STATUS of the RINGED SEAL

in

THESIGER BAY, N.W.T., 1987-1989

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Kingsley, M. C. S. and T. Byers. 1990. Status of the ringed seal in Thesiger Bay, N.W.T., 1987-1989. Report prepared for the Fisheries Joint Management Committee. Unpublished. v + 21 pp.

One hundred and ninety-seven ringed seals, Phoca hispida, (84 males, 112 females, 1 unknown sex) were collected from Thesiger Bay off the south coast of Banks Island, N.W.T. from 4 July to 6 September 1989. One hundred and twenty-two had been collected in 1988 and 75 in 1987. Forty-six percent of the 1989 sample were pups, a substantial increase over 1987 when less than 3% were pups.

Measurements, aging samples, and organ and tissue samples were taken. Condition values were significantly higher in 1989 seals than in 1987. No pathological conditions were found in the seals necropsied, although two 6-year-olds (one male and one female) caught in the first half of July had infestations of liver trematodes. Comparison of 1989 with 1987 and 1988 data on age structure and reproductive status indicates that there was a substantial failure of recruitment from 1984 to 1987, but that it was temporary and that reproductive activity recommenced in 1988 and returned to normal levels in 1989. In 1989, 96.4% of mature females had ovulated and had been pregnant at least once (95.4% and 72.7% respectively in 1988; 60% and 52% in 1987), and the number of pups taken in the harvest was large. At the same time as a resumption of reproductive activity in younger (5- through 7-year-old) seals, there was a shift in the adult age structure: 1981 through 1984 year classes became much more prominent, replacing the previously dominant 1978 through 1980 year-classes.

Organochlorine residues in seal blubber were slightly lower in 1988 than 1987, except dieldrin which was found in greater concentrations in 1988. In comparison with other Arctic and northern European populations our seals had low to normal organochlorine loads. The lack of pups in 1987 was not due to predation on newborns, as female adults examined had not reproduced. It unlikely that contamination would have been responsible for the interruption of reproduction, as reproduction has recovered without any significant change in contaminant levels. High concentrations of mercury and selenium in liver are similar to levels recorded in Amundsen Gulf ringed seals in 1972 and 1978 (Smith and Armstrong 1978).

It appears that reproduction in ringed seals is sporadically interrupted by factors not yet clearly defined that include ice conditions, food availability, and population density. The drop in production in the years 1985through 1987 is a repetition of a similar documented case in the early 1970s.

INTRODUCTION

The ringed seal (Phoca hispida) is a small phocid, ubiquitous in ice-covered Arctic waters. It feeds generally on nektonic crustaceans and small fishes, and is an important link in Arctic seas between primary production and the top consumers, polar bear (Ursus maritimus) and man (Stirling 1977; Stirling and McEwan 1975; Stirling and Archibald 1977; Smith 1980). It is a large marine vertebrate distributed widely and evenly all over the Arctic; and it is actively hunted almost year-round by northern people who are, therefore, apt to notice changes in populations and are able to provide specimens for biological examination. It may therefore be a useful indicator of ecosystem health.

In spite of the European embargo on pelts of young seals, which seriously affected the market for all sealskins, and the general shift away from a subsistence to a cash economy, ringed seals still play an important part in the economy of Sachs Harbour. The livers and tender meat of the young of the year are esteemed, and their skins are used for handicrafts and clothing. Although snowmobiles are preferred for winter transportation, dog-teams are legally required for guides for spring polar bear sport hunts which bring guiding fees to Sachs Harbour every year, and seal meat and blubber are important as dog food.

From 1984 to 1987 Sachs Harbour seal hunters noticed a sharp decline in the presence of ringed seal pups in the spring and summer harvest, and feared a permanent drop in seal productivity. The Sachs Harbour Hunters and Trappers Committee presented this concern to the Fisheries Joint Management Committee, set up under the Western Arctic Land Claims Agreement to advise the Minister of Fisheries and Oceans on management concerns and research priorities. In 1987 the F.J.M.C. asked for, and accepted, a proposal from the Department of Fisheries and Oceans to investigate the condition of the population and to determine whether any abnormal factors existed to explain the recent scarcity of pups in the open water harvest by the Sachs Harbour Inuvialuit.

Three additions were made in 1988 to the scope of the project: analysis of heavy metal levels, as baseline data to contribute to environmental impact assessment of possible ocean dumping of scrap; an aerial survey of northern Amundsen Gulf and the west coast of Banks Island; and an extension of the population structure study to the seals taken at Holman Island, N.W.T. This report presents the findings of the three years of the study.

Previous Studies:

The biology of the ringed seal in the western Canadian Arctic has been studied intensively for two decades (Smith 1973, 1976, 1987; Smith and Stirling 1975, 1978; Stirling 1973; Stirling et al. 1977, 1982; Kingsley 1984, 1986; Kingsley and Lunn 1983; Kingsley et al. 1982). These years of research have suggested that annual reproductive success and recruitment may fluctuate significantly from year to year. Ice conditions, female physical condition and predation by Arctic foxes (Alopex lagopus) may be limiting factors (Stirling et al. 1977, 1982; Smith and Stirling 1978; Smith 1987).

There is little baseline data for the waters off southwest Banks Island. Cumulative results of aerial surveys from 1974 to 1979 (Stirling et al. 1982) show that the area from Cape Parry north to and including Thesiger Bay had the highest concentration of ringed seals in the eastern Beaufort Sea. In the Beaufort Sea, the areas north and east of Cape Dalhousie, south of Cape

Kellet, and west of Nelson Head had the highest densities of ringed seals (mean rank of this area from 1974 through 1979 was 1.67 of 4). Mean densities in Thesiger Bay, east of a north-south line drawn through Cape Kellet and north of an east-west line through Nelson Head, ranged from 0.161 to 0.6 /sq. km (Stirling 1982, aerial survey detailed data). Northern Amundsen Gulf, east of Nelson Head and north of 70° 30′ had high densities of ringed seals, up to 3 /sq. km., in four years of aerial survey from 1981 through 1984 (Kingsley 1986).

Acknowledgements

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METHODS

A biological collection programme was put in place to examine, from samples taken from the normal hunting activity in the community of Sachs Harbour, the physical condition of the seals, the age and sex structure of the population, the reproductive history of females, and contaminant levels in body tissues. All seals were collected by Inuk hunters of Sachs Harbour. Seal hunting is a local activity, for which hunters seldom travel far, and the Sachs Harbour harvest is for the most part taken in Thesiger Bay off the southwest coast of Banks Island, between the Beaufort Sea to the west and Amundsen Gulf to the south and east.

