

Mass Natural Mortality of Walruses (*Odobenus rosmarus*) at St. Lawrence Island, Bering Sea, Autumn 1978

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ABSTRACT. In October-November 1978, several thousand living walruses came ashore in at least four localities on St. Lawrence Island where they had not been present before in this century. They hauled out also at two other sites which they have occupied annually but in much smaller numbers. At least 537 animals died on the haulout areas at that time, and approximately 400 other carcasses washed ashore from various sources. This was by far the greatest mortality of walruses ever recorded in an event of this kind. At least 15% of the carcasses on the haulouts were aborted fetuses, 24% were 5-6-month-old calves; the others were older animals ranging in age from 1 to 37 years old. About three-fourths of the latter on the haulouts were females; in the non-haulouts areas, the sex ratio was about 1:1. Forty of the best preserved carcasses were examined by necropsy. The principal cause of death was identified as extreme torsion of the cervical spine, with resultant cerebrospinal hemorrhage, apparently due to traumatization by other walruses. Nearly all of the dead were extremely lean, having less than half as much subcutaneous fat as healthy animals examined in previous years.

RÉSUMÉ. En Octobre-Novembre 1978, quelques milliers de morses vivants échouaient dans au moins quatre localités de l'île St. Laurent, qu'ils ne fréquentaient jamais avant, depuis le début du siècle. Ils se traînaient aussi jusqu'à deux autres sites qu'ils fréquentaient chaque année mais en nombre bien moins important. Au moins 537 animaux mourraient sur les plages d'échouage, à cette époque et approximativement 400 autres carcasses étaient rejetées sur le rivage provenant de sources variées. C'était de loin la plus grande hécatombe de morses jamais enregistrée dans un événement de ce genre. Au moins 15% des carcasses sur ces aires d'échouage étaient des foetus avortés, 24% étaient des jeunes de 5 à 6 mois; les autres étaient des animaux plus âgés dont l'âge allait de 1 à 37 ans. Environ les 3/4 de ces derniers étaient des femelles. En dehors de ces points d'échouage, le rapport des sexes était environ de 1 à 1. Quarante des carcasses les mieux conservées, étaient examinées avec autopsie. Celle-ci révélait qu'une extrême torsion de l'épine cervicale était la principale cause de mortalité, avec comme conséquence une hémorragie cérébrospinale, apparemment due à une traumatisation par d'autres morses. Presque tous les morts étaient très penchés car ils avaient moins de la moitié du gras sous-cutané qu'ont les animaux en bonne santé, examinés les années précédentes.

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INTRODUCTION

In November 1978, residents of the Eskimo village of Savoonga, Alaska reported that unusually large numbers of walruses were hauling out on St. Lawrence Island in four locations where they had not been known to occur for at least the past 40 to 50 years. At the same time, herds were hauling out on the Penuk Islands, off the eastern end of St. Lawrence Island (Fig. 1), as

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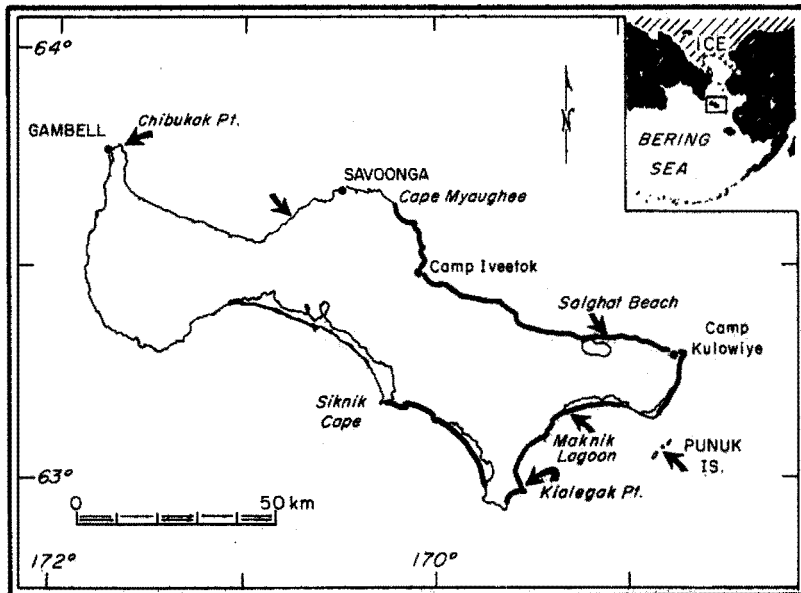


FIG. 1. Chart of St. Lawrence Island, showing localities mentioned in the text and (inset) the position of the island relative to the continents and the edge of the pack ice in late October to early November 1978. Arrows indicate areas where walrus herds hauled out at that time. The parts of the coastline that were aerially surveyed on 19 June 1979 are indicated by the heavy lines.

they usually do in autumn, as well as on Chibukak Point, near Gambell, where they have occurred irregularly in the past 17 years. Eyewitness accounts at some of the haulouts indicated that many animals were dying, apparently of natural causes, and that many fetuses had been aborted prematurely. Numerous other carcasses of animals that died at sea were washing ashore in many areas. The animals coming ashore were said to be mostly very lean, whereas walrus in autumn have tended to be very fat in previous years. The poor condition of the animals, together with the abundance of natural deaths and abortions, led to some speculation that a disease or toxic agent was striking the walrus population in epizootic proportions. Because the St. Lawrence Islanders rely on walrus for much of their food and cash income, they were understandably alarmed and concerned.

At the time when these events occurred, the weather was very stormy, with high winds and heavy seas from the south. The walrus, mainly adult females and young, were arriving from the northwest, presumably having swum from the edge of the pack ice which was then just north of Bering Strait, some 300 km away. The Eskimos remarked that the animals coming ashore appeared to be weak and physically exhausted, sleeping so soundly that it was possible to walk up and touch them without waking them. Observers on the Penuk Islands in early November estimated that there were at least 6000 walrus on the beach at one time. Hunters camped at Kialagak

Point stated that the animals covered about 2.5 km of beach and, in some places, extended inland onto the tundra.

According to the reports from Eskimos camped on Punuk, a few adult bulls were present among the females. These bulls were extremely belligerent, rushing through the resting herd to engage other bulls in battle. On one occasion, two bulls fought with such vigor that one appeared to have mortally wounded the other. In their rushes through the herd, the bulls trampled and struck at other animals with their tusks, and some calves (about 6 months old) were believed to have been killed by them. One night, an entire herd stampeded off the beach into the sea, leaving behind about 25 dead and disabled animals at the water's edge, below a wave-cut terrace.

