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A POPULATION STUDY OF THE ALASKA FUR-SEAL HERD

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A POPULATION STUDY OF THE ALASKA FUR-SEAL HERD

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Figure 1. A fur-seal rookery at the height of the pupping season; Polovina, 16 July 1948. A count of harem bulls is conducted in mid-July each year. Large dark bulls, medium-sized cows, and small black pups are closely spaced on the breeding area. Bachelors and subadult males are gathered on the hauling-ground beach area in the background. (VBS 2403)

SUMMARY

Twice since its discovery in 1786-87 the Pribilof fur-seal herd has been exploited to the verge of extermination, first under Russian and later under American ownership. Twice it has recovered. Under the present management system and within the framework of present environmental conditions the herd appears to have reached its population ceiling. At the same time, adjustments within the herd will continue to take place so that, for example, some of the smaller breeding units (rookeries) may continue to grow at the expense of the larger ones. The herd now fluctuates between a late-spring minimum of 1,300,000 seals and a summer maximum of 1,840,000.

To obtain an approximation of the size of the fur-seal herd and its different age and sex classes, the authors have used the accumulated counts of harem bulls, the commercial sealing statistics, field counts and estimates of living and dead pups, returns at various ages of tagged and branded seals, age and mortality data based on the recovery of tags and the reading of teeth for age, studies of reproductive success from seals taken on land and at sea, and aerial photographs of seal rookeries.

The total size of the herd is estimated by three methods, of which the first listed below is considered the most reliable. All figures represent maximum-size estimates of the population, including the newborn-pup increment.

From tag recoveries	1,840,000
From the trend of the commercial harvest	1,670,000
From the trend of the harem bull count	1,550,000

The average number of pups born annually in recent years as estimated by six methods is:

From tag recoveries	530,000
From rapid field estimates	440,000
From sample counts plus ground-area measurements from aerial photos	580,000
From sample counts plus harem-bull counts	470,000
From the trend of the commercial harvest	590,000
From the trend of the harem-bull count	550,000

Although the various estimates differ, all are of a similar order of magnitude, and it can be said with confidence that the approximate number of fur seals in the Pribilof herd is a million and a half. The herd can be expected to fluctuate about its present mean size because of weather conditions, food supply, and mortality from hookworm.

INTRODUCTION

The breeding colonies of fur seals [1/] on the Pribilof Islands were discovered in 1786 and 1787 by Gerassim Pribilof, Russian navigator and fur trader. The herd at the time of discovery was estimated to contain 2,500,000 seals (Sims, 1906, p. 38). In the next 150 years the seals went through alternate periods of intensive exploitation, when their numbers were reduced, and periods of rest, when they were allowed to recover (appendix A). In 1911, when the United States Government took over direct administration of the sealing industry, the seal population had reached an all-time low of about 215,000 animals. Under careful management, backed by the Treaty of 1911 which prohibited pelagic (open-ocean) sealing in the North Pacific, the seal herd recovered rapidly and at the same time returned a profit to the Government.

With renewed growth of the population, the problem of taking a census grew increasingly difficult. The earliest estimates were little more than field guesses. Later, when the herd was at low ebb, maps were drawn and field counts were made with considerable care. Notable among the early investigators were Bryant, Elliott, members of the Jordan Commission, Hanna, Clark, Osgood, Preble, and Parker (see Literature Cited). As a result of their work, a system of computing annually the size and growth rate of the seal herd was established in 1922. This system used as its point of departure field counts of pups and harem bulls as well as counts of bachelors in terms of the numbers killed. In the years that followed, 1923-48, the count of pups was abandoned, and population computations were based largely on earlier counts without renewed evidence of the size of the two most important herd elements, pups and breeding cows. For 10 or 12 years the management was able under this system to predict quite accurately each season's commercial take of seals. Beginning in the late 1930's, the take began to fall each year progressively below expectations. Simultaneously, the computed size of the average harem began to show an increase, from about 42 cows in 1935 to about 94 in 1947. This increase (on paper) developed through use of a system wherein the number of cows and pups was computed annually along a straight line of increase, with little regard for observations that the kill and the count of harem bulls failed to increase in a similar way. It was not realized that the growth trend of the herd was following a sigmoid curve, rather than a rectilinear one, and consequently was flattening out as it approached its natural ceiling. By 1940 it became obvious that the old system of computation was no longer applicable--that the herd was approaching its population limit, a limit imposed by the natural, as well as artificial, factors of life and death. Published computations of the size of the herd based on the old extrapolation procedure are shown in table 1.