Field Sampling:

All seals brought into Sachs Harbour by the hunters were processed according to standard necropsy procedures for pinnipeds (Fay et al. 1979). For each seal the following were recorded:

1. Date, habitat and location of kill; whenever possible, approximate time and distance from shore; on ice, accompanying seals at holes or cracks;
2. Hair slip and general coat condition;
3. Ridge counts on fore-claws;
4. Total length and axillary girth to nearest half-centimetre;
5. Total body weight (this as well as sculp weight to nearest pound, later converted to kilograms);
6. Blubber thickness between sternum and skin to nearest mm;
7. Sculp weight (ears to hips);
8. Obvious injuries or pathological conditions;

From each animal the reproductive organs were removed and preserved in 10% formalin; stomach contents, and samples of blubber, muscle (from flank or back over ribcage), liver, and kidney were removed and frozen. The lower jaw skinned out and saved for later aging. In August 1989, the lungs and bronchi of 40 seals, (27 pups, 7 juveniles, 6 adults) were dissected and examined for nematodes.

Laboratory Analysis of Samples:

Seals were aged by counting annual layers in the dentine (Smith 1973). The jaws were boiled to loosen the teeth, and a canine was pulled out. Cross sections about 0.1 mm thick were sawn below the crown, fixed alcohol and glycerine, and examined under polarised transmitted light. Layers in the dentine were counted three to five times in blind replicate readings. The reader changed from year to year, but the same reader made all readings in a given year. In all age-based analyses the tooth age was used rather than the claw age, which is less reliable owing to wearing of the claw. Claw ages were 1 to 2 years less than tooth ages for sub-adults and 4 to 8 years less for adults.

Reproductive history of females was determined from the condition of the uterus. Multiparous females, that had borne more than one pup, were identified by both uterine horns being stretched or swollen; primiparous females, that had only given birth once, by stretching of only one horn.

Two indices of body condition, i.e. fatness, were calculated for each seal. The first was defined by:

$$C_1 = (\text{Girth} / \text{Total Length}) \times 100;$$

the second by:

$$C_2 = (\text{Total Weight} / \text{Total Length}) \times 100$$

(Smith 1987).

Emaciated seals, in obviously poor condition, were excluded from analyses of condition data whether obvious pathological conditions were found or not.

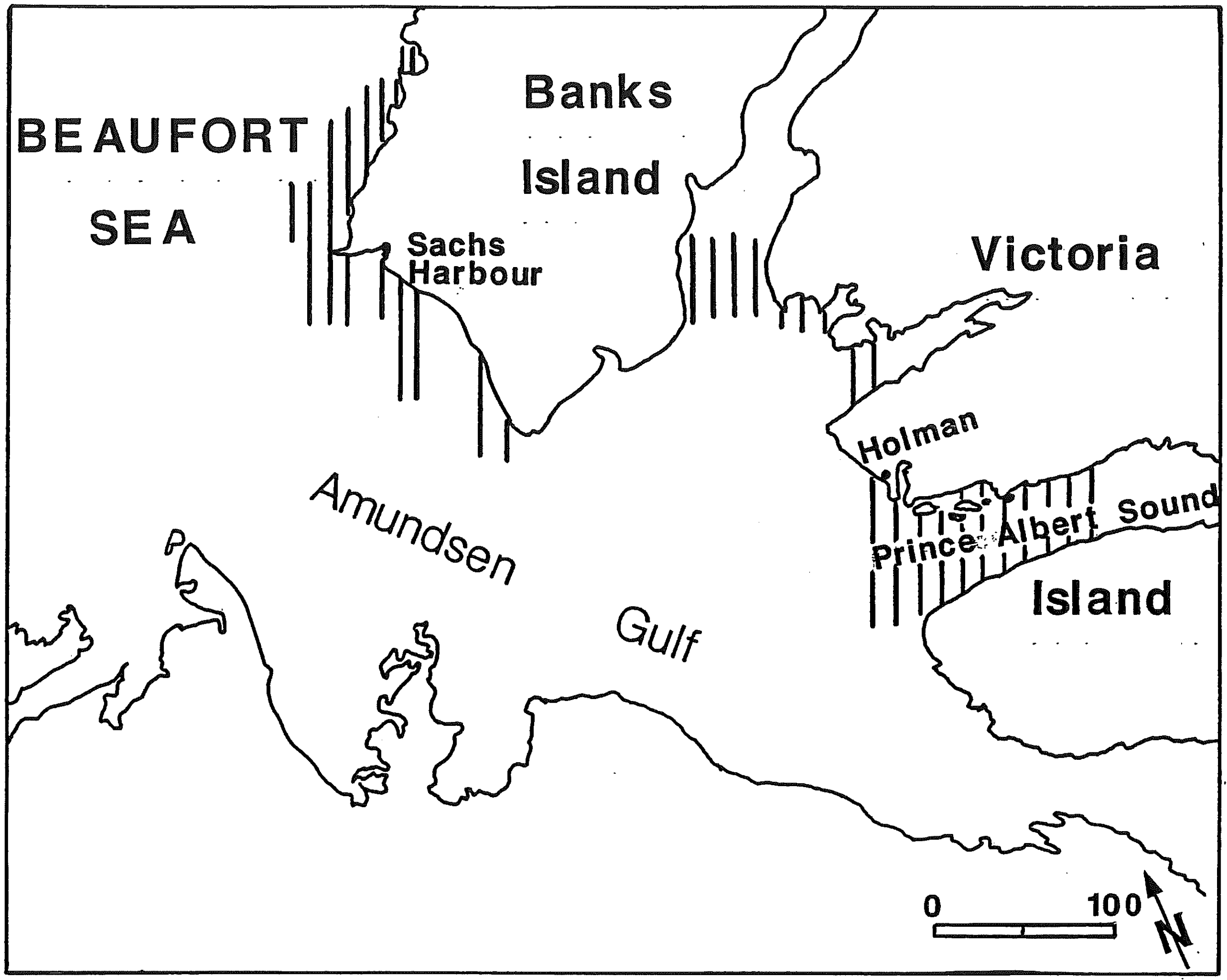

Fig. 1. Aerial survey area with transect lines flown, 1988.

Aerial Survey:

An aerial survey was conducted on June 9-11, 1988 to count ringed and bearded seals on the sea ice of the eastern Beaufort Sea and western Amundsen Gulf (Fig. 1). The survey was a strip transect design, and data was collected and analysed as in Kingsley (1986). The aircraft was a Britten-Norman BN2A-27 "Islander". A single survey strip of a quarter-mile on each side was delimited by marks on the windows.

