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Implications of Warm Temperatures and an Unusual Rain Event for the Survival of Ringed Seals on the Coast of Southeastern Baffin Island

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ABSTRACT. We recorded an unusually warm period in early April 1979 along the coastline at the end of the Hall Peninsula on southeastern Baffin Island, Nunavut. Maximum temperatures remained at or above freezing for almost a week, and rain fell on our field camp on three consecutive days. In contrast, meteorological data collected from three nearby coastal stations (Brevoort Island, Cape Dyer, and Resolution Island) between 1950 and 1992 indicated that the mean minimum and maximum air temperatures for the month of April are normally10–20˚C cooler than the averages we recorded at our camp. Periodic warming to near freezing, probably due to the maritime influence of nearby open water in Davis Strait, occurs in this area in late March and early April, but not usually to the degree we observed. Between 1950 and 1992, additional similar rain events were recorded only twice at the coastal weather stations. In late March, we found slumped roofs over some ringed seal (*Phoca hispida*) birth lairs and others that had collapsed, probably because of four days of weather only slightly below freezing and heat generated by seals within the lairs. After the rain in April, we found subnivean lairs with melted roofs, and several snowdrifts that had previously contained lairs were completely washed away. Newborn pups were left lying on the bare ice, subject to thermoregulatory stress and vulnerable to significantly increased predation by polar bears (*Ursus maritimus*) and arctic foxes (*Alopex lagopus*). If the climate continues to warm in the Arctic, as is predicted, it is likely that rain will be more widespread during early spring. If that occurs, the premature removal of protection offered by subnivean birth lairs may expose young ringed seal pups to high levels of predation, which may negatively affect populations of ringed seals and the polar bears that depend on them for food.

Key words: ringed seal, *Phoca hispida,* predation, birth lairs, climate change, polar bear, *Ursus maritimus*

RÉSUMÉ. Au début d’avril 1979, on a enregistré une période anormalement tempérée le long du littoral aux confins de la péninsule Hall dans le sud-est de l’île Baffin, au Nunavut. Les températures maximales sont restées au niveau du point de congélation ou au-dessus pendant presque une semaine, et il a plu sur notre campement trois jours de suite. À titre de comparaison, les données météorologiques recueillies entre 1950 et 1992 à trois stations côtières situées à proximité immédiate (Brevoort Island, Cape Dyer et Resolution Island) indiquent que la moyenne des températures minimales et maximales de l’air pour le mois d’avril est normalement de 10 à 20 ˚C plus froide que celle enregistrée à notre campement. Fin mars et début avril, il se produit dans la région un réchauffement périodique se rapprochant du point de congélation, dû probablement à l’influence maritime des eaux libres toutes proches du détroit de Davis, mais pas en général au niveau que nous avons observé. Entre 1950 et 1992, on n’a remarqué que deux fois d’autres épisodes pluvieux similaires aux stations météorologiques côtières. À la fin mars, on a trouvé des toits de tanières de mise bas de phoques annelés (*Phoca hispida*) affaissés et d’autres effondrés, probablement en raison de la température qui était restée juste au-dessous du point de congélation pendant quatre jours et de la chaleur dégagée par les phoques à l’intérieur des tanières. Après la pluie en avril, on a trouvé des tanières subnivales dont le toit avait fondu, et plusieurs amoncellements de neige qui abritaient auparavant des tanières avaient été complètement emportés. Les phoques nouveau-nés gisaient sur la glace vive, sujets au stress lié à la thermorégulation et exposés à une prédation beaucoup plus grande de la part des ours polaires (*Ursus maritimus*) et des renards arctiques (*Alopex lagopus*). Si, comme on le prédit, le climat continue de se réchauffer dans l’Arctique, la pluie sera vraisemblablement plus généralisée au début du printemps. Si c’est le cas, le retrait prématuré de la protection fournie par les abris subnivaux pourrait exposer les petits phoques à de hauts niveaux de prédation, affectant ainsi de façon négative les populations de phoques annelés, et donc celles des ours polaires qui en dépendent pour se nourrir.