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1/ *Callorhinus ursinus* Linnaeus, 1786

Table 1.--Published computations of the size of the seal herd, by years, 1911-47.

[As of the end of the pupping season, or about 10 August each year. Data from Bureau of Fisheries and Fish and Wildlife Service. Estimates for the last 10 years are undoubtedly too high. There have been no published estimates since 1947 and the formula by which these estimates were obtained is no longer applicable.]

Year	Number of seals	Year	Number of seals
1911	123,600	1930	1,045,101
1912	215,738	1931	1,127,082
1913	268,305	1932	1,219,961
1914	294,687	1933	1,318,568
1915	363,872	1934	1,430,418
1916	417,281	1935	1,550,913
1917	468,692	1936	1,689,743
1918	496,432	1937	1,839,119
1919	524,235	1938	1,872,438
1920	552,718	1939	2,020,774
1921	581,443	1940	2,185,136
1922	604,962	1941	2,338,312
1923	653,008	1942	2,585,397
1924	697,158	1943	2,720,780
1925	723,050	1944	2,945,663
1926	761,281	1945	3,155,268
1927	808,870	1946	3,386,008
1928	871,513	1947	3,613,653
1929	971,527		

Management of the fur-seal herd was under the jurisdiction of the Bureau of Fisheries until this organization was succeeded by the Fish and Wildlife Service in 1940. In the same year, studies were begun to determine as closely as possible the true size of the herd. These studies were interrupted by World War II, but after its termination the biologists working cooperatively with management officials were able to determine the approximate size of the herd and of its various age and sex components, through the use of accumulated statistics and new research techniques. The present report is an essential step toward a better understanding of the Alaska fur-seal herd, a resource which furnishes revenue and a livelihood to nationals of the United States and Canada.

The purpose of this report, then, is to show the average size of the Pribilof seal herd today, to trace briefly its fluctuations in the past, and to describe the methods used in estimating the population.

Sources and methods

An exact enumeration of the number of living seals at any particular time during the year is impossible. The number of seals alive changes constantly during the year. Mortality through natural and artificial causes combined is high. For example, it is about 74 percent for both sexes up to age 3 from natural causes alone, and nearly 99 percent for males up to age 5 from natural and artificial causes combined. From sealing records, counts, and calculations, the sizes of all age and sex classes in the herd have been estimated. Data gathered from seals taken at sea and on the breeding islands during the recorded history of the Pribilofs have been used, although the most useful and important data are those accumulated since 1947.

Studies of the fur-seal population are still in progress and are planned for the future. Since new data are accumulating annually, and because of the volume of statistical work necessary in analyzing these new data, the writers have set deadlines for inclusion of source material in the current report: (1) Tag recoveries, series A, through the summers of 1950 and 1951. (2) Age composition of the kill from tooth-ridge counts in 1950, 1951, and 1952. (3) Pregnancy rate; samples of females taken 1944-1952 inclusive from St. Paul Island, Sitka, and Northwest Coast are combined. (4) Commercial kill and annual count of bulls, through 1951.

Certain terms unfamiliar to the reader, or familiar terms with an unusual meaning may be found in the Jordan report (1898-99).

Counts and measurements of seals

Sealing statistics include the numbers and length-measurements of all seals taken in commercial sealing operations on the Pribilofs since 1918 and, collectively, are one of the best sources of population data.

Bull counts conducted annually since 1905 by the general manager of the Pribilofs are also of great value. Pups were counted on the Pribilof rookeries between 1912 and 1924. Counting was discontinued when, as the herd grew, the numbers rose above 200,000. It was resumed in 1948 for the purposes of the present study. Sample counts of living pups and complete counts of dead pups have been used in conjunction with breeding-ground area measurements based on aerial photographs. Pup counts have also been studied in relation to bull counts and to counts of bachelors killed. Evidence on the number of pups born on the Pribilofs in recent years has been derived from 19,183 seals tagged as pups in 1947, of which 2,413 were recovered at ages 3 and 4 during commercial killing operations. In addition to the tagged animals used in this study, annual tagging programs were conducted in 1948, 1949, 1951, 1952, and 1953. For every tagged seal recovered, the time and place of tagging and recovery and the body length at time of recovery are recorded.