RESULTS and DISCUSSION

Ice Chronology:

In 1987, Thesiger Bay was clear of all consolidated ice by July 9, there being only a 2/10 cover of floating pan ice. By July 30, Amundsen Gulf was relatively ice-free except for a wide belt of fast ice along the coast of Victoria Island and 2-6/10 ice cover at the mouth of Amundsen Gulf. By the first week of June in 1988, the west coast of Banks Island to about 70 - 100 km. offshore, all of Thesiger Bay, and Amundsen Gulf were clear of all ice save for a few large floes. Fast ice remained on the west coast of Banks Island until the third week of June, and in the large inlets of south-western Victoria Island until the third week of July. In 1989, break-up started in Amundsen Gulf about June 14, and by the first week of July all of Amundsen Gulf and most of Thesiger Bay were clear of pack ice. Ice in the bay cleared later and not as completely in 1989 than the 2 previous years, floating pack present within sight of Sachs Harbour all summer. Freeze-up, with 9/10 ice cover, commenced in 1989 during the third week of October and in the 2 previous years at the end of October.

Age and Sex Structure of Collections:

Collections made on fast ice near the mating season tend to be biased towards breeding adults, which exclude sub-adults from the prime breeding habitat, but open water collections are less biased in this way (Smith 1987), though they may be biased by other factors. In 1987, 86.7% of the Thesiger Bay ringed seal summer collection was from open water, 91.9% in 1988 and 97.0% in 1989.

The 1987 sample showed the year classes 0+ through 3+ (i.e. the 1984 through 1987 cohorts) accounting for only 5% of the total population (Fig. 2). Young of the year were more abundant in both 1988, at 28.4% of the sample, and in 1989 at 46.2%, but in the samples from both those years the 1985 through 1987 year-classes continued to be poorly represented. There is no good accumulation of baseline data for Thesiger Bay to indicate the long-term catch composition. Assuming that hunting habits in the community were similar in the three years, and that therefore the collections made were an approximate index of abundance, Fig. 2 shows that the 1985 through 1987 year-classes were weak in all three years, that the 1988 year-class was stronger (about 30 taken in both 1988 and 1989), but that the 1989 year-class was very strong (nearly 100 taken in 1989). This is consistent with the high reproductive rates and the lower mean age at first reproduction observed in 1989 (see below).

The year-class analysis of Fig. 2 also reveals a shift in the structure of the adult component of the population. In the 1987 collection, the adult age structure is dominated by classes from 1977 to 1983, but in the later collections, the 1977 through 1980 classes are less numerous and the non-pup age structure is dominated by classes from 1981 to 1984. The adult year-class structure was similar in the 1988 and 1989 collections, except for the tail of old seals in 1988, not found in 1989. The 1988 and 1989 adult age distributions differ at about the 1% level of significance, but in contrast, the 1987 collection differs from their pooled distribution at the 0.01% level or better (SAS PROC NPAR1WAY; SAS Institute 1963). I.e., coincident with a recovery to more normal levels of reproductive activity, there was also a shift in adult demography with an aged population being either displaced or heavily augmented with younger classes. Whether this change caused the recovery of reproductive activity or was caused by it because breeding

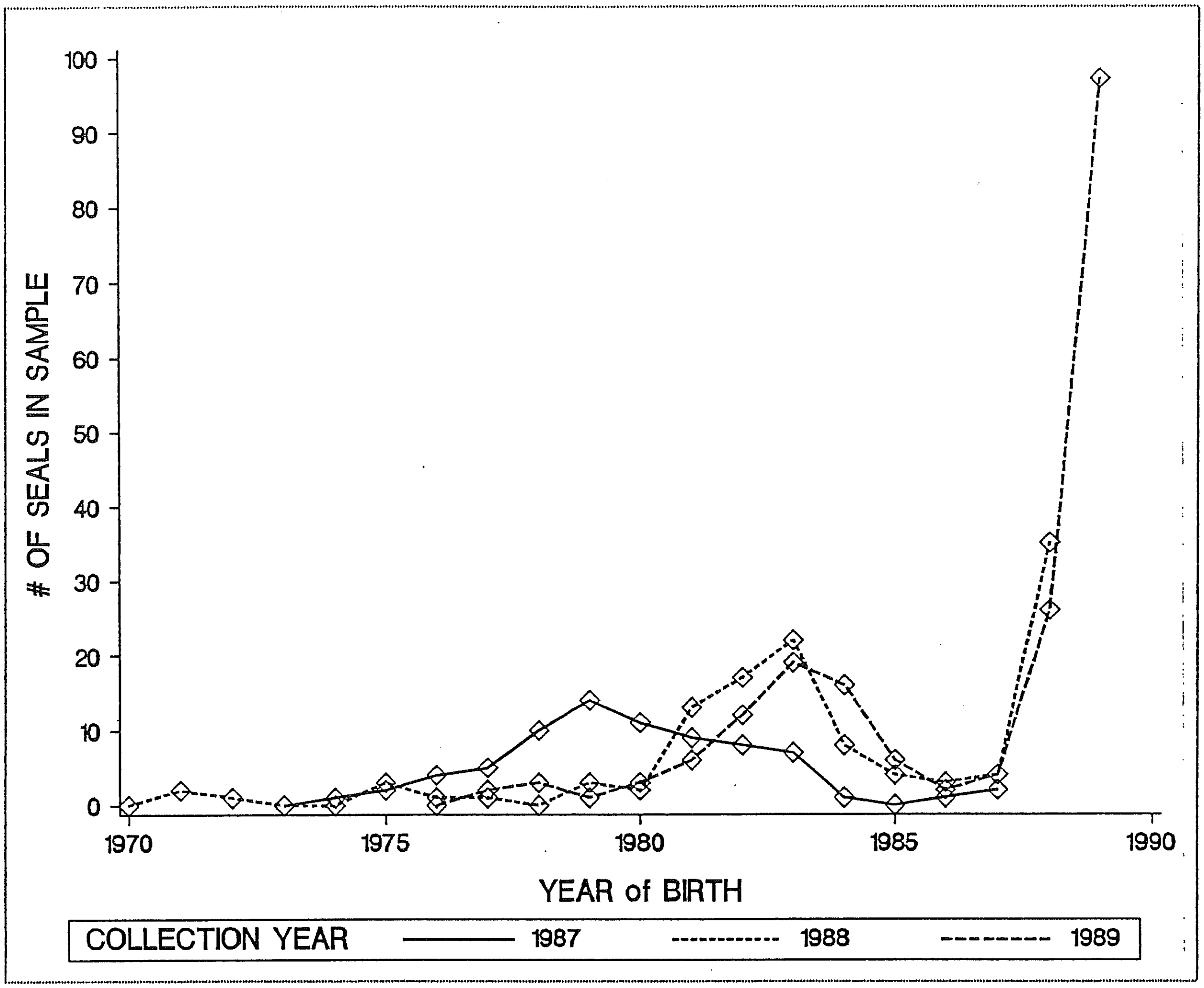

Fig. 2. Abundance of ringed seals by year class in collections at Sachs Harbour, N.W.T., 1987 through 1989.

activity affects distribution, it is impossible to say.