On receiving the report of this mortality, Fay went to Savoonga in late November 1978 to investigate the matter further. Regrettably, by that time most of the carcasses were drifted over by snow and were no longer visible or accessible. We returned to the scene in June 1979, after the snow had receded enough to expose most of the bodies, to obtain documentation of their numbers, sex and age composition, and causes of death.

METHODS

We surveyed the beaches of St. Lawrence Island via chartered aircraft on 19 June 1979, some seven months after the unusual events had occurred. The objective of that survey was to obtain some measure of the distribution and abundance of carcasses and to locate the major concentrations for further study. The aircraft was flown at an altitude of about 100 m and speed of 275 km/hr. Numbers and locations of carcasses were recorded on a chart of the island.

On 20 June, we began work on the carcasses at Salghat Beach, where one of the known haulouts had occurred. Two days later, we moved eastward to Camp Kulowiye to examine a series of carcasses that apparently had been cast ashore. Six days were spent on the Punuk Islands, and on 30 June we returned westward to Camp Iveetok to examine another series of beachcast carcasses.

Examination methods consisted of walking the shoreline, counting, mapping, and determining the sex and relative age of the carcasses. Postcanine teeth were retrieved for age determination where possible. Haulout areas whose limits were distinguishable by tracks, feces, and general disruption of surface features were paced off, and estimates made of numbers of animals that could have been accommodated. Those estimates were based on the findings of Krylov (1966) that, in herds of mainly adult females and young, the amount of space occupied by each individual ranged from 1.2 to 5 m², and of Tomilin and Kibal'chich (1975) that the mean area per individual was between 1.6 and 1.8 m². The former was regarded as the maximal and the latter as the most probable range of variation.

All carcasses that were relatively well preserved were necropsied in the following manner:

1. External examination for wounds and other lesions.
2. Measurement of blubber thickness over the sternum or, alternatively, over the shoulder.
3. Removal of the skin from the head and body, examining for subcutaneous hemorrhages, holes, or other lesions.
4. Removal of the blubber; examination of any lesions in it or in the superficial musculature.
5. Dissection of the superficial muscles; examination of the deeper musculature and bones for fractures, hemorrhages, or other lesions.
6. Thoracic and abdominal cavities opened; external and internal examination of all organs for any gross signs of pathological conditions.
7. Observation of any unusual amounts of fluids in body cavities, and estimations of their volume.
8. Separation of the head from the body and inspection of the brain and spinal cord at the junction.

The ages of animals, other than calves and fetuses, were determined by counts of cementum layers visible with 10X magnification in thin sagittal sections of the teeth.

All names of places on St. Lawrence Island are from the U. S. Geological Survey chart of that area (Alaska Topographic Series N6252-w16830/ 60x210) and do not necessarily correspond to local Eskimo vernacular for the same locations.

MAGNITUDE OF MORTALITY

St. Lawrence Island

Complete aerial coverage of the coast of St. Lawrence Island and the Penuk Islands on 19 June was prevented by inclement weather. Only 196 of the approximately 480 km of shoreline was surveyed, and this was entirely on the northeastern and southeastern parts of St. Lawrence Island alone (Fig. 1). We sighted 132 carcasses during that survey, including two major concentrations, 24 on the eastern part of Salghat Beach and 31 on the western part of the barrier beach of Maknik Lagoon. Only 9 carcasses were sighted in the vicinity of Kialegak Point.

The Salghat and Kialegak areas had been identified earlier as haulouts used by large herds in autumn 1978. The consensus of hunters who had been to the Maknik site more recently was that it too had been a haulout, as indicated by walrus tracks and feces on the beach.

TABLE 1. Comparison of numbers of walrus carcasses counted from the survey aircraft with actual numbers counted on the ground along portions of the coast of St. Lawrence Island, June 1979

Locality	Shoreline (km)	Carcasses counted		Aerial/ground counts (%)
		Aerial	Ground	
<i>Haulout areas</i>				
Salghat Beach	1.1	24	30	80
Kialegak Point	2.5	9	10	90
<i>Non-haulout areas</i>				
Myaughee-Iveetok	24	9	57	16
East of Salghat	7	2	4	50
Camp Kulowiye	5	1	13	8
Totals				
Haulout areas	3.6	33	40	82.5
Non-haulouts	36	12	74	16.2

TABLE 2. Estimated numbers of walrus carcasses present on the coast of St. Lawrence Island, June 1979

Locality	Shoreline (km)	Number of carcasses		
		Aerially counted	Estimated ¹	
			Range	Mean
<i>Aerially surveyed</i>				
Haulout areas	6.6	64	71 - 80	78
Non-haulouts	189.4	68	136 - 850	420
Total surveyed	196	132	207 - 930	498
<i>Not surveyed</i>	284	-	204	-
Totals	480		411 - 1134	712

¹ In surveyed areas, based on aerial counts amounting to 80-90% (mean 82.5%) of ground counts on haulouts and 8-50% (mean 16.2%) on non-haulouts. In areas not surveyed, based on estimated minimal rate of occurrence (0.72/km) in surveyed non-haulout areas.

We counted carcasses via small boat and on foot along 37.1 km of the northern coast that had been aerially surveyed. A count in the Kialegak area (2.5 km) was done by one of the Savoonga residents. Those counts disclosed that 114 carcasses actually were present where only 45 had been counted from the aircraft (Table 1). Many of those not sighted from the air were partly buried in the beach, often with only part of the torso exposed. Most of the others were in rock outcrops, under masses of kelp, or in windrows of driftwood. All but one of the carcasses were at or above the autumn 1978 storm tide level; the one exception (at Camp Iveetok) had washed ashore just prior to our arrival. Carcasses that had lain in place for a year or more were scarce and easily distinguished from the others by their dry, hard tissues and exposed bones. We did not include these in the counts.