Age determination

The ages of all seals tagged as pups and later recovered are known directly. The ages of untagged animals are determined from tooth-ridge counts. The teeth of a seal show a series of annular ridges on the dentine, or ivory, of the root (fig. 2). These are a result of changes in the physiological condition of the seal during the year. Ridges are formed during the winter, and depressions during the summer (Scheffer, 1950a). They usually provide reliable readings for ages both of males and of females, up to 10 or 12 years. Other features, such as length of tooth, attrition of the crown, and closure of the pulp canal, provide additional evidence of age. Teeth recovered from a large series of tagged seals whose ages are accurately known have provided standards for age determination. Since 1949 it has been the practice to save the right upper canine from every seal skull which is expected to have subsequent research value.

A random sample of 20 teeth was taken daily from the killing fields in 1950, 1951, and 1952 (with some exceptions during the first few days of the season). Each tooth was read for age. Studies were then made of the age composition of the entire kill as well as the age variation during different periods in the season, among the different hauling grounds, and in different years.

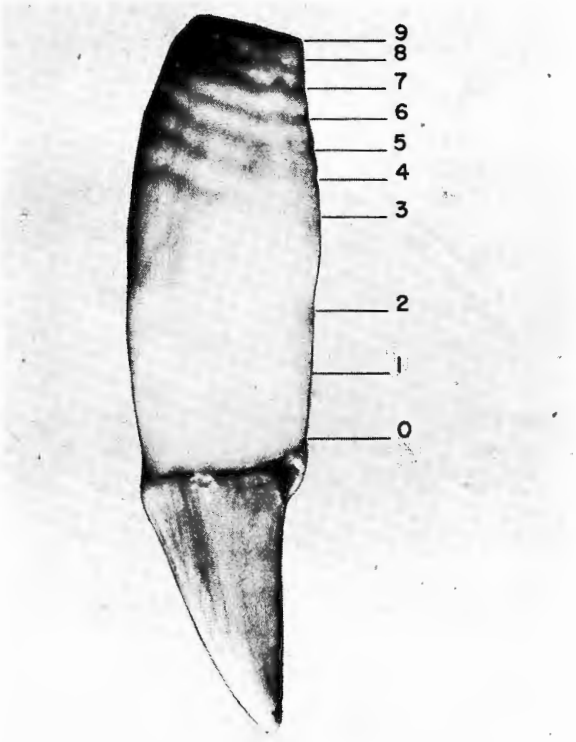


Figure 2. Fur-seal tooth. Right upper canine of a known-age (tagged) 9-year female seal showing annular growth-ridges on the root: actual length of tooth 35 mm. (VBS 2898A)

COMPONENTS OF THE HERD

The census of the seal herd might logically be arranged in two primary divisions, male and female, further subdivided into age classes from 0 to 30 years. However, on the Pribilofs the seals group themselves into several natural categories according to the social structure of the breeding ground (fig. 3). During many years of commercial sealing a terminology for these categories has developed. The terms--bull, bachelor, pup, cow, and yearling--have been borrowed from a variety of zoological sources. Since they are well established in the records of the sealing industry, they are used in the present study. In a final census of the herd (page 37) an additional breakdown by age and sex classes is attempted. In the present discussion the herd components are treated from known to unknown, the bulls (easily counted) first and the yearlings (estimated) last.