An aerial survey of Amundsen Gulf in 1984 showed a low population estimate for that area (Kingsley 1986), although the estimated population for Prince Albert Sound was higher than in 1981 through 1983; however, survey estimates in 1985, although not completely recovered, were closer to normal (Kingsley unpublished data).

The persistence of the gap in the age profile agreed with a similar observation for the 1973-1975 cohorts in Holman collections, which persisted for up to 4 years (Smith 1987 Table 23), and indicated either a reproductive failure spread over a wide area, or else little mixing of seal populations to replace the missing cohorts. Smith's samples from open-water hunts out of Holman and in Prince Albert Sound had between 14% and 42% young-of-the-year in good seal production years: 1971-72 and 1976-81. His collections were made in waters surrounded by annually dependable fast ice and good breeding habitat. The southwest coast of Banks Island is close to the Cape Bathurst polynya, which opens up by early summer in most years and may affect the dependability of the fast ice breeding habitat of Thesiger Bay.

We have at the moment no ready explanation for the low recruitment of 1984-87 year classes. Arctic foxes and polar bears are significant predators of ringed seal pups (Smith 1976, 1987; Stirling 1977; Burns and Kelly 1982; Lydersen and Gjertz 1986), and low snowfall, as in 1985, may increase predation on pups, or expose them to the elements (Smith and Hammill 1980). However, predation on pups is not a likely cause for the low recruitment, because there is evidence that female reproductive activity was also low. Physiological dysfunction due to high burdens of chlorinated hydrocarbons has been cited as causing reproductive failure in ringed seals, but there is no reason to suppose that burdens have varied, or could vary, in the short term as widely as the change in reproductive rate would imply. Other possible reasons are: reduced conception rates associated with poor condition; poor ice conditions in the breeding areas which may have rendered them unsuitable for pupping; or a sub-lethal epizootic affecting reproductive capacity.

Heavy ice cover in the Beaufort Sea in the winter of 1974/75, lingering through much of the following summer, was associated with a crash in ringed seal condition and pregnancy rates (Stirling et al. 1977), a drop in densities found in aerial survey, and reduced reproduction rates and condition indices for polar bears, which live on ringed seals (Kingsley 1979). In the summer of 1985, the Beaufort Sea cleared of ice slowly and late (Lawrence, pers. comm.), and multi-year ice was further south in the winter of 1985-1986 than in winter 84-85 or 86-87 (Stirling et al. 1988). Late break-up is often followed by an early freeze-up (Hammill 1987), so primary productivity may be reduced at both ends of the summer. The litter-produced rate of 6-year-old female bears, i.e. novice reproducers, in 1986 and 1987 was less than a quarter of the 1985 value, and the weights of cubs borne to females of all ages was also lower (Stirling et al. 1988). There has also been recent evidence from radio-tagging that polar bears of the Beaufort Sea population have made unusual movements into the Chukchi Sea (Stirling pers. comm.). These other indicators confirm the direct evidence from the Thesiger Bay seal data of low seal recruitment.

The sex ratio was close to unity for the 1987 and 1988 Thesiger Bay collections: female:male ratios for 1987, 1988 and 1988 pups were 36:39; 64:59 and 20:21 respectively. In 1989, however, the sex ratio favoured females, 112 to 84 (49 female and 41 male pups).

Reproductive Status:

Female ringed seals normally mature sexually between 6 and 8 years of age (Smith 1973, Table 8; 1987, Table 11). In the Thesiger Bay samples, the female fecundity profile differs between 1987, 1988, and 1989 (Fig. 4). Fecundities (ovulation rates) improved from 60% of females 6 or more years old in 1987 to 95.4% in 1988 and 96.4% in 1989. In 1987, 13 of 25 sexually mature females (52%) had previously borne pups, and 8% more (2/25), although they had not, had ovarian bodies (corpora) or developing follicles (i.e. only 60% had started reproductive life).

In 1988 and 1989 reproductive activity was higher. Of 22 females 6+ and older in 1988, 16 (72.7%) had previously borne pups (27 of 28 or 96.4% in 1989), and 5 more, which had not, had corpora in their ovaries for a total of 95.4% (all 1989 females with corpora had been pregnant before). In 1988 all five-year-olds, 3 of 4 four-year-olds and 1 of 3 three-year-olds had also ovulated, and one of 12 five-year-olds had borne more than one pup. In 1989 all three- and five-year-olds and 1 of 2 four-year-olds had ovulated ; 5 of 7 five-year-olds were parous.