Mots clés: phoque annelé, *Phoca hispida,* prédation, tanières de mise bas, changement climatique, ours polaire, *Ursus maritimus*

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INTRODUCTION

The circumpolar ringed seal (*Phoca hispida*) is the smallest of the Arctic seals and the main prey species of the polar bear (*Ursus maritimus*). A primary adaptation of the ringed seal for survival in the landfast ice, where seals are highly vulnerable to predation by terrestrial carnivores, is its small body size. This allows the seals to dig subnivean

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lairs in snowdrifts over their breathing holes and remain hidden when they haul out to rest in cold weather and to give birth to altricial pups in spring (McLaren, 1958; Smith and Stirling, 1975; Stirling, 1977; Smith et al., 1991). The lanugo with which the pups are born, once dry, would probably provide adequate insulation for the pup to survive birth on exposed sea ice if there were no predators (Smith et al., 1991). However, because of the constant threat of predators, female ringed seals maintain access to a complex of subnivean haul-out lairs and forcibly take their pups underwater to escape predators until the young can move independently to an alternative lair. When the lanugo of the pup is wet, the insulation of the subnivean birth lair is critical to its survival during cold weather (Taugbøl, 1984). In this paper, we describe how periods of warm weather, aggravated by a heavy rain event, caused slumping and collapse of subnivean lairs, washed away snowdrifts containing subnivean birth lairs, and increased the exposure of young ringed seal pups on the sea ice, where they were vulnerable to high levels of predation. We also discuss the potential significance of these observations in the context of climatic warming.

METHODS

Field Methods

In late March and most of April 1979, we were conducting ecological research on ringed seals and polar bears in the large bays along the end of the Hall Peninsula on southeastern Baffin Island, Nunavut (Fig. 1), using previously described methods (Smith et al., 1979; Smith and Hammill, 1980, 1981; Stirling et al., 1980). To document the distribution and density of ringed seals' subnivean haul-out and birth lairs, we traveled by snow machine and used a trained dog to locate lairs beneath snowdrifts by smell (Smith and Stirling, 1975). Predation on seals by polar bears and other carnivores was documented both during our travel on the ice in search of subnivean lairs and from a helicopter while searching for polar bears (Smith, 1976, 1980; Stirling and Archibald, 1977; Hammill and Smith, 1991).

Weather Data

From 17 March to 24 April, we used a standard maximum-minimum thermometer to record temperatures on days when we were at the Winton Bay field camp. Snow or rain were documented but not measured. When we were traveling away from the camp, only descriptive written records of weather were kept.

Systematic meteorological records are available from four stations on or near the coast of southeast Baffin Island adjacent to our study area, albeit for varying numbers of years. These sites, listed in order of their increasing distance from the Winton Bay field camp, are Brevoort Island (1960–75; 1989–92), Resolution Island (1950–61), Iqaluit (1950–99), and Cape Dyer (1960–90) (Environment Canada, unpubl. data). Resolution Island and Cape Dyer are approximately 200 km SW and 350 km NE, respectively, of Brevoort Island (Fig. 1). From this database, we extracted mean minimum and maximum temperatures for the months of March and April, as well as days on which there were both trace (defined by Environment Canada as less than 2 mm) and measurable amounts of rain, to compare with our observations from Winton Bay.

We were particularly interested in the frequency of occurrence of periods of several days with unseasonably warm weather, as well as of rain, because of their possible negative effects on the stability of ringed seal birth lairs when pups are young and not yet entering the water voluntarily. We thought that single days of above-freezing weather, or rain, were less likely to have a significant effect than several continuous days of such conditions. Thus, we defined a "warming event" as a period of three or more consecutive days on which the maximum temperature reached 0˚C or greater, with no rain recorded. A "rain event" was defined as a period of three or more consecutive days during which rain was recorded, with measurable precipitation that exceeded trace amounts on at least one day.

RESULTS

Weather Conditions during the Study

We measured maximum and minimum temperatures and kept records of precipitation at the Winton Bay field camp from 17 March to 24 April 1979 (Table 1). For most of the time before 8 April, temperatures remained below freezing, although there was a period of about four days, beginning on 21 March, when the maximum temperatures were near freezing and reached +3˚C on one day (22 March). Beginning on 9 April and continuing for almost a week, the maximum temperature reached or exceeded freezing during the day (Table 1). Rain fell at the field camp all day on 9 April, and continued until midday on 10 April and in light sporadic periods through 11 April. From 12 April through 24 April, when we ended the surveys in the study area, we experienced clear days free of precipitation, with maximum temperatures above or only slightly below freezing (Table 1).