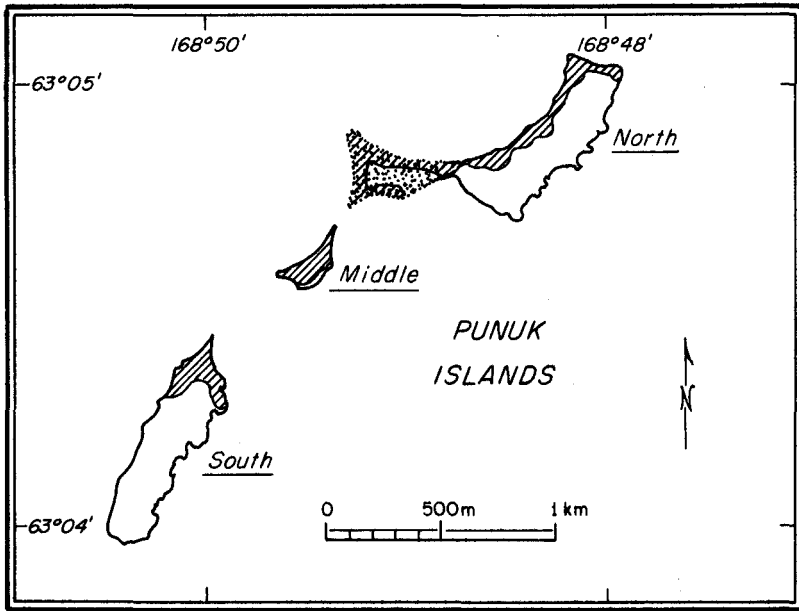


FIG. 2. Chart of the PUNUK ISLANDS, showing the areas occupied by walrus (cross-hatched) in the autumn of 1978 (Adapted from Army Map Service series Q801, sheet 1347 III NW).

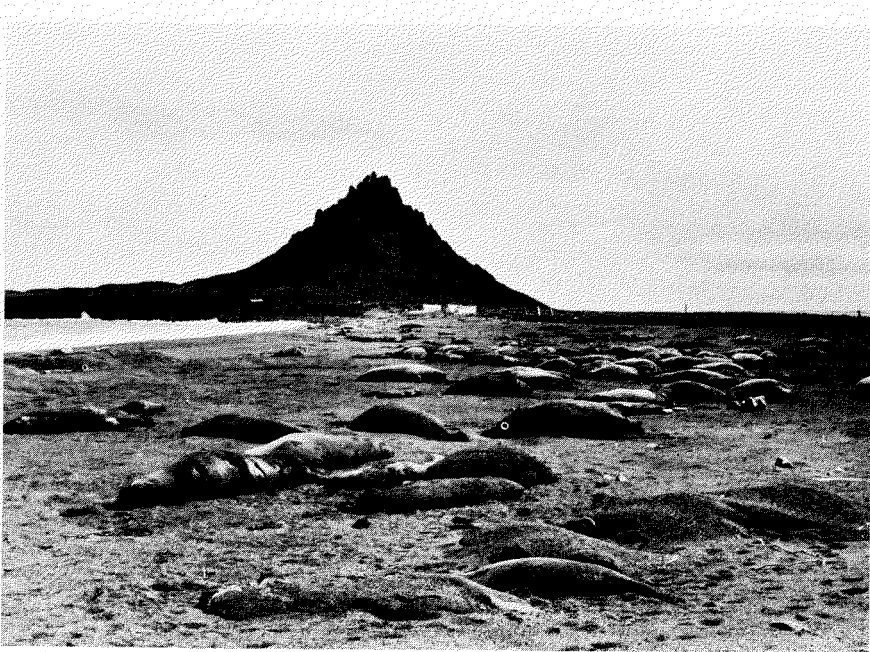


FIG. 3. Walrus carcasses on and partly buried in the beach of the western sandspit of North PUNUK Island, June 1979.

The comparison of aerial and ground counts indicated that the success rates of aerial sightings in the known haulout areas were between 80 and 90% (mean 82.5%), and in the other areas only 8 to 50% (mean 16.2%). Applying these rates to the 196 km of shoreline that were aerially surveyed, we estimate that the total number of carcasses was at least 207 but not more than 930, with a mean estimate of 498 (Table 2).

We were unable to count carcasses on the 284 km of shoreline of the western part of St. Lawrence Island but received reports that they were numerous along the northern coast between Savoonga and Gambell, and that a few were present also along the western and southern coasts. It may be assumed that the number of carcasses per kilometer of beach was comparable at least to the minimum in non-haulout areas on the eastern part of the island (0.72/km), that is at least 204 carcasses.

Thus, for St. Lawrence Island as a whole, the total number of carcasses remaining in June 1979 of animals that died in autumn 1978 probably was not less than 411 nor more than 1134. The most probable estimate is about 712, to which should be added about 50 aborted fetuses reported by the Eskimos.

Punuk Islands

The three Punuk Islands were surveyed in their entirety on foot during 24 to 30 June; a total of 466 carcasses was counted. All of these were on the haulout areas that had been occupied in autumn 1978 (Fig. 2).

On the North Island, there were some additional carcasses buried in the beach (Fig. 3) that were not counted, since time did not permit their excavation for sex and age determination. There apparently had been others that had died there and been washed away by the surf, for we were unable to find the group of about 25 that the Eskimos reported to have died at the water's edge.

These counts and estimates indicate that the combined total of carcasses on St. Lawrence and the Punuk Islands, from mortality that occurred in autumn of 1978, was between about 900 and 1600; a most probable estimate is approximately 1200 carcasses.

SEX AND AGE COMPOSITION OF THE DEAD ANIMALS

St. Lawrence Island

Incoastal areas that were surveyed, the carcasses were distributed almost linearly along the beach, most of them at the autumn 1978 high water level. In the vicinity of Camp Ivetok and Camp Kulowiye, they were scattered at random, whereas at Salghat Beach they were clumped in three groups along 1.1 km of the shore. The composition of each of those groups was similar, with a ratio of three calves to two older animals in each of them. The ratio of males to females in the carcasses of the older animals at both the Ivetok and Kulowiye sites was about 1:1; at the Salghat site, it was 1:3 (Table 3).

TABLE 3. Sex ratios of walrus fetuses, calves, and older animals in the carcasses examined on St. Lawrence and the Penuk Islands, Bering Sea, June 1979

Locality	Sex composition per age class									Total
	Fetuses			Calves			Older			
	M	F	Unk.	M	F	Unk.	M	F	Unk.	
<i>St. Lawrence Island</i>										
Camp Ivetok	0	0	0	0	0	0	4	3	0	7
Camp Kulowiye	0	0	0	1	1	3	4	4	0	13
Salghat Beach ¹	0	0	0	9	8	1	3	9	0	30
<i>Penuk Islands</i>										
North I. spit (N)	8	15	19	20	25	7	26	155	1	276
North I. spit (W&S)	1	2	3	15	13	1	45	43	3	126
North I. northern part	1	2	4	2	1	5	1	3	0	19
Middle Island	0	0	7	0	0	11	0	0	11	29
South Island	5	4	5	0	0	2	0	0	0	16
<u>Totals</u>	15	23	38	47	48	30	83	217	15	516

¹ Eskimos reported the presence of about 50 fetuses on Salghat Beach in November 1978, but none remained at the time of our investigation in June 1979.