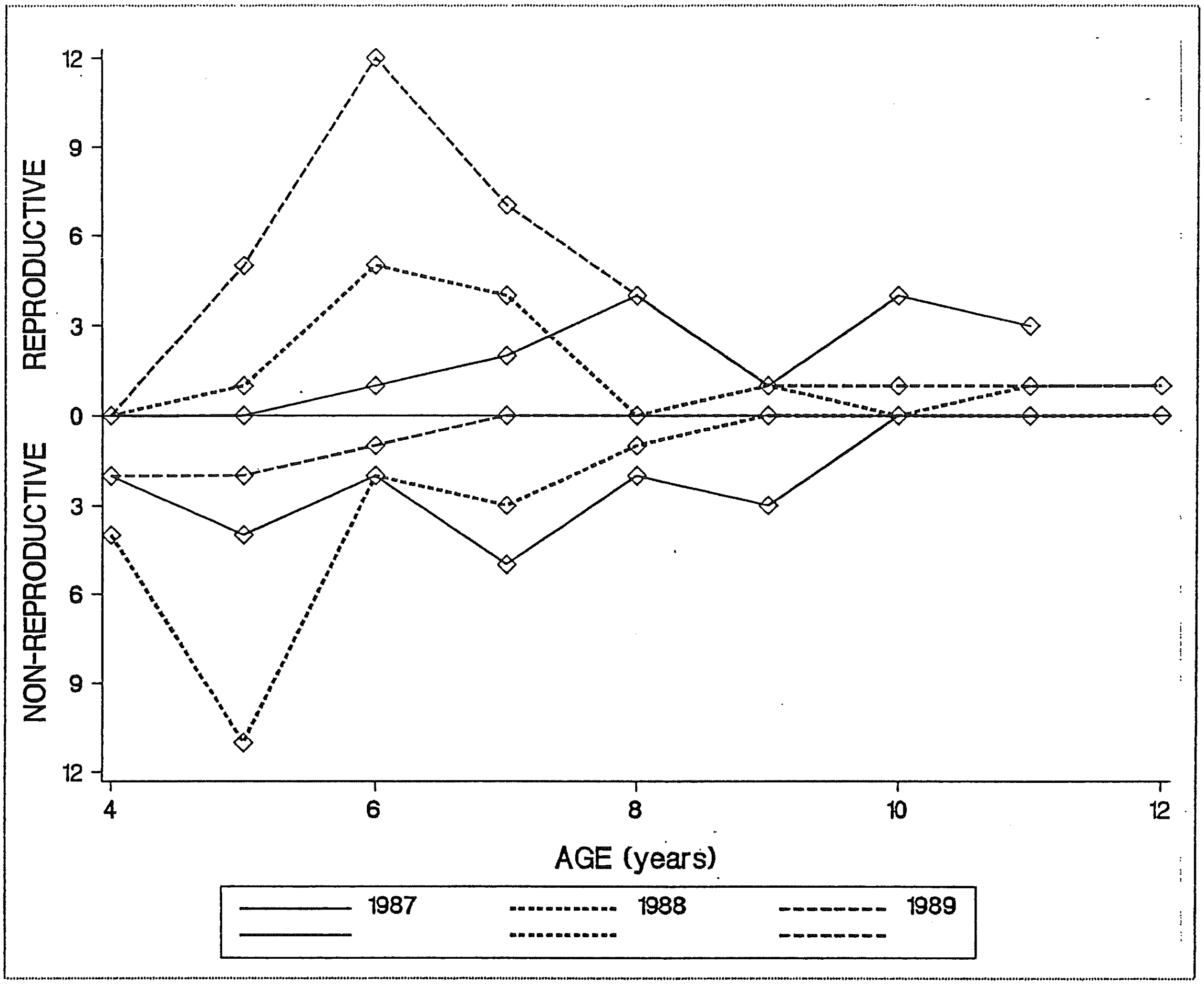

Fig. 3. Frequency of previous reproductive activity in female ringed seals collected at Sachs Harbour, N.W.T., in 1987 through 1989.

Mean age of first production, calculated by DeMaster's method, was 8.46 yr (std err. 0.43 yr) in the 1987 sample. This is abnormally old. In the 1988 sample, although pups were more numerous than they had been in the previous years, the mean age of first production was still high at 7.63 yr (s.e. 0.27 yr). In the 1989 sample, it had dropped further to 5.36 yr (s.e. 0.19 yr), to a level slightly lower than normal.

In our 1987 data, 10 of 16 females (62.5%) of age classes 7+ through 9+ had no signs of any previous pregnancy (Fig. 4). In other words, of the female seals that had reached 6 years of age in 1984-1987, fewer than normal had started to reproduce, but seals 10+ and older in 1987, which had become 6+ in 1983 or before, had all reproduced. In 1988, only 55.5% (5 of 9) of females of the 7+ through 9+ (no 10-year-old females in sample) classes were parous, but again, all females older than 10 years had reproduced. In the 1989 sample, all females older than 6 years had reproduced at least once. It is clear from the reports of the Sachs Harbour hunters and from these data that the ringed seals of the western Arctic had lower reproductive rates than usual in 1986 and 1987. The age profiles in our data may indicate that the gap in reproduction had lasted since 1984, and this is supported by the numbers of relatively old seals in the 1987 sample with no reproductive history. But we have not found any climatic events in the early 1980s to cause it, and polar bear reproduction and condition were still normal up to 1985 (Stirling et al. 1988). The age gap in our data in 1987 may then have been caused by poor survival of the 1984-85 cohorts. No pathological conditions were noted in the reproductive tracts of 1989 female seals. In 1987 a 7-year-old female collected on June 10 had an ovarian cyst 2.5 cm in diameter. Another seven-year-old, shot on August 17, 1988, showed evidence of an extrauterine pregnancy, having a 2 kg foetus lying in her abdominal cavity. All five females collected from Amundsen Gulf in 1988 (4, 5, 5, 7 and 10 years old) had ovarian corpora. The four-year-old and the oldest two were multiparous.

Similarly, in 1974 and 1975, years of low production in Amundsen Gulf, only 61% and 54% of females had reproduced (Smith 1987); and Stirling et al. (1977, 1982) found an ovulation rate of only 51% in the eastern Beaufort Sea and Thesiger Bay in 1975, a year of pup scarcity (2% of 186 seals).

Table 1. Condition indices of Thesiger Bay ringed seals in 1987 through 1989, and of ringed seals sampled at Holman Island in 1988.

Sample Period	C_1 (%)			C_2 (kg/m)			Blubber Thickness (mm)		
	1989	1988	1987	1989	1988	1987	1989	1988	1987
Sachs Harbour									
June 01-15	---	80.31	76.26	---	40.19	37.43	---	31.8	33.6
sample size:		25	10		24	10		25	10
July 01-15	78.94	77.24	69.76	36.26	39.07	31.39	29.3	29.9	25.5
	48	18	4	48	18	4	48	18	4
July 16-31	77.62	80.21	69.40	33.40	41.12	29.87	29.3	33.0	24.0
	28	8	11	28	8	11	28	8	12
Aug. 01-15	77.83	79.97	74.04	34.50	38.48	33.43	29.3	35.0	30.7
	23	9	44	23	9	43	23	9	44
Aug. 16-31		79.6			39.5			36.1	
		16			16			16	
Holman Island									
Aug. 1-15		85.1			45.4			39.2	
		6			6			6	
Aug. 16-31		87.8			46.3			45.2	
		2			2			2	

Physical Condition:

Indices of physical condition in all years decreased from June through July, and rose again through August. This agrees with known cycles of condition in ringed seals (McLaren 1958; Smith 1987), which lose a lot of their fat reserves in the moulting fast starting in May and continuing through the summer. Condition (C_1) of adult ringed seals at Holman (Smith 1987) declined from the beginning of June through July to a mean low of between 70 and 75, then returned to values over 80 by the first half of August. The mean condition of the Holman sub-adult samples followed much the same pattern, but didn't start increasing again until the second half of August. Sub-adult seals have been found to lose on average a smaller proportion of their blubber than adults (Ryg et al. 1988). Seals were in better condition in 1988 and 1989 than in 1987. Mean condition indices were significantly higher for the entire summer, and sternum blubber was thicker through July (Table 1). A small collection of seals at Holman in 1988 were in better condition than Thesiger Bay seals.