Previous Temperature and Rain Records from Southeastern Baffin Island

Although data were not collected from all the southeastern Baffin Island weather stations over the same years, collectively, the records we accessed spanned 50 winters (1950–99). During that time, no warming or rain events during March were recorded from any of the three adjacent coastal weather stations (Brevoort Island, Resolution

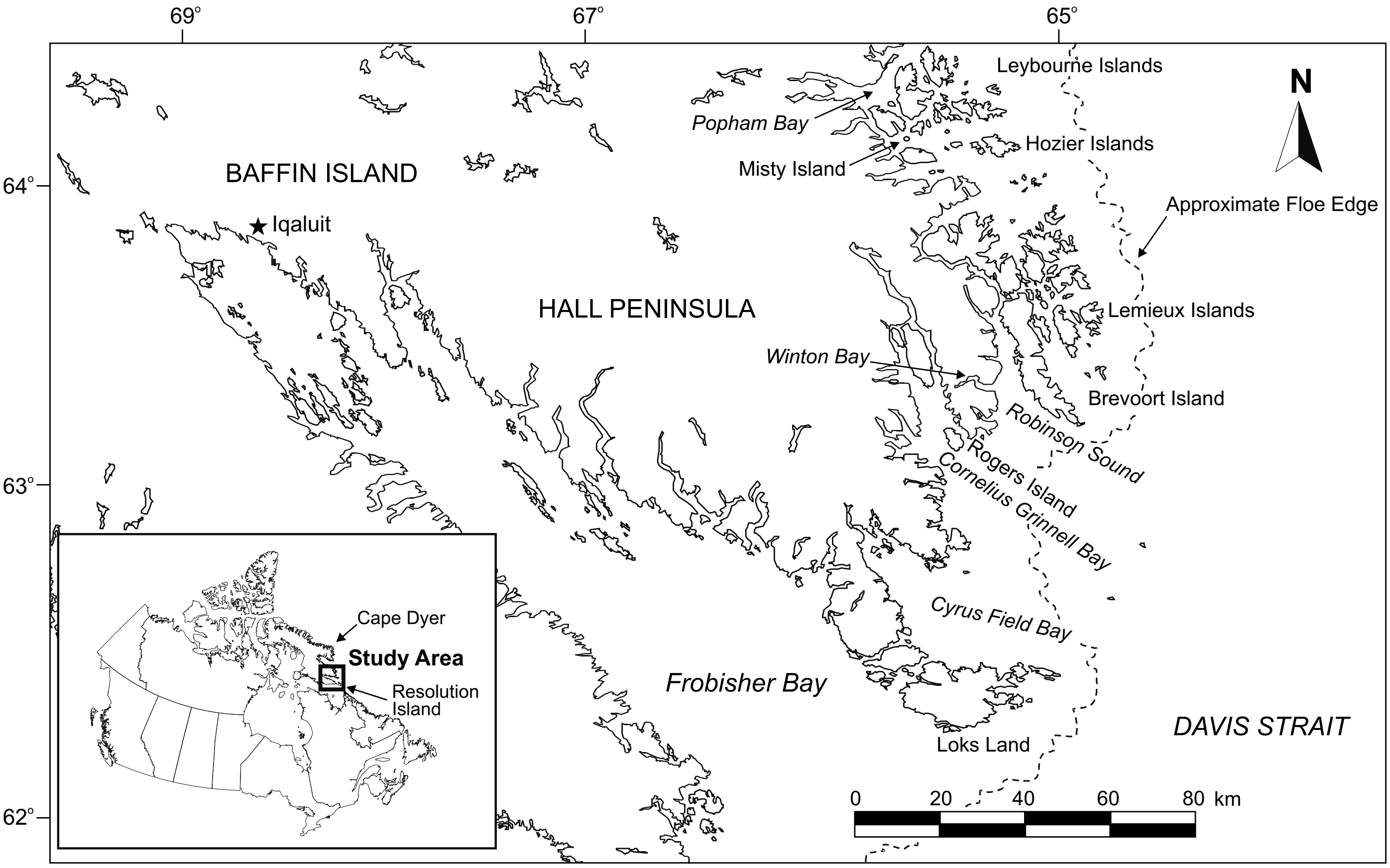

FIG. 1. Map of the study area at the end of the Hall Peninsula on southeastern Baffin Island. Cape Dyer lies outside the map area to the north, and Resolution Island lies outside the map area to the south.