Figure 3. Social structure of the breeding ground. Tolstoi rookery and hauling ground. In foreground are breeding seals and pups; beyond the breeding area, the idle bulls are massed. Males nearest the rookery are generally the most virile and alert; they await an opportunity to charge into the breeding area to forcefully displace an exhausted harem master. In the distance are two groups of bachelors, 2 to 5 years old; from similar groups the commercial kill is taken. Photo taken 15 July during annual count of harem bulls at height of breeding season. (KWK 51 653)

Bulls

Adult males, known as bulls, are divided into two classes: harem bulls and idle bulls. A harem bull is a bull guarding one or more cows on the breeding ground and is easily classified. A harem bull may remain continuously with his harem without water or food for a considerable period. Bartholomew (1953) observed that the total period of harem duty for 16 bulls ranged from 18 to 41 days with a mean of 31 days. The longest recorded period is 59 days (Scheffer, 1950b) but some bulls undoubtedly remain longer. The idle-bull group includes (1) subadults not large enough to win a place on the breeding grounds, (2) senile animals whose worn teeth and lack of physical vigor deny them access to the breeding area, (3) exhausted bulls which have spent their strength on the rookeries and have retired to the hauling grounds. The idle bulls are vaguely defined, since the distinction between an idle bull and a large bachelor is a matter of personal opinion. For the purpose of tables and computations an arbitrary dividing line must be drawn between bulls and bachelors. The writers have followed tradition and drawn this line between the sixth and seventh years. The known facts concerning sexual maturity in the male are outlined in appendix B.

Counts of bulls

Harem-bull statistics obtained by direct count over a period of years (and from aerial photographs of Sivutch rookery in 1948) provide a valuable index of the size and growth of the herd. Each year since 1905, Government officials in charge of the Pribilofs have conducted a harem-bull census (Sims, 1906). Before 1905, counts were made infrequently. Table 2 shows the annual bull count since the cessation of pelagic sealing in 1911. The general manager now makes his count in mid-July, completing it in 8 to 10 days. On the basis of their proximity to cows, he classifies the bulls as harem or idle. After the early morning sealing drive from a hauling ground, the manager walks along the adjacent rookery where, from the ground and from elevated walkways, he counts the bulls holding harems (fig. 4). The count is probably accurate within 5 percent, since the harem bulls are a stable group and they stand out clearly above the smaller cows clustered around them. Simultaneously, the manager counts the idle bulls which are scattered near the fringes of the rookeries (fig. 5). Since some are patrolling the seaward margins of the rookeries and others have been driven with the bachelors to the killing field, the count of idle bulls is probably accurate within 20 percent only. Table 3 gives a breakdown of the bull count by rookeries in recent years. Over a long period, 1926-51, the ratio between the number of harem bulls on St. Paul and those on St. George has remained quite constant; of the total number of harem bulls an average of about 82.9 percent occurred on St. Paul and 17.1 percent on St. George (table 4). Table 5 shows the trend of the bull count since 1911, fitted to a smooth curve.

Table 2.--Number of harem and idle bulls counted annually on the Pribilofs, 1911-51.

[From U. S. Bureau of Fisheries except for 1914, from Osgood, Preble, and Parker (1915, p. 27), and for 1951, from the general manager's report. Counts were not made on St. George Island in 1936 and 1938, because of bad weather, and on either island in 1942, because of war. In the annual counts from 1940 to 1948, arbitrary values of 400 harem and 165 idle bulls for Sivutch rookery (Sea-Lion Rock, St. Paul Island) were used; from 1949 to 1951, counts of 150 harem and 50 idle bulls were used, based on aerial photographs taken on 15 July 1948. Starting in 1950 the Sivutch bulls are included in the Reef rookery count.]