Table 2. Mean lengths of young of the year in the Thesiger Bay harvest, 1988 through 1989, and at Holman Island and Brown's Harbour, 1972 through 1977.

Sample Period	Sachs Harbour		Amundsen Gulf	Brown's Harbour
	1989	1988	*	*
June 16-30		90.9 (3)	91 (20)	
July 16-31	86.0 (27)	91.9 (3)	95 (12)	
Aug. 16-31	88.2 (18)	88.5 (17)		90 (10)

sample size in parentheses; * = from Smith 1987.

With the exception of the July 1989 sample, pups collected for this study in Thesiger Bay in open water had similar standard lengths to Smith's (1987) from Amundsen Gulf (Table 2). The July 1989 mean for Thesiger Bay pups was substantially shorter than Smith's July young-of-the-year mean. The 1989 sample contained 2 females, a 6- and a 7-year-old, meeting Smith's (1987) criterion for stunted seals (two standard deviations below the mean standard length for that age). They both had normal to high condition indices. Two others, a pup and a sub-adult, were healthy but short, measuring more than 1.5 standard deviations below their age class means. The 1987-88 sample population contained only one stunted seal, although 10 (3 adult and 2 sub-adult females, 1 adult and 2 sub-adult males and a male and female pup) were at least 1.5 std dev. below their means. A yearling shot on 30 June 1988 was over 4 standard deviation units below the mean length for its age class. It was in poor condition with only 8 mm. of blubber, its body condition values (C_1=65.6; C_2=8.2) significantly below the sample means ($t[C_1]=2.288$, $p<.05$; $t[C_2]=4.260$, $p<.01$). It was not retained for later examination in the laboratory, being mistaken in the field for a more nearly normal young of the year and processed as such.

In 1987, the condition of non-ovulating mature females (Table 3) was worse than that of females that had borne pups. Condition index may be associated with ovulation rates (Stirling et al. 1982). Three of the 8 non-ovulating mature females appeared to have somewhat retarded growth (at least 1.5 standard deviations below the means for their ages).

Pathology:

We found no emaciated seals in 1989. Three mature seals (a 9 year-old female and two 8 year-old males) in the 1987 sample were found to be emaciated. The female had body condition indices of 62.97 and 28.21. The males had condition indices of 58.08 and 22.92, and 63.64 and 28.63. These thin seals

Table 3. Condition indices of ovulating and non-ovulating ringed seals, Thesiger Bay, 1987.

Collection period		Ovulation Status: ovulating	non-ovulating	t-test
June 01-15	C_1	76.34 ± 2.33	78.36 ± 0.69	
	C_2	34.53 ± 3.20	34.08 ± 0.11	
	n	4	2	
July 01-15	C_1	73.57 ± 3.12	66.02 ± 1.10	
	C_2	30.66 ± 0.75	23.42 ± 0.81	
	n	2	2	
Aug. 01-15	C_1	75.59 ± 5.74	69.28 ± 5.89	4.437
	C_2	39.01 ± 6.14	28.56 ± 1.44	7.925
	n	10	4	
Total (June-Aug.)	C_1	75.52 ± 4.71	70.74 ± 6.27	4.838
	C_2	36.84 ± 5.86	28.66 ± 4.15	8.193
	n	16	8	

had obviously enlarged gall bladders (8.2 to 9.1 cm. long); the mammalian gall bladder becomes distended with backed-up bile during fasting or starvation (Hightower and Janowitz 1979). There were no pathological conditions to explain these cases of emaciation. Two 1988 seals were emaciated, the above-mentioned stunted yearling and a 7-year-old female. The female had suffered an abnormal parturition, and had not been able to deliver her pup. The 1.8-kg pup was found in the abdominal cavity, and shed lanugo covered the mother's abdominal organs. A small (4- to 5-mm.) hole was noticed in the wall of the regressing uterus, which may have indicated a rupture due to an abnormal presentation.

Internal parasite infections were found in a few seals in 1989. Trematodes were found in the livers of two 6-year-olds, a female and a male. Both these seals had below normal condition values which were not statistically significant. Nematodes (Otostrongylus sp.) were found in lungs and bronchi of 14 of 27 pups examined and in one yearling. This suggests a prevalence of infection by Otostrongylus in young ringed seals in Thesiger Bay similar to that reported for the Holman area (Onderka, 1989). Half of the 14 had low C_1 values but only 1 was significantly below the mean ($t=1.738$, $p<.05$). On superficial examination, 2 seals in 1988 and two in 1989 were found to have lung cysts (4-year-old and 6-year-old females in 1989; a 10-year-old female and a 9-year-old male in 1988). However, the male had above average condition indices ($C_1=70$, $C_2=34$), and those of the females ranged from well above average for the 6-year-old ($C_1=84.6$) to not significantly below average for the 4-year-old ($C_1=69.3$, $C_2=31.7$) and 10-year-old ($C_1=69.0$, $C_2=33.5$).

Table 4. Ringed seal densities in ice of 6/8+ cover, western Canadian Arctic, 1981 through 1988.

Year	Density /sq.km.	Estimated Pop. '000	Density /sq.km.	Estimated Pop. '000
Prince Albert Sound			Amundsen Gulf	
1981*	3.46 (0.67)	16.9	3.08 (0.66)	14.0
1982*	2.03 (0.21)	15.0	2.61 (0.26)	54.9
1983*	2.34 (0.13)	17.8	3.02 (0.15)	56.5
1984*	2.37 (0.26)	18.3	1.60 (0.16)	31.2
1985	2.66 (0.13)	20.6	2.63 (0.17)	50.0
1988	6.94 (0.85)	48.9	4.63 (1.18)	12.5
Thesiger Bay and west coast of Banks I.				
1988	1.30 (0.23)	2.2		

* from Kingsley 1985.

Population Density:

In normal years, densities of about 2.5 seals/sq. km. result in estimated populations of about 55,000 in Amundsen Gulf and 17,000 in Prince Albert Sound (Kingsley 1986). In 1988, Amundsen Gulf cleared of ice early, and seals crowded onto the remaining ice in southern Prince of Wales Strait, northern Amundsen Gulf, and the mouth of Prince Albert Sound. Similar ice conditions had obtained in 1981, when densities averaged 3.1 to 3.5 seals/sq. km., and were higher near the ice edges (Kingsley 1986). In 1988, ringed seal densities recorded in Prince Albert Sound were higher yet (Table 4), and the population estimate of 48,900 was about 3 times that of 1981-1984. The mean density of seals on the residual ice in northern Amundsen Gulf was greater in 1988 than in 1981, but the estimated 1988 Amundsen Gulf population of 12,500 was somewhat less than the 1981 estimate of 14,000. The total estimated population for Amundsen Gulf and Prince Albert Sound was 61,400 in 1988, compared with a total for normal years of about 72,000.