Island, and Cape Dyer) or from Iqaluit (at the head of Frobisher Bay).

Table 2 summarizes mean temperatures (minimum and maximum) and warming and rain events in April in the study area and at nearby coastal weather stations. From these data it is clear that, overall, April is normally a cold month, with temperatures well below freezing. The sample sizes for April are huge (Environment Canada, unpubl. data) compared to our measurements from only 19 days at Winton Bay, precluding a meaningful statistical comparison. However, the mean minimum and maximum temperatures for April (minimum = -16.7˚C ± 2.3 (SD) and maximum = -10.7˚C ± 2.5 respectively) at Brevoort Island, only a few kilometres from our field camp, as well as at the other stations, were considerably cooler than those that we recorded in 1979 at Winton Bay (Table 2).

Of a total 13 different warming events recorded between 1950 and 1999 from all four other weather stations in the region, only three occurred in the first half of April, when the protective value of subnivean lairs is most important for ringed seal pups. All other warming events began on or after 21 April. The warming event in late April 1953 was recorded at both Resolution Island and Iqaluit (Table 2).

Between 1950 and 1999, a total of three rain events were recorded in April. The rain event in 1979 was widespread, and it was documented on the same days at both Cape Dyer and our Winton Bay field camp. Although measurable amounts of rain did not fall farther inland at Iqaluit at the same time, traces of rain were recorded there on 9 and 11 April 1979. Rain events in April were also documented at Resolution Island in 1958 and at Brevoort Island in 1968.

Birth Lair Surveys by Snow Machine

When surveying with the trained dog on the sea ice, we attempted to search all types of ice in the study area. Areas of flat, stable ice found in fiords and small bays had the least snow cover over ringed seal birth lairs, ranging from 60 to 90 cm (n = 6). Snow cover over birth lairs in hummocky ice in large bays such as Cyrus Field Bay was deeper, ranging from 65 to 130 cm, because of increased accumulation behind the pushed-up ice (n = 35). Small sample sizes of lairs in the bays precluded statistical comparison. The pressure ice along the coastal tidal zone was roughest because of the high tidal amplitude and hence caused deep snow accumulation over birth lairs, ranging from 60 to 150 cm (n = 9). However, it was difficult to quantify measurements of lairs in the tidal zone because they were so far beneath the snow surface and often under ice slabs, where the dog indicated she could

TABLE 1. Daily records of minimum temperatures, maximum temperatures, and precipitation at the Winton Bay field camp. Blanks indicate personnel were away from camp. “Warm” or “melting snow” indicates temperatures during field travel that were near or above freezing but were not measured.

March 1979				April 1979			
Date	Min (˚C)	Max (˚C)	Precipitation	Date	Min (˚C)	Max (˚C)	Precipitation
17		-10		1	-	-	melting snow
18	-23	-6		2	-	-	
19	-21	-6		3	-26	-23	
20	-15	-5	snow	4	-17	-12	snow
21	-17	-3		5	-13	-2	
22	-5	+3		6	-10	-6	snow
23	-3	-1		7	-10	-3	
24	-22	-1		8	-18	-2	snow
25	-26	-12		9	-7	+1	rain, snow
26	-26	-12		10	0	+4	rain
27	-26	-13		11	-3	0	rain, snow
28	-15	-8	snow	12	-1	+9	
29	-18	-4	snow	13	-1	+4	
30	-	-	snow	14	-4	+9	
31	-	-	warm	15	-	-	
				16	-	-	
				17	-	-	
				18	-16	+6	
				19	-	0	
				20	-14	-1	
				21	-14	-2	snow
				22	-4	-1	
				23	-9	0	
				24	-19	-3	

smell something, but we could not dig. Thus, although the coastal pressure zone was obviously important to seals, our evaluation of its relative importance was inadequate, and it is likely underrepresented in our data.