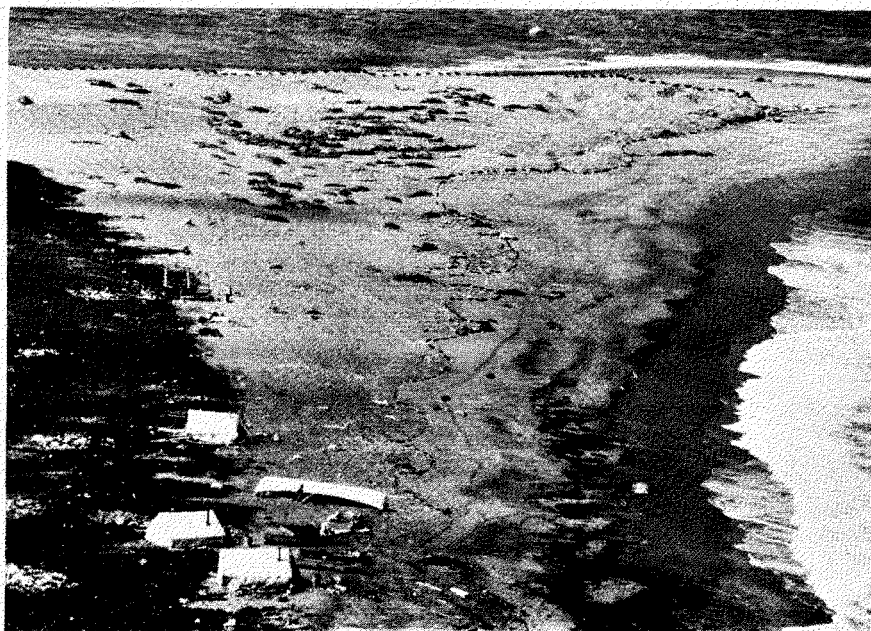


FIG. 4. Distribution of walrus carcasses on the northern beach of the spit, North Penuk Island, June 1979. Dotted line indicates the autumn 1978 high water level.

Penuk Islands

On the Penuk Islands, nearly all of the carcasses were well above the high water level (Fig.4). They were very unevenly distributed, more than 90% of

TABLE 4. Standard lengths (cm) of walrus carcasses measured on St. Lawrence and the Penuk Islands in June 1979

Age class	Males			Females			Sex unknown		
	N	Range	Mean	N	Range	Mean	N	Range	Mean
Fetuses	7	59-78	66.1	13	44-86	65.7	3	54-79	67.3
Calves	24	119-162	144.0	15	124-159	138.3	0	-	-
Juveniles & subadults (♂ 3-8 yrs; ♀ 2-5 yrs)	5	175-265	235	7	192-254	221	0	-	-
Subadults & young adults (♂ 9-13 yrs; ♀ 7-9 yrs)	3	282-340	304	6	246-295	268	0	-	-
Mature adults (♂ >14 yrs; ♀ >10 yrs)	7	300-342	320	30	252-296	279	0	-	-

them being on the North Island, 6% on the Middle Island, and 3% on the South Island (Table 3). About 95% of those on the North Island were situated on the sand spit that makes up the western third of the island (Fig. 2), which has been the traditional haulout area for at least the past 100 years. On the spit the ratio of calves to older animals was approximately 1:3, whereas on the Middle Island it was about 1:1; there were no carcasses of older animals on the South Island.

Nearly all of the fetuses were slightly smaller than those obtained previously by Fay in late November and December, indicating that they had been aborted somewhat earlier (i.e. October-November). Their sex ratio tended to be uneven (1:1.5) but did not differ significantly from that of the calves ($\chi^2_{(1)} = 1.09$). They ranged in standard length from 44 to 86 cm, with a mean of about 66 cm (Table 4).

The carcasses of calves corresponded in size and dental development to animals 5 to 6 months old, indicating that they had died in autumn, like the fetuses. Standard lengths ranged from 119 to 162 cm, with means of 144 and 138 cm for males and females respectively. Their sex ratio on the Penuk Islands, as elsewhere, was about 1:1.

The age/sex composition of the carcasses was non-uniform over the different parts of the Penuk Island haulouts (Tables 3 & 5). On the North Island, the sex ratio of those older than calves was 26 males:155 females (1:6) on the northern beach of the spit; on the western and southern beaches it was 45:43 (1:1). This difference was highly significant ($\chi^2_{(1)} = 41.2$). General observation indicated that most of the carcasses on the Middle Island were of males. On the South Island, only the carcasses of fetuses and calves remained.

There was a significantly higher proportion of physically mature adults ($\delta >$ (or males) 15 years old; ♀ (or females) $>$ 10 years old) on the western and southern parts of the spit than on the northern part ($\chi^2_{(1)} = \delta 4.34$; $\text{♀} 6.62$). In addition, there was a tendency for a greater proportion of fetuses per sexually mature female ($>$ 5 yrs old) on the northern than on the western and southern parts of the spit, whereas the reverse was true of the calf:female ratio. However, only the latter was significant ($\chi^2_{(1)} = 5.96$).

TABLE 5. Comparative age-compositions of carcasses on the northern (N) versus western and southern (W&S) beaches of the spit on the North Island of the Penuk Islands, June 1979

Sex and location	N	Age class (years)					
		1-5	6-10	11-15	16-20	21-25	>25
<i>Males</i>							
Spit, N side	26	8	6	3	3	2	4
Spit, W & S sides	34	3	4	6	6	6	9
<i>Females</i>							
Spit, N side	153	11	34	47	33	16	12
Spit, W & S sides	41	1	3	17	10	5	5

PATHOLOGY

St. Lawrence Island

A total of 15 carcasses was necropsied on St. Lawrence Island. These were chosen at random from those that were best preserved, most of them having been recently covered by snow. Some bias may have been introduced by this choice, since these were the carcasses that were nearest the seaward edge of the beach.