The 1988 data confirm earlier findings (Kingsley et al. 1982; 1985) that in early ice years, seals move in large numbers from early open areas to haul out on remaining ice in inlets and sounds, and confirm that summer aerial surveys are not good indicators of winter distribution.

Ringed seal densities were lower off the south-west and west coasts of Banks Island. The densities in these areas in 1974 through 1979 (Stirling et al. 1982) never reached the high values regularly attained in Amundsen Gulf.

Table 5. Percent occurrence of food items in ringed seal stomachs, Thesiger Bay, 1988 through 1989.

Food Taxon	% Occurr.[1]		% Freq.[2]	
	1988	1989	1988	1989
Polychaetes (tubes)	2.7	0.9	<0.1	<0.1
Amphipods	78.4	72.1	39.1	87.6
Mysids	35.1	60.4	46.0	7.9
Copepods	5.4	19.8	2.6	0.1
Decapods	33.8	14.4	0.4	0.6
Cumaceans	14.9	6.3	0.2	0.4
All Crustaceans	91.9	85.6	88.6	96.6
Bivalves	2.7	0.9	<0.1	<0.1
Cephalopods (mandibles)	1.4	0.9	<0.1	<0.1
Kelp	1.4	0.9		
Fish	64.9	79.3	11.3	3.3
Sample sizes:	74	111	8988	14679

[1]% of stomachs containing taxon
[2]taxon as % of food items

Feeding:

The diet of the ringed seals in our study area consists almost entirely of nektonic crustaceans and fish (Table 5) (cf. McLaren 1958; Lowry et al. 1980; Smith 1987). The dominant crustacean prey are mysids and lyssianassid and hyperiid amphipods, mostly _Parathemisto_ spp. As ringed seals get older, more stomachs contain fish, and more of them, while amphipods occur in fewer stomachs and in smaller numbers (Table 6). Significantly more pups than either sub-adults or adults ate amphipods, and fewer ate fish (Chi^2 4.313 and 8.059, $p<.05$).

In 1989, a year of high mysid consumption, significantly more adults than either of the younger groups ate fish, fewer adults ate mysids (Chi^2 5.890 and 9.552, $p<.025$). Pups ate more crustaceans and less fish than the older groups (Chi^2 4.331 and 10.330, $p<.05$). Fish were a higher proportion of the stomach contents of 1988 adult and sub-adult seals, 23.0% and 17.3% respectively, whereas in 1989, although fish occurred in most stomachs, they made up less than 6% of the food consumption in all age groups (Table 6). In 1988 amphipods were by far the most common crustacean prey, but mysids occurred in higher frequencies in 1989 and were more frequent than amphipods in sub-adult and adult stomachs.

Contaminants:

Organochlorine analysis of 21 ringed seal blubber samples from 1988 showed residues were lower than in the 1987 samples for all organochlorines except dieldrin (Table 7). However, marine mammals accumulate organochlorines in blubber through life, and the adult part of the 1988 sample was younger than in 1987; i.e. the change in organochlorine residue levels was due to the change in distribution of adult ages. The 1988 samples were at normal to low residue levels compared to other Canadian Arctic seal populations, and hundreds of times lower than northern European seals. Mean levels of all organochlorines except dieldrin are higher in the six 1987 Thesiger Bay ringed seals than recorded in ringed seals elsewhere in the Canadian Arctic in the

Table 6. Age-related variation in the diet of ringed seals, Thesiger Bay, 1988 through 1989.

	Age 0+		Age 1-6		Age 6+	
Food Taxon	1988	1989	1988	1989	1988	1989
Percent Occurrence in stomachs						
Amphipods	100.0	88.7	72.1	60.0	68.8	50.0
Mysids	35.7	69.8	32.6	62.5	43.8	27.8
All crustaceans	100.0	92.4	88.4	87.5	81.2	61.1
Fish	57.1	75.5	62.8	82.5	75.0	83.3
Sample size	14	53	43	40	16	18
Frequency as percent of food items found						
Amphipods	92.1	50.0	86.6	28.2	80.2	9.1
Mysids	1.9	41.0	10.1	50.7	11.6	60.7
All Crustaceans	94.5	93.1	97.7	83.8	96.8	77.0
Fish	5.5	6.8	2.2	16.2	3.1	23.0
Sample size	4247	5161	9351	3078	1160	749

past 15 years, although harp seals (Phoca groenlandica)from 1976-78 in Grise Fjord, Pangnirtung, and northwest Greenland (Ronald et al. 1984) had greater DDT (both sexes) and PCB (adult males) levels.

Of the two female samples analyzed in 1987, a non-ovulating 7-year-old had less PCB, total DDT and toxaphene residues than a multiparous 10-year old. However, the nullipara had twice the HCH levels and 3 times the CBz of the multipara, as well as greater dieldrin levels (Table 7).

There is evidence associating reproductive dysfunction and population declines among ringed seals and common (harbour) seals (Phoca vitulina) in Europe with chronic contamination with chlorinated residues (Helle 1983; Reijnders 1980; Addison 1989). Narrowing or blocking of the uterine tubes has been associated with DDT and PCB contamination in ringed seals in the Baltic Sea (Helle 1976). Common seals have declined in the western Waddensee where levels of DDT and PCBs are high, and interference with reproductive processes was indicated by feeding captive seals on Waddensee fish (Reijnders 1986). DeLong et al. (1973) found high organochlorine levels in female California sea lions (Zalophus californicus) bearing prematurely or aborting, but Addison (1989) found the evidence for a direct causal link ambiguous.

It is not clear, however, what is cause and what is effect. Female marine mammals unload organochlorines into milk during lactation, and reproductive failure blocks this depuration route. Thus, reproductive failure may be either the cause, or the effect, of high individual organochlorine levels, or both may be a 'parallel result of some other cause' (Addison 1989). Uterine stenosis reported in Baltic Sea seals (Helle et al. 1976) may have been due to infection. The California sea lions had abnormal concentrations of heavy metals and had bacterial and viral infections, complicating the direct cause-

Table 7. Organochlorine contaminant levels in ringed seals in the Canadian Arctic, Greenland, and north-western Europe.