Table 3 summarizes the number and condition (intact vs. melted) of ringed seal haul-out lairs and birth lairs (Smith and Stirling, 1975) located between 19 March and 20 April in 1979. Even before the end of March, we noted deeper and softer snow conditions in the area than we had previously experienced in the higher latitudes of either Amundsen Gulf or Barrow Strait (Smith and Stirling, 1975; Hammill and Smith, 1989, 1991). The depths of drifts over haul-out and birth lairs in the study area were more than double those recorded in Amundsen Gulf (Smith and Stirling, 1975). As early as 21 March, we noted slumped roofs over a few birth lairs. On one occasion, our survey dog broke through a slumped, thin-roofed, birth lair and caught a newborn pup inside. Before the rain event of 9–11 April, there were two other periods during late March and early April when daily maximum temperatures were at or close to freezing (Table 1). Of 15 seal lairs found from 19 to 31 March, six had collapsed roofs. Roofs had also melted open in 12 of 30 seal lairs found during 1 – 8 April, after several days of “warm” (but unmeasured) temperatures at the end of March (Table 1). Seal pups had been killed at one-third of the lairs depredated by polar bears (15/45) (Hammill and Smith, 1991).

Between 12 and 24 April (after the rain event of 9 – 11 April), we found that the roofs of 28 of 105 lairs located during the dog searches had collapsed (Table 3). The majority of the lairs found during this period were in the deeper snowdrifts of the Cyrus Field Bay area. However, in the shallow drifts north of this area, we saw an additional (but uncounted) number of melted-out lairs that were not included in the total above because they had not first been located during the dog searches. These melted-out lairs were sighted from a distance because the adult and newborn seals were hauled out on the ice beside them. Thus, the numbers for melted haul-out and birth lairs are underestimated for this time period.

Birth Lairs and Predation Attempts Recorded during Helicopter Surveys

On 12 April, we flew near the floe edge across the southern ends of Robinson Sound and Cornelius Grinnell Bay (Fig. 1), where one bear had captured a seal pup by breaking into a birth lair, but an additional four adult female seals were seen lying with their pups by breathing holes on bare ice.

On 13 April, we searched polar bear habitat from Brevoort Island north through the Leybourne and Hozier Islands to Popham Bay (Fig. 1). We noted one area just south of Misty Island where the snow cover over a large (but uncounted) number of birth lairs and breathing holes was washed away or had collapsed because of the rain.

On 14 April, we surveyed the eastern coast of Cyrus Field Bay (Fig. 1). Through most of the area, we found the rain had been heavy enough to completely wash away many of the snowdrifts, leaving the ice covered with only a thin, flat, frozen layer of what had previously been a mixture of water and slush. Either the roofs of ringed seal

TABLE 2. Mean April temperatures, warming events, and rain events at the Winton Bay field camp and from weather stations in coastal areas of southeastern Baffin Island (data from Environment Canada). Weather stations are listed in order, from the closest to Winton Bay to the most distant from it.

Weather Station	Years of recording weather data	Mean minimum April temperatures (˚C ± SD)	Mean maximum April temperatures (˚C ± SD)	Dates of April warming events without rain[1]	Dates of April rain events[2]	Rain (in mm) on consecutive days
Winton Bay Camp	1979	-10.3 ± 7.3	-1.2 ± 7.3	12–14 April 1979	9–11 April 1979	not measured
Brevoort Island	1960–75 1989–92	-16.7 ± 2.3	-10.7 ± 2.5	27–29 April 1979	1– 4 April 1968	28, T, 0, 5
Resolution Island	1950–61	-11.3 ± 2.8	-6.5 ± 2.6	1– 8 April 1953 21–27 April 1953 27–30 April 1958	6– 8 April 1958	T, 15, 13
Iqaluit	1950–99	-24.2 ± 3.1	-10.0 ± 2.6	23–30 April 1953 22–26 April 1971 25–30 April 1973 22–27 April 1981 12–14 April 1986 21–26 April 1989 25–30 April 1994 24–30 April 1995	9–11 April 1979	T, 0, T
Cape Dyer	1960–90	-20.7 ± 3.0	-10.8 ± 2.2	26–30 April 1975	9–11 April 1979	28, T, 5

[1] A warming event is defined as a period of three or more consecutive days on which the maximum temperature reached 0˚C or higher, but no rain was recorded.

[2] A rain event is defined as a period of three or more consecutive days over which rain was recorded, with measurable precipitation exceeding 0.2 mm—the trace amount (T) defined by Environment Canada—on at least one day.

birth lairs inside the former drifts had collapsed or the drifts had been completely washed away (Fig. 2), with the result that several pups and their mothers were lying exposed on the open ice. The females fled into the water when approached, but their whitecoat pups were not yet capable of independent movement and so were unable to follow (Fig. 3). In some cases, the females came back to the breathing hole and tried to reach their pups in order to drag them into the water to escape.