Year	St. Paul Island		St. George Island		Both islands	
	Harem	Idle	Harem	Idle	Harem	Idle
1911	1,090	258	266	71	1,356	329
1912	1,077	93	281	20	1,358	113
1913	1,142	77	261	28	1,403	105
1914	1,316	159	243	13	1,559	172
1915	1,789	546	362	127	2,151	673
1916	2,948	2,278	552	354	3,500	2,632
1917	4,166	2,341	684	365	4,850	2,706
1918	4,610	2,245	734	199	5,344	2,444
1919	4,573	2,158	585	81	5,158	2,239
1920	3,542	1,078	524	83	4,066	1,161
1921	3,443	711	466	36	3,909	747
1922	3,184	493	378	15	3,562	508
1923	3,051	303	361	9	3,412	312
1924	3,127	375	389	15	3,516	390
1925	3,103	283	423	28	3,526	311
1926	3,478	368	556	55	4,034	423
1927	3,916	846	727	126	4,643	972
1928	5,059	1,208	991	241	6,050	1,449
1929	5,998	1,339	1,189	294	7,187	1,633
1930	6,823	1,555	1,489	344	8,312	1,899
1931	7,557	1,519	1,676	369	9,233	1,888
1932	8,268	1,940	1,820	409	10,088	2,349
1933	8,334	1,933	1,879	408	10,213	2,341
1934	8,841	1,860	1,929	422	10,770	2,282
1935	9,444	2,082	2,103	453	11,547	2,535
1936	10,055	2,253	-----	---	------	-----
1937	10,689	2,516	2,411	515	13,100	3,031
1938	10,720	1,787	-----	---	------	-----
1939	9,122	2,616	1,858	357	10,980	2,973
1940	9,662	3,968	1,988	571	11,650	4,539
1941	10,089	5,059	1,942	396	12,031	5,455
1942	------	-----	-----	---	------	-----
1943	10,948	3,523	2,107	330	13,055	3,853
1944	11,080	2,539	2,294	450	13,374	2,989
1945	10,750	4,055	2,434	750	13,184	4,805
1946	10,566	3,605	2,430	611	12,996	4,216
1947	10,160	3,331	1,808	479	11,968	3,810
1948	10,386	3,400	1,814	563	12,200	3,963
1949	9,304	2,861	1,745	552	11,049	3,413
1950	9,442	3,152	1,959	574	11,401	3,726
1951	9,434	3,581	1,825	549	11,259	4,130

Figure 4. The harem-bull count. General Manager Clarence L. Olson counting harem bulls on Reef rookery at the height of the pupping season, 15 July 1949. Towers and walkways provide safe vantage points for the observer. The pole is carried both as an aid in counting and to ward off charging bulls. Painted numbers on the rocks define boundary areas to aid the counter and identify camera stations (VBS 2620).

Fecundity of bulls

From the observations noted in appendix B, the suggested pattern of maturity of the males is as follows: The male seal produces spermatozoa at age 3 or 4, is sexually mature at age 5 or 6, begins to breed at age 7 to 9, and attains the status of a peak-of-the-season breeder, or harem master, at about 12 to 15. Judging from their worn teeth, many large harem masters may be at least 20 years old. Three branded males 18 years old were seen in 1938 holding large harems (U. S. Bureau of Fisheries, 1938, p. 163). While the foregoing is the probable pattern, it does not exclude the possibility that some 6-year-olds breed, or that some bulls are fully prime by age 10 or 11.

On the basis of population estimates, about 46 pups are born for each organized harem counted on the Pribilof Islands in mid-July. This does not mean that, on the average, each counted harem bull fathers 46 pups. The mid-July bull may occupy a territory which will be occupied later in

the season by another bull. As a rule, the mid-July bull is succeeded by a younger male which impregnates late-arriving young females. The ratio, (total number of pups born) / (total number of harems counted in mid-July) is called the "average harem" in records of the fur-seal industry (e.g., U. S. Bureau of Fisheries 1947, p. 74). The size of the average harem is discussed in appendix C.

Figure 5. Idle bulls. Idle bulls along the landward edge of Gorbatch rookery at the height of the breeding season, 15 July 1944. Among the idle bulls are a few bachelors 3 or 4 years old. Idle bulls also cruise in the water along the seaward edge of the rookery searching for an opportunity to invade the breeding area, and several are visible on the rocks at the water's edge. The branded bull (right foreground) was presumably marked in the 1927-29 series and is 18 to 21 years old (VBS 1706).

Bachelors

Male seals after their first year and before age 7 are called bachelors (figures 1, 3, and 7). They gather in large groups to sleep and play on hauling grounds near the breeding areas. Little is known of their coming and going during the summer, except that they appear on land in order of decreasing age, the 2-year-olds and yearlings arriving last.

Table 3.--Harem and idle bulls counted in 1949, 1950, and 1951 by rookeries.
[See headnote, table 2]

Rookery	1949 Harem	1949 Idle	1949 All bulls	1950 Harem	1950 Idle	1950 All bulls	1951 Harem	1951