period in western Hudson Bay are not clear. Although some shallow dens may provide shelter from wind, clear hypotheses related to thermal or insect-related benefits that a bear could not achieve simply by lying on the ground at the same location are difficult to confirm or reject. Thus, bears may simply excavate shallow dens and pits to rest in because they are more comfortable.

Shallow dens are found in the same habitat types and locations as deep dens, bears appear to rest in both, and both are used predominantly by adult female bears. Shallow dens may be more limited excavations because they are used only temporarily during the ice-free season, whereas deep dens are used well into or through the winter. Lutsyuk (1978) described "temporary dens," which were similar in size and shape to shallow dens, in the snow near maternity dens on Wrangel Island, Russia in the spring. Similarly, Belikov (1980) observed that temporary dens were typically used for only a few days, after emergence from maternity dens.

Alternately, shallow dens may be abandoned or partially completed efforts to build deep dens. It is unlikely that every attempt to dig a den is successful, and abandonment of denning attempts has been documented for other species in the Arctic. For example, Cheesemore (1969) found partially completed arctic fox (*Alopex lagopus*) dens that had been abandoned once they reached permafrost. Harington (1968) interpreted claw marks in a snowbank adjacent to a polar bear den to be an abandoned attempt by a polar bear to dig there. If shallow dens were the beginnings of deep dens, one would expect to find a continuum of depths, from shallow to deep. However, this is not the case: deep and shallow dens have quite different average depths (203 cm and 124 cm respectively for fresh excavations) and intermediate excavations have not been observed (Table 1). Finally, shallow dens may, like pits, simply be used for resting, and this hypothesis may explain the lack of excavations of intermediate length.

Most bears using pits were adult males. Consolidated banks, frozen or unfrozen, are not present along the coast in our study area, so digging dens there is not an option. This is unlike the situation on the James Bay Islands, where 45 m high sand and gravel banks are present (Jonkel et al., 1972). The location of pits in exposed areas along lake edges and beach ridges appears to facilitate cooling in the warmer months; but, judging by their abandonment during strong winds later in the fall, such pits do not provide adequate shelter during inclement weather.

Distribution and Characteristics of Dens and Pits

The distribution of dens and pits located during these surveys reveals clear associations with habitat types, similar to those described more briefly by Stirling et al. (1977) and Derocher and Stirling (1990). Dens on lakeshores, which predominate in the sample, are more visible than dens along more heavily vegetated stream banks, or on isolated hummocks, so the apparent preference for this habitat may be influenced to some degree by observer bias. Pits were found in all habitat types except spruce forest, possibly because it would be more difficult for observers to see them there from a helicopter, but probably because such areas generally lack exposure or proximity to water and wind (which would facilitate cooling). Lack of visibility may also be an important negative factor for family groups and subadults using pits in forested areas because of the potential for predation by adult males.

Spruce trees grew in a fringe along the upper edges of banks over most dens while lichen tundra lay behind. Several authors (e.g., Craighead and Craighead, 1972; Jonkel et al., 1972; Harding, 1976) suggest that tree roots are important for stabilizing the ceilings of terrestrial dens dug by other species of bears. The entrance tunnels of deep dens curve in order to run parallel to the bank, where they can remain under the root

system of the overlying spruce trees, which prevent the roof from collapsing. We observed peat banks slumping above dens that lacked spruce trees above them, which is probably unimportant for a shallow den that is simply used to rest in. However, the persistence of some individual deep dens for many years in the thermally dynamic active layer of peat confirms the critical importance of tree roots in supporting the roof. A den collapse can be serious. Clarkson and Irish (1991) documented the case of a female polar bear and her newborn cub that were killed when their snow den collapsed near the coast of the southeastern Beaufort Sea during a warm period in winter. Similarly, Stirling and Derocher (1993) noted extensive slumping of snowbanks in the study area in March 1990 as a consequence of unseasonably warm weather and rain, although no mortalities as a consequence were documented.

Jonkel et al. (1972) and Ramsay and Stirling (1990) reported that maternity dens in the study area most commonly have a southerly aspect. In this study, we also found a tendency for the entrances of both deep and shallow dens to have a southerly aspect, but there was a high degree of variance. Given the relatively flat nature of the habitat, we suggest that any relief, no matter what its exposure, may be adequate for den excavation, but that a southerly direction is preferred. Pits generally faced northeast, which is what would be expected if they were positioned to take advantage of onshore winds from Hudson Bay for cooling.

The majority of pits, and all deep and shallow dens, were typically found on dry areas above water or wetland. Doutt (1967) and Jonkel et al. (1972) reported shallow dens and pits in sand and gravel ridges in the James Bay Islands. In the study area, relief is provided by peat banks along lakes and streams and coastal beach ridges. We found only pits associated with beach ridges in the study area, probably because there are no bushes or trees with a root system that could stabilize the ceiling of a den, as found on the sites described by Doutt (1967) on South Twin Island in James Bay. However, even if the vegetation were closer to the beach, as it is along the coastlines of Ontario and Manitoba south of the Nelson River, it is likely that pregnant females still would go further inland to den to avoid adult males, as it appears they do in the study area (Jonkel et al., 1976; Stirling et al., 1977; Kolenosky and Prevett, 1983).

We found no dens on inland beach ridges, possibly because the ridges are too unstable to support the roofs, even though some of them are forested and some are overlain by peat. There are also large alluvial deposits along both the Knife River north of Churchill and the Owl and Broad Rivers within the study area, all of which are overlain by frozen peat (Dredge and Nixon, 1992). While denning in the frozen peat to the south of the Churchill River is common, bears are rarely observed in the inland areas to the north and have not been reported denning there.

South and east of the Nelson River in northeastern Manitoba and along the northwestern coast of Ontario, there are extensive flat wetlands, the permafrost is discontinuous, and sites that provide sufficient relief for construction of dry dens, such as banks or hummocks, are scarce. The denning sites used by polar bears in these areas are little-known, except that they appear to be farther inland and more widely dispersed than they are north of the Nelson River in our study area (Jonkel et al., 1976, Stirling et al., 1977; Kolenosky and Prevett, 1983). In the wetland areas to the south of our study area, some polar bear maternity dens have been excavated into permafrost hummocks (Jonkel et al., 1976; Stirling, unpubl. data). Jonkel et al. (1976) reported that the most common excavations in these hummocks were shallow dens, which—if true—may reflect differences in the availability or suitability of substrates for excavating and maintaining deep dens. However, it has not been determined whether the difference between the study area and areas farther south in frequency of occurrence of different types of dens is statistically significant.

ACKNOWLEDGEMENTS

We thank D.S. Andriashek, A.E. Derocher, N.J. Lunn, S. Miller, and P.A. Scott for assistance in the field and in the laboratory. M.A. Ramsay gave us permission to include unpublished observations on bears handled during his research in the study area. Constructive criticism of earlier drafts of this paper was received from S.C. Amstrup, S. Boutin, M. Dale, A.E. Derocher, D. Garshelis, N.J. Lunn, J.O. Murie, and P.A. Scott. The study was supported by the Canadian Wildlife Service, the Department of Biological Sciences of The University of Alberta, the Canadian Circumpolar Institute (Northern Science Training Program), the Manitoba Department of Natural Resources, the Churchill Northern Studies Centre, and the Natural Sciences and Engineering Research Council (operating grant to I. Stirling).

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