On 15 and 16 April, we searched between Brevoort Island, the Hozier Islands, and Popham Bay again, but on a different route from that taken on 13 April. Bare ice and collapsed birth lairs were noted in one area of a few square kilometres to the east of Brevoort Island and a similar-sized area near the Hozier Islands. One seal pup had been killed on the bare ice near its breathing hole at each of these areas.

Between 8 and 16 April, we found ringed seal pups that had been killed at 23.4% (18/77) of the birth lairs dug into by polar bears along the SE coast of the Hall Peninsula, in areas where the lairs had not collapsed because of rain. Similarly, between 17 and 27 April, we found pups that had been killed at 28% (14/50) of the birth lairs broken into by bears along the SE coast of the Cumberland Peninsula to the north, where there were no collapsed birth lairs.

DISCUSSION

April Temperatures, Warming Events, and Rain Events

Even though the different sizes of samples used to estimate mean minimum and maximum April air temperatures precluded a meaningful statistical comparison, the April temperatures we recorded at Winton Bay in 1979 were warmer than normal for coastal areas of southeastern Baffin Island between 1950 and 1999 (Table 2). The large standard deviations in our data from 1979 are also indicative of the wide variation we recorded in daily temperatures, both minimum (from -26˚C to 0˚C) and maximum (from -23˚C to +9˚C). Our data included one of only three warming events recorded in the first half of April over a 50-year period (Table 2), which also confirmed that the temperatures we recorded between 9 and 16 April 1979 at the Winton Bay field camp were warmer than would normally be expected.

Although there were no periods in the historical weather data for Brevoort Island (the closest weather station to our ground survey area) that qualified as a warming event during March, there were 17 days in the periods 1960–75 and 1989–90 when the maximum temperature was warmer than -5˚C, occasionally for two or more consecutive days. Similarly, for four days between 21 and 24 March 1979, we recorded temperatures ranging between -3˚C and +3˚C (Table 1).

Only three April rain events were recorded at coastal sites on southeastern Baffin Island between 1950 and 1990, on Resolution Island (1958), on Brevoort Island (1968), and from Winton Bay to Cape Dyer (1979). Even single-day reports of trace amounts of rain in April are uncommon. At Cape Dyer, for example, during the 930 days in April from 1960 to 1990, trace amounts of rain (other than during the rain event of 1979) were recorded only 15 times (Environment Canada, unpubl. data).

Although warming and rain events as we have defined them for this paper are unusual, it is clear that temperatures

TABLE 3. Number and condition of ringed seal haul-out and birth lairs (Smith and Stirling, 1975) found on dog searches during three periods in March–April 1979.

Date	Number of Intact Haul-out Lairs (%)	Number of Melted Haul-out Lairs (%)	Number of Intact Birth Lairs (%)	Number of Melted Birth Lairs (%)	Total (%)
19–31 March	7 (47)	5 (33)	2 (13)	1 (7)	15 (100)
1–8 April	7 (23)	7 (23)	8 (27)	8 (27)	30 (100)
11–20 April	17 (16.5)	8 (8)	57 (56)	20 (19.5)	102 (100)

in the vicinity of southeastern Baffin Island show a pattern of significant fluctuations (including periodic warmer spells, even for very short periods) that does not occur to the same degree at the same time at higher latitudes. However, the ends of the Hall and Cumberland Peninsulas on southeastern Baffin Island are close to the open water and pack ice of Davis Strait (Fig. 1). Thus, the maritime influence of weather systems from the south or southeast brings periodic warming and moisture to the coast of southeastern Baffin Island earlier in the spring than would be possible in the consolidated fast ice of areas such as the inter-island channels of the Canadian Arctic Archipelago or Amundsen Gulf.