Year	Sex	Age	n	HCH	CBz	Chlor	DDT	PCB	Txph	Diel	Source
Sachs Harbour											
(88)	M	4	11	2.67	0.61	4.23	3.8	5.8	1.9	0.50	this report
	F	5-6	10	2.34	0.51	3.44	3.6	5.2	1.3	0.41	
(87)	M	8	4	6.00	1.32	8.19	10.5	11.8	5.0	0.43	this report
	F	8	2	5.63	1.08	8.35	6.8	7.8	12.2	0.35	
(72)	M	-	3				9.3	7.2			Bowes &Jon-
	F	-	2				19.1	12.2			kel (1975)
Tuktoyaktuk											
(86-87)		-	7	2.90		4.05	2.9	6.3	3.4		Muir (unpub.)
Cambridge Bay											
(86)	M	-	10	3.02		5.57	4.7	8.8	3.8		"
	F	-	6	2.98		4.93	3.0	6.7	3.1		
Grise Fjord											Muir et al.
(72)	F	-	3	1.32	0.32	2.23	8.1	6.4	<0.1	0.54	(in prep.)
Admiralty Inlet											
(75-76)	F	3	5	2.41	0.30	3.62	6.3	6.0	<0.1	0.68	" "
(83)	M	6	10	2.27	0.32	4.62	13.3	7.9	<0.1	0.74	
	F	6	16	2.04	0.24	2.84	4.8	3.1	<0.1	0.77	
Barrow Strait											
(84)	M	10	19	2.74	0.25	4.57	7.1	5.7	<0.1	0.96	" "
	F	9	14	3.08	0.27	3.53	4.8	3.8	<0.1	0.73	
West Greenland											
(74-76)		-	57				10.2	9.6			Johansen
East Greenland											et al. (1980)
(74)		-	7				31.0	32.0			
Gulf of Bothnia											
(73)	M	-	24				1300.0	1000.0			Helle
	F	-	29	(uter. abn.)			1300.0	1100.0			et al. (1976)
	F	-	8	(uter. norm.)			620.0	890.0			
Gulf of Finland											
(76-82)		7	19				759.0	758.0			Perttila
	F	>7	1	(uter. norm.)				>2500.0			et al. (1986)
	* F	>7	1	(uter. abn.)				680.0			
	* F	>7	1	(uter. abn.)				790.0			

Age is mean age in most studies.
* It is unclear whether these females were ringed or grey seals.
uter. norm. = normal uterus   CBz = chlorobenzenes
uter. abn. = abnormal uterus   HCH = hexachlorocyclohexanes
Chlor = chlordane   Txph = toxaphene   Diel = dieldrin

effect relationship (Reijnders 1986). Organochlorines, being immunosuppressive agents (Reijnders 1984), may have heightened the California and Baltic pinnipeds' susceptibility to infection. Contaminant levels in our sample were not at levels expected to cause reproductive failure, and we saw no indication of any pathological conditions in female reproductive tracts that could be attributable to contaminant effects. We conclude that the reproductive failure was not due to organochlorine contamination.

Mercury and selenium concentrations in the livers of 13 seals (Table 8) were positively correlated with age (Hg: p<.005; Se: p=.001). This agrees with previously reported results (Sergeant 1980; Smith and Armstrong 1978; Drescher et al. 1977; Heppleston and French 1973). There was also a significant correlation (r=.8516, p<.001) between Hg and Se concentrations. Smith and Armstrong (1978) also report this correlation. This finding may be due more to these metals' comparable accumulation rates with age in pinnipeds than to any significant interactions between the two contaminants (Perttila et al. 1986).

Table 8. Heavy metal concentrations in ringed seal livers in Thesiger Bay in 1988 (μg/g wet weight).

Sex	Age	Cu	Cd	Hg	Se	Zn
M	0+	7.37	0.10	0.66	0.87	32.3
M	2	4.72	2.81	3.64	3.79	39.8
M	4	6.90	7.77	42.20	18.90	43.5
M	6	4.45	7.45	18.00	10.50	40.0
M	9	3.87	2.62	48.30	20.30	24.4
M	9	8.09	3.67	63.80	31.20	35.6
Mean:	5.0	5.9	4.07	29.43	14.26	35.9
F	1	8.55	0.45	0.64	1.37	34.6
F	3	17.10	2.05	1.88	2.47	42.5
F	4	3.10	4.34	2.81	4.22	32.7
F	6	13.50	4.86	35.10	22.80	47.0
F	6	14.90	5.55	21.90	29.80	48.4
F	7	4.77	9.45	91.10	31.00	48.1
F	7	3.52	5.27	36.00	12.80	49.3
Mean:	4.8	9.35	4.57	27.06	14.92	43.2

Mean mercury and selenium concentrations in the livers of 13 seals (1988 samples) are relatively high in comparison to other Arctic locations (Wagemann and Muir 1984), and are well above the federally accepted tolerance levels of 0.5 ppm. in food, but are similar to concentrations found in ringed seals from eastern Amundsen Gulf in 1972 and 1977 (Smith and Armstrong 1978) (Table 8). The concentrations of mercury in our seals are significantly higher than for 1972 Cape Parry seals, which were, however, younger than the Thesiger Bay sample.

Zinc mean concentrations are within the range of means (34.3 to 44.0 μg/gm) for the highest recorded levels in Canada (Wagemann and Muir 1984). Cadmium levels are low, and residues of lead, arsenic, vanadium and copper are negligible (<0.1 μg./gm.).

CONCLUSIONS

Reproductive success was low among the ringed seals of the eastern Beaufort Sea in 1986 and 1987 and possibly also in 1984 and 1985, results from our sample being confirmed by the state of polar bears during that period. Reproduction was resumed in 1988 and returned to normal levels in 1989; the mean age of first production dropped by 3 years between 1987 and 1989.

The resumption of reproduction was associated with a shift in the demography of the adult population, the 1977 through 1980 year classes of adults being replaced by younger adults of the 1981 through 1983 year classes.

There is now no evidence that this event was due to poor body condition, widespread disease or heavy parasite infestation, or high pollution contamination in the area. Poor reproductive success in 1974 and 1975 was apparently associated with a winter of heavy ice in the Beaufort Sea, and a similar occurrence may have been responsible this time, but the retrospective evidence for a direct climatic cause is not good.

These indications that reproductive failures lasting for more than one year may be recurring phenomena are of ecological interest for the effect they may have on the predator-prey relationship between ringed seals and polar bears. They also have implications for the conduct and interpretation of impact assessment evaluations of ringed seal populations.

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