It was determined that 11 of the 15 animals had died from traumatic injuries, 5 of which were identified with certainty as gunshot wounds (Table 6). An old gunshot wound probably had contributed to the death of another (♂ (or male 35a). The latter had a broken left scapula, necrosis of the adjacent muscles, and bacterial invasion (color and odor suggested *Escherichia coli*) of the wound. A conical mass of necrotic material extended outward from the broken shoulder to the skin, where at the apex of the cone, there was a 5 mm circular scar that appeared to be the entry point of a bullet. However, no bullet remains were evident in the wound. This animal had been secondarily traumatized more recently by another agent, as indicated by extensive deep intramuscular hemorrhages in the thoracic and pelvic regions, as well as adjacent to the old wound. These new injuries, and extensive lacerations of the hind flippers with one fractured phalanx, suggest that the agent was a killer whale, *Orcinus orca*.

The death of male 381 also was attributed to killer whale predation. In this animal there were fractures of both scapulae, all of the ribs, the pelvis, and three parts of the spinal column; the lungs and heart had been punctured in several places by the broken ribs. Massive intramuscular hemorrhage was associated with each of the fractures, and there were several litres of free blood in the thoracic cavity. The hind flippers of this animal also showed multiple lacerations with some phalanges exposed but not broken. Female 383, which had bled to death internally from a ruptured spleen, also may have been injured by killer whales.

The three calves (27, 28, 31) also had died from trauma but of a rather different type than that in the older animals. Whereas the latter appeared to

TABLE 6. Principal pathological findings in walrus carcasses necropsied on St. Lawrence Island and the Punuk Islands, June 1979

Place	Field no.	Sex	Age (yrs) or age class	Pathological findings ¹								
				Spinal torsion	Intra-cerebral hemorrh.	Lung congestion	Free blood in b.c.	Broken bones	Uterine prolapse	Umbil. hernia	Biliary stasis	Gunshot
<i>Salghat</i>												
	27	♂	calf	+++	+++	+++	+++	-	-	-	-	-
	28	♀	calf	+++	+++	+	+	-	-	-	-	-
	23	♂	adult	-	+++	-	-	+	-	-	-	+++
	29	♂	adult	-	+++	-	-	+	-	-	-	+++
	20	♀	adult	-	+++	-	+++	+	-	-	-	+++
	30	♀	8	-	-	-	-	-	-	-	-	+?
<i>Ku'Lowiye</i>												
	31	♀	calf	+++	+++	+++	+	-	-	-	-	-
	35a	♂	subadult	-	-	-	-	+++	-	-	-	+?
	32	♀	4	-	+++	-	-	+	-	-	-	+++
	33	♀	v. old	-	-	-	-	-	-	-	+++	+?
<i>Ivsetok</i>												
	381	♂	adult	-	?	+++	+++	+++	-	-	-	-
	386	♂	adult	-	-	-	-	-	-	-	-	+?
	387	♂	adult	-	-	-	-	-	-	-	-	+?
	382	♀	4	-	+++	-	+++	+	-	-	-	+++
	383	♀	adult	-	-	-	+++	-	-	-	-	-
<i>Punuk</i>												
	40	♂	calf	+++	+++	-	-	++	-	-	-	-
	43	♂	calf	+++	+++	-	-	-	-	-	-	-
	45	♂	calf	+++	+++	-	-	-	-	-	-	-
	46	♂	calf	+++	+++	+++	+++	-	-	-	-	-
	59	♂	calf	+++	++	-	+	-	-	-	-	-
	263b	♂	calf	+++	+++	+++	++	-	-	-	-	-
	319	♂	calf	+++	+++	-	++	-	-	-	-	-
	322	♂	calf	+++	+++	-	-	-	-	-	-	-
	35b	♀	calf	+++	+++	++	-	-	-	-	-	-
	41	♀	calf	+++	+++	-	-	-	-	-	-	-
	42	♀	calf	+++	+++	-	-	-	-	-	-	-
	49	♀	calf	+++	+++	-	+++	-	-	-	-	-
	263a	♀	calf	?	?	?	?	?	-	+++	?	?
	315	♀	calf	+++	+++	-	++	-	-	-	-	-
	321	♀	calf	+++	+++	++	++	-	-	-	-	-
	47	♂	26	+	++	+++	+++	-	-	-	-	-
	158	♂	13	+++	?	-	-	-	-	-	-	-
	374	♂	24	++	+++	-	+++	-	-	-	-	-
	376	♂	23	+	-	-	+++	-	-	-	-	-
	48	♀	16	+++	+++	-	-	-	-	-	-	-
<i>Punuk</i>												
	51	♀	14	++	?	-	-	-	-	-	-	-
	135	♀	11	+++	-	++	++	-	-	-	-	-
	169	♀	14	?	?	?	?	?	+++	-	?	?
	220	♀	23	+	-	-	-	-	-	-	-	++
	271	♀	11	++	++	-	-	-	+++	-	-	-

¹ Degree of severity: +++ most severe, ++ less severe, + least severe, - not present, ? not examined, +? uncertain diagnosis or cause of death unknown

have been struck severe blows by large, blunt objects, the calves had died mainly as a result of extreme torsion of the spine, principally in the cervical region. In addition to tearing and extravasation of the spinal musculature, this torsion and vertebral dislocation produced contusions and hemorrhage of the spinal cord and brain. In each case there was moderate to massive hemorrhagic congestion of the lungs, associated with free blood in the thoracic cavity and bleeding through the nose. In no case were there any broken bones or lacerations of the extremities. The nature of the injuries

indicates that these animals died as a result of being trampled by other, larger walruses on the Salghat haulout.

Female 33 showed some intramuscular hemorrhage in the sternal, intercostal and pelvic regions but no broken bones, no internal bleeding, and no detectable cerebro-spinal damage. She was extremely jaundiced, her blubber being bright yellow, suggesting some dysfunction of the biliary drainage of the liver. Since all of the bile ducts were greatly distended, we presume (but could not demonstrate) that there was blockage of the main ducts proximal to the gall bladder, which was not exceptionally large.

No indications of the cause of death were evident in the remaining three animals.

Punuk Islands

On the North Island of the Punuk Islands, we examined 15 calves and 10 older animals (Table 6). At least 14 of the calves appeared to have died primarily from cerebro-spinal damage due to spinal torsion, as had the three examined on St. Lawrence Island. The fifteenth calf (♀ (or female) 263a), which was not examined internally, showed umbilical hernia through which some of the viscera were extruded.

The pathological conditions in most of the older animals were remarkably similar to those in the calves. Torsion of the cervical spine, cerebro-spinal hemorrhage, and internal bleeding were the most common findings associated with death, followed by two cases of intestinal prolapse, and one case (♀ (or female) 220) of collapsed lungs, due to severe compression.