Collapse of Haul-Out and Birth Lairs in Late March and April, 1979

The roofs of 40% (6/15) of the haul-out and birth lairs found by the end of March and 50% (15/30) of those located in the first week of April had already melted and collapsed (Table 3), something that we have never seen at higher latitudes. After the rain event of 9–11 April, 28% of the lairs in the deeper drifts of Cyrus Field Bay had also collapsed (Table 3), but this percentage underestimates the real value because an unknown number of washed-out lairs that were visible to us while traveling, but not first located by the dog, were not recorded. Kelly and Quakenbush (1990) reported temperatures in occupied ringed seal haul-out lairs ranging between 3.5˚ and 9˚C and durations of haul-out bouts by the occupying seals that ranged between about 5 and 11 hours. The Inuit of the area told us they commonly looked for slumped roofs in April as a cue for detecting birth lairs. Similarly, Kumlien (1879) noted young seals born on the open ice near our study area that were killed by predators, though beyond noting some warmer days, he gave no more specific information. However, the combined observations of both the local Inuit and Kumlien confirm that periodic warming, slumped roofs of lairs, and occasional exposure of young pups on the sea ice because of complete roof melting are recurrent phenomena in southeastern Baffin Island in late March or early April.

Between October and the end of March, an average of over 2 m of snow falls in the vicinity of our study area near Brevoort Island (Environment Canada, unpubl. data), but our qualitative observation was that the drifts were less consolidated by wind than those in Amundsen Gulf or Barrow Strait, where we had previously worked. In a few instances, the snow over a birth lair was soft enough, even when deep, that one of us fell through into the lair itself. In addition, it was our subjective observation that the successive spells of relatively mild air temperatures, combined with the heat emanating from hauled-out seals, caused the snow over the lair to crystallize. We suggest that the crystallized snow is weaker and may also have contributed to the slumping of the roofs of ringed seal haul-out and birth lairs that we observed (and local Inuit noted) in late March and April on Hall Peninsula. We did not observe such slumping or collapse in our earlier studies at higher latitudes, where the March and April temperatures are colder (e.g., Smith and Stirling, 1975; Hammill and Smith, 1989). However, in a study of Inuit methods of hunting ringed seals near Arctic Bay, Nunavut, between 7 April and 3 June, Furgal et al. (2002) reported that hunters sometimes use a depression in a snowdrift to locate a birth lair, particularly later in the season as the ambient temperature increases. Regardless, in areas like southeastern Baffin Island, when short-term temperature increases become warming events followed or accompanied by rain events, as in 1979, widespread collapse of the roofs of ringed seal subnivean haul-out and birth lairs can occur, as well as the complete washing away of protective snowdrifts (e.g., Fig. 2).

Recording of a rain event at coastal locations about 400 km apart (Winton Bay and Cape Dyer), as well as trace amounts of rain well inland at Iqaluit on 9–11 April 1979 (Table 2), indicates that this particular storm covered a large area. However, either the amount of precipitation or its effect appeared to vary at different locations over the areas surveyed. At some locations, the snow covering the birth lairs was completely washed away (Fig. 2), while at others the effect varied from a slumping roof over a subnivean lair to nothing detectable. Using both the helicopter and snow machines, we surveyed most of the landfast ice area between the bays and the floe edge along the Hall Peninsula from Loks Land to Popham Bay, the Lemieux Islands, and the Hozier Islands (Fig. 1). From our observations, it appeared that the areas receiving enough rain to collapse or wash away birth lairs had a patchy distribution. The largest area with collapsed lairs that we

FIG. 2. A former subnivean ringed seal birth lair washed away by rain.

FIG. 3. A newborn ringed seal pup in white lanugo lying exposed on bare ice because its subnivean lair had been washed away by rain.

examined by snow machine was Cyrus Field Bay, while additional, smaller areas were located by helicopter near the north end of Rogers Island, at the southern end of Cornelius Grinnell Bay, to the east of Brevoort Island, south of Misty Island, and in the Hozier Islands (Fig. 1).

At Cape Dyer, an average of about 4.5 m of snow falls during the winter (Environment Canada, unpubl. data), so the absence of collapsed lairs following the rain event may simply mean that the snow cover was deep enough to absorb the moisture without being washed away. However, the snow covering the lairs was still sufficiently weak for one of us to fall through the roof of a few lairs when walking over them.

Thermoregulation

The peak of pupping by ringed seals along the coast of southeastern Baffin Island occurs in early April, though obviously some pups are born earlier or later (Smith, 1973). Thus, in general, the period when the newborn altricial pups benefit most from the thermal protection afforded by subnivean birth lairs is from late March to early April.