In none of the cases that we examined in detail on the Punuk Islands was there any evidence of gunshot wounds. Also, there were no outward signs of gunshot in any of the other 441 carcasses there. All of the deaths appeared to have been due to natural causes, which were identified as trauma, trampling, and suffocation. This suggests that the only "causative agents" were the living walruses that hauled out there.

PHYSICAL CONDITION

The thickness of the subcutaneous blubber layer was measured on 17 of the calves and 21 of the older animals, with the objectives of assessing their general physical condition and testing the Eskimos' reports that the animals seen by them in autumn 1978 were mostly very lean. Regrettably, no comparative data were available from animals harvested in previous years during autumn, but comparison was possible with data from harvested animals taken in late winter to summer, 1958 to 1973. The animals that died on St. Lawrence and the Punuk Islands in autumn 1978 had less blubber than their counterparts in previous years (Fig. 5). A G-test for goodness of fit (Sokal and Rohlf, 1969: 575) indicated that the difference was very highly significant ($G = 31.9$, $v = 2$, $p < .005$). The difference was least extreme in the calves, but it must be recognized that those from the 1958-73 harvest samples were about 5 months younger and 20% smaller in length than the autumn 1978 dead calves.

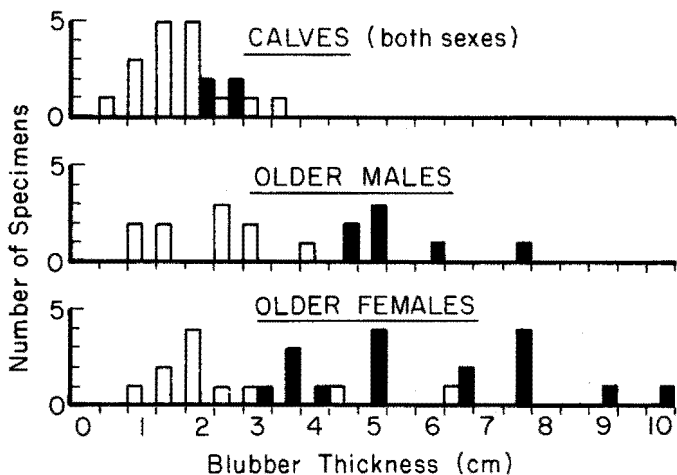


FIG. 5. Frequency of occurrence of blubber thicknesses in carcasses of walrus that died on St. Lawrence and the Penuk Islands in autumn 1978 (open bars), in comparison with that in walrus harvested in late winter to mid-summer, 1958-73 (solid bars).

The greatest differences were seen in the older males and females, which had less than half as much blubber as their 1958-73 counterparts. According to the Eskimos, this is extremely unusual, as they have previously recognized that the walrus (especially the males) are much fatter in the fall than during any other season, with blubber thicknesses of 12 cm or more.

The possibility that the carcasses we examined were not representative of the population as a whole cannot be discounted. That is, it is possible that the animals that died were in exceptionally poor condition and as a result were predisposed to being mortally injured. If they were already weakened, they may have been less able than the others to avoid such injury. However, it is unlikely that the adults that were shot would have been affected by such selection, yet they too had very thin blubber (2-3 cm).

ESTIMATED NUMBERS OF WALRUSES THAT HAULIED OUT

St. Lawrence Island

At the time of our visit, the carcasses of animals that had died at Salghat Beach in the autumn of 1978 were situated along 1.1 km of the shore. This was apparently the full extent of the haulout, as there were no signs of their having used a larger area. In late October, when the animals hauled out on this shore, the beach was about 25 to 30 m wide. They had not advanced onto the tundra above the beach, but some probably were in the intertidal zone below. We have estimated that the total area occupied by the living animals had been at least 1100 by 30 m or about 33 000 m², and that this could have accommodated about 19 000 (\pm 1000) walrus (Table 7).

TABLE 7. Estimated means and extremes of numbers of walrus that hauled out on shore in six locations on St. Lawrence and the Penuk Islands, Bering Sea, in autumn 1978

	Approx. area of haulout (10 ³ m ²)	Estimated thousands of walrus/haulout area occupied		
		Minimum - maximum	Mean range	Rounded
		@ 5 - 1.2 m ² /walrus ¹	@ 1.8 - 1.6 m ² /walrus ²	mean
<i>St. Lawrence I.</i>				
Salghat	33.0	6.6 - 27.5	18.3 - 20.6	19±1
Maknik	60.0	12.0 - 50.0	33.3 - 37.5	35±2
Kialegak	62.5	12.5 - 52.1	34.7 - 39.0	37±2
<i>Penuk Islands</i>				
North Island	53.8	10.8 - 44.8	29.9 - 33.6	32±2
Middle Island	23.0	4.6 - 19.2	13.8 - 14.4	14±0.3
South Island	18.1	3.6 - 15.1	10.0 - 11.3	11±0.3

¹ Based on Krylov (1966)

² Based on Tomilin and Kibal'chich (1975)

It was not possible to determine the dimensions of the Maknik Lagoon haulout, because unfavorable sea conditions prevented a boat landing. The carcasses there were distributed over about 3 km of beach, which was at least as wide as that at the Salghat site, but it is probable that some re-distribution of the bodies had taken place as a result of heavy surf. A conservative estimate of the area covered by the animals is at least 2 km (i.e., about 60 000 which suggests the possibility that about 35 000 (± 2000) walrus had hauled out there. This area is not known to have been used previously as a haulout in autumn. The Eskimos believe that it was used in this case as an alternative to the Penuk Islands, which may have been fully occupied at the time.

Eyewitness accounts by Eskimos who were camped at Kialegak Point in November, when a major walrus haulout occurred, indicated that the animals had occupied about 2.5 km of the shoreline. In one area at the eastern end of the haulout, the walrus were said to have advanced at least 50 m inland, onto the tundra. This was evident during our aerial survey of the shoreline. A conservative estimate of the average overall depth of the haulout is 25 m or more, suggesting that the total area occupied was not less than 62 500 m². The number of animals that could have been accommodated in that area was about 37 000 ± 2000. The abundance of very old walrus bones and teeth found by us in this area in the past suggests that it is an ancient hauling-out site. However, it is not known to have been used as such in the present century prior to 1978.

Penuk Islands

The haulouts on the Penuk Islands were examined in greater detail than those elsewhere, and it is clear that the total area occupied by walrus was at least three times greater in 1978 than at any time in the past 30 years. Prior to 1978, the animals had utilized only the sandspit at the western end of the North Island, which has a low, sloping beach along most of its perimeter. No

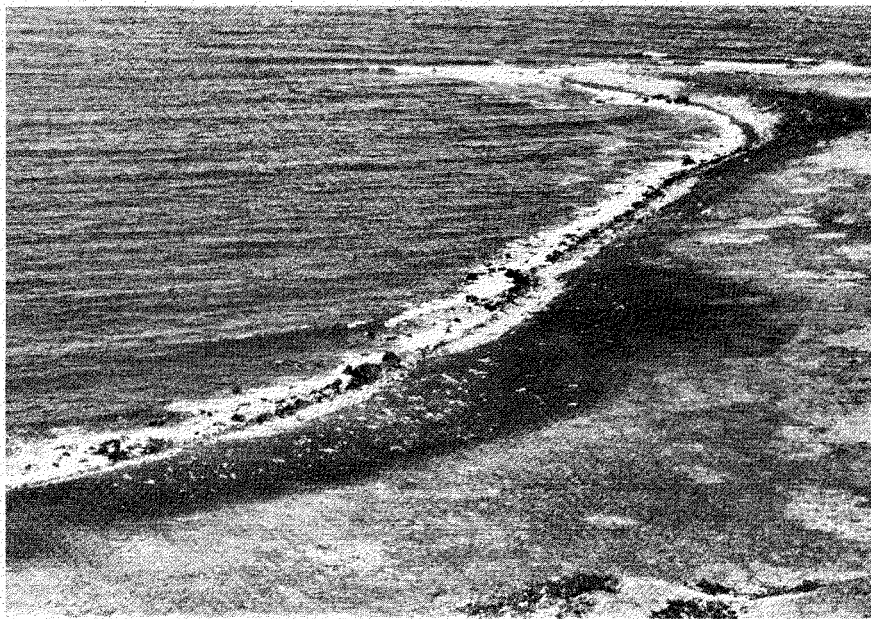


FIG. 6. Walrus haulout area on rocky shore and upland tundra of the northwestern part of North Penuk Island, June 1979. The abundance of exposed rocks in the dark, mucky area occupied by the walruses contrasted sharply with the apparently smoother carpet of vegetation above the haulout.



FIG. 7. Walrus haulout area (foreground and left, above) on the upland tundra of South Penuk Island, June 1979. The impression in the muck made by the body of one animal is evident (center, foreground). At upper right is undisturbed tundra.

part of this spit is elevated more than 3 m above mean sea level, though the remainder of the island, east of the spit, rises much higher and has a steep, rocky shoreline. The higher elevations above the wave-swept shoreline support tundra vegetation, typical of that in well-drained areas on St. Lawrence Island.

In the autumn of 1978, the walrus had occupied nearly all of the sandy beaches of the spit on the North Island, as they had in 1976 and 1977. But they had advanced also onto the tundra along the entire northwestern and northern coasts of the island, as well as over most of the Middle Island and the northern part of the South Island. Where they had invaded the tundra, nearly all of the extant vegetation had been trampled into the mud thawed by the heat of their bodies (Figs. 6, 7), and numerous rocks and old walrus bones were exposed that had not been apparent previously. The abundance of these very old, earth-stained bones in each of the tundra haulouts on the North, Middle, and South Islands suggests that these were ancient hauling grounds that had been used sometime in the distant past.

The total area that had been utilized by the walrus on the North Island in 1978 was about 33 500 m² on the sandspit and 20 000 m² on the northwestern and northern coasts. If all of it was occupied at one time, as the Eskimos' observations suggested, it probably accommodated about 32 000 (\pm 2000) walrus.

The animals had hauled out over the entire Middle Island with the exception of a narrow strip along the southeastern side, and had destroyed nearly all of the tundra vegetation. The area occupied there was about 23 000 m², which could have accommodated some 14 000 (\pm 300) individuals. On the South Island, they had advanced about 50 m onto the tundra and up to 20 m in elevation, covering an area of about 18 100 m². Approximately 11 000 (\pm 300) walrus could have hauled out in this area.

The greater abundance of dead walrus on the western spit of the North Island than elsewhere implies that this area was utilized either more frequently or more intensively than any of the others. Since it has been the traditional haulout site, we presume that the other areas were utilized only when the spit was fully occupied. If all of the areas had been occupied at one time, it is conceivable that some 50 000 to 60 000 walrus were on shore on the Penuk Islands sometime during the late autumn of 1978.

DISCUSSION

The occurrence of large numbers of walrus in autumn at St. Lawrence Island and the nearby Penuk Islands is not in itself unusual. These islands lie directly in the path of the walrus population during its southward migration from summering grounds in the Chukchi Sea to wintering areas in the Bering Sea. The unusual aspects of the 1978 event were (a) the large numbers that came ashore, both in the traditional locations (Penuk Islands and Chibukak Point) and in four other locations on St. Lawrence Island where they had not been present in the memory of the Eskimos living there, and (b) the large

numbers of carcasses that drifted ashore or were found dead on the haulouts, including numerous aborted fetuses. In previous years, a few individual walrus had hauled out on the northern coast of St. Lawrence Island during the autumn migration, but at no regular location other than Chibukak Point, where they first began to do so in 1962 (Fay, unpublished). They were present annually on the Penuk Islands in autumn, at least since the past century (Elliott, 1886), but usually not in numbers great enough to cover more than the sandy beaches of the peninsula on the North Island. In most years, a few carcasses drifted ashore on the northern coast of St. Lawrence Island. A few more were present in most years on the Penuk haulout, including a few calves but no fetuses, according to the Eskimos' reports and confirmed by our observations in the summers of 1962, 1977 and 1978.

The late Lawrence Kulukhon, who resided from 1916 to 1942 at Salghat Beach and who frequented the eastern end of St. Lawrence and the outlying Penuk Islands, reported that between 1930 and 1932 an unusually large number of walrus hauled out in autumn on the Penuk Islands. These were sufficient to cover the southwestern peninsula of the North Island and most of the Middle Island as well. In the following spring, he found about 100 carcasses there, mainly adult females, and several more that had drifted ashore on eastern St. Lawrence Island. A similar congregation occurred in the following autumn, leaving about the same number of carcasses. However, they did not occur there again in such numbers at any time during his residence.