In areas where rain had washed away snowdrifts with lairs in them, the adult female ringed seals and their pups lay on the open ice (Fig. 3), exposed to the weather and in clear view of predators. Although dry pups in lanugo are probably able to maintain their body temperature in cold weather, it does not appear they can do so if wet (Taugbøl, 1984; Kelly, 2001). Ringed seal pups do not begin to enter the water on their own until they are several days old, although a female may forcibly move her pup from a lair that is being dug into by a polar bear to another lair in a complex. Prior to weaning at about 6–8 weeks of age, pups may spend up to 50% of their time in the water (Lydersen and Hammill, 1993). Thus, when temperatures fall below 0˚C, continued access to birth lairs for thermoregulation is probably critical to the survival of pups in most areas, at least until they have shed most of their lanugo.

Predation

The importance of the birth lair for protecting very young seals from predation, particularly by polar bears, is apparent from statistics on the number of times that bears successfully caught seals (as determined by blood or other remains on the snow) as a proportion of the number of times they broke into lairs in attempts to capture the occupants. For example, Stirling and Archibald (1977) reported that bears killed seals in 8.2% (56/676) of their attempts in the western Canadian Arctic and 6.4% (11/172) in the High Arctic. Smith (1980) reported a higher kill rate in the High Arctic of 19.1% (21/110) in lairs dug into by polar bears. Smith (1976) also reported a 26.1% (30/115) success rate in predation attempts on young ringed seal pups by arctic foxes (*Alopex lagopus*) in Prince Albert Sound and eastern Amundsen Gulf. From his snow machine surveys in our study area at the southeastern end of the Hall Peninsula (Fig. 1), Smith (1980) reported a success rate of 33.3% (15/45) for bear attacks on seal lairs, while during our helicopter surveys, we found success rates of 23.4% (18/77) along the Hall Peninsula and 28% (14/50) along the Cumberland Peninsula. Despite the variability in these success rates, it is clear that the presence of the snow around and over birth and haul-out lairs provides significant protection from predation for ringed seals, especially young pups.

The generally higher success rates of predation attempts in our study area and along the Cumberland Peninsula (compared to the Western or High Arctic), may reflect softer snow in the drifts, as well as slumping and weakening of roofs due to periodic external temperature increases and warming from seals in their lairs. The unusually warm and wet weather in late March and April 1979 (Table 2) probably increased the vulnerability of pups by contributing to the deterioration of birth lairs.

Clearly, in areas where the protection of the birth lair is washed away, the young seals are highly vulnerable to predators. Even though we surveyed several areas only a day or two after the rain, we saw several cases of predation of pups, and we suspect that most of the pups in these areas were eventually killed by polar bears (Stirling and Archibald, 1977; Smith, 1980), arctic foxes (Smith, 1976), or possibly gulls (Lydersen and Smith, 1989). We also observed ravens (*Corvus corvax*) feeding on the carcasses of ringed seal pups, but we do not know if they killed the pups or were only scavenging.

CONCLUSIONS

In 1979, when we recorded the rain event described above, we simply thought it was interesting as a meteorological anomaly and speculated that it might also reflect the influence of the large maritime area of Davis Strait. Even if rain caused increased mortality of ringed seal pups in a particular year, it would probably not be significant over the longer term to such a long-lived species. Thus, we did not quantify the number and extent of the areas most affected to the degree that—it is now clear—would have been useful. Since then, reflecting on this event within a larger meteorological framework has suggested that the observation may be relevant in the context of global climatic warming.

Several recent studies have demonstrated the progressive warming of the Arctic climate with consequent effects on the time of sea-ice breakup and melting of both annual and multiyear ice (e.g., Skinner et al., 1998; Vinnikov et al., 1999; Comiso, 2002). Similarly, Kelly (2001) speculated that progressive warming of the weather in spring will cause birth lairs to melt earlier, exposing pups at increasingly early ages to predation and freeze-thaw cycles similar to those we recorded in the periods before and after the rain event. We suggest that if the climate continues to warm, an additional consequence will be increased rainfall earlier in the spring, which will result in more frequent and widespread collapses of subnivean birth lairs, such as we observed on southeastern Baffin Island in 1979. Should early season rain become regular and widespread at some future time, we predict that mortality of ringed seal pups will increase, especially in more southerly parts of their range, and that local populations may be significantly reduced. As ringed seals are the primary prey species of polar bears throughout much of their range, a significant decline in ringed seal numbers, especially in the production of young, is capable of producing negative effects on the reproduction and survival of polar bears (e.g., Stirling, 2002).

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