Murie (1936) described the finding by natives of "a number" of walrus carcasses on the Penuk Islands and "near a hunter's camp at East Cape" [Camp Kulowiye?] in the spring of 1935, based on field notes provided by the late Otto William Geist, who spent several years in that area in archeological studies (Geist and Rainey, 1936). Presumably, this was one of the same incidents reported by Kulukhon, for Murie noted (p. 341) that "... this had not been observed probably for the last fifteen years." He reported further that "... practically all of the carcasses were badly crushed" and that their hair had been worn off, apparently as a result of the living animals having crawled over them repeatedly. Most of these were females, but there were some "smaller to medium-sized males" among them. Cahalane (1947), evidently describing the same event, attributed the death of the animals to their being "smothered and crushed" by other walrus, when a herd was driven ashore by killer whales. Schiller (1954) cited the finding by a Savoonga resident of 54 carcasses, mostly females, on the Penuk Islands in June 1949 and indicated that they "... were believed to have been killed [by other walrus] during breeding activities" (p. 208) in the previous autumn. He investigated another case of mass mortality of 52 walrus that occurred near the northeastern end of St. Lawrence Island in October 1951. From his examinations of 14 of these (5♂ : 9♀), Schiller concluded that the occurrence of, "... intestinal prolapse, ... free blood in the body cavity, severe mutilation, and other observations" (pp. 208-209) indicated that the cause of death was "an explosive force."

In late October 1955, about 35 walrus carcasses drifted ashore on the northwestern coast of St. Lawrence Island, during a period of strong northerly winds (W. Caldwell, *in litt.*, 1956). These were mostly bulls, at least one of which had a gunshot wound (from a Soviet bullet, according to the Eskimos). Several others showed broken bones and severe lacerations, regarded as typical of killer whale predation and apparently similar to those examined by Schiller (1954).

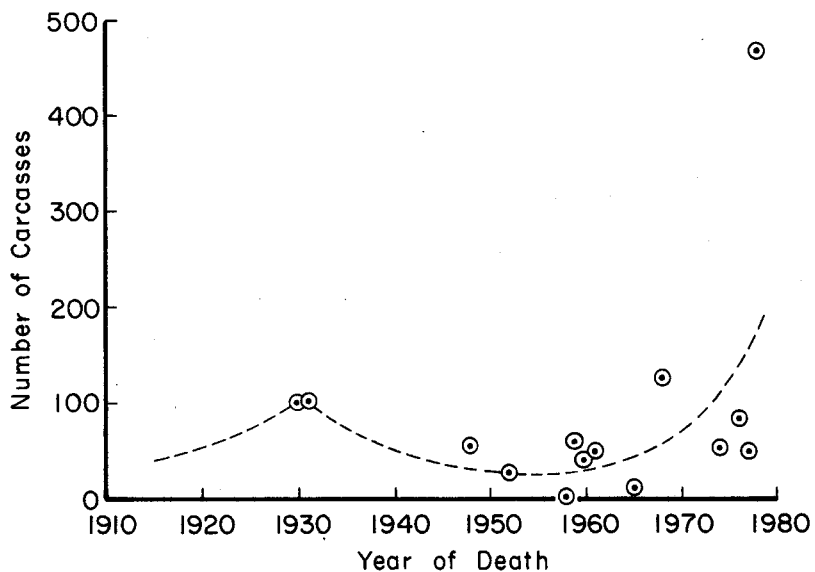


FIG. 8. Numbers of carcasses counted on the Penuk Islands in relation to the year in which the animals died. Dashed line is the suggested trend.

Since 1952, we have attempted to obtain by personal observation and by interview with the St. Lawrence Islanders a continuous record of the number of carcasses found each year on the Penuk Islands. Although we have not succeeded in this, the data obtained, when combined with those of Marks (*In Burns*, 1965: 30-31) as well as the accounts of Kulukhon and Schiller, indicate that the annual numbers have been highly variable, and suggest they tended to be lowest between the late 1940's and early 1960's and have risen dramatically since that time (Fig. 8). This probably has been partly a reflection of increase in size of the walrus population, which is believed to have more than doubled during that period (Estes and Gol'tsev, 1980). We suspect also that it is partly reflective of the changing distribution of the population, which has been especially evident in recent years in the Bering Strait region. There, thousands of walruses have been frequenting the Diomed Islands, King Island, and Arakamchechen Island throughout the summer since the late 1960's, whereas they formerly were scarce to absent in that area in summer (Gol'tsev, 1968; J. J. Burns and F. H. Fay, unpublished).

The amount of mortality on the haulouts at other localities in the Bering and Chukchi Seas also appears to be highly variable and, at times, very

significant. At Cape Blossom, Wrangell Island, Gol'tsev (1968) observed that about 50 carcasses were left on the haulout after some 5000 animals had utilized it in 1958. In the same location in 1964 he found about 500 carcasses that had accumulated in the interim, and he accounted for an additional 250 to 300 that died in that year when 33 000-35 000 animals hauled out there. Tomilin and Kibal'chich (1975) found about 2000 carcasses on the Cape Blossom haulout in August 1972, these having accumulated from previous years. At that time, they observed that 21 calves were trampled and two fetuses aborted during a brief stampede of part of the herd that was utilizing the area. In addition, there were 149 new carcasses on the haulout when a congregation of about 36 000 females and young departed there in September of that year.

This kind of mortality seems to occur only on haulouts occupied by large herds of females and young, and not on those utilized by males alone. For example, in October 1962, when about 10 000 male walrus occupied the Inchoun haulout of northeastern Chukotka, Gol'tsev (1968) found only eight carcasses, none of which showed any signs of "violent death." Similarly, at Round Island in Bristol Bay, Alaska, where some 10 000-12 000 bulls haul out annually during the ice-free season, the number of carcasses on shore of animals dying from natural causes seldom exceeds 20, and few of those show any sign of trauma comparable to that seen in carcasses at Punuk and Cape Blossom (J. Taggart, C. Zabel, B. P. Kelly, and F. H. Fay, unpublished).

In general, our findings have confirmed the Eskimos' allegations that the greater part of the autumn 1978 mortality of walrus in the St. Lawrence Island-Punuk Islands area was due to traumatization by other walrus. Only 5 of 15 carcasses necropsied on St. Lawrence Island were certainly identified as victims of gunshot wounds, and none of 466 on the Punuk Islands had been shot. We did not rule out the possibility that the numerous abortions were caused by an infectious or toxic agent, but the probability of this seems to us less compelling than that of trauma alone. We also confirmed that the dead animals, at least, were in very poor physical condition, as alleged by the Eskimos, but cannot dismiss the possibility that the sample was biased by the weaker animals having been predisposed to this kind of mortality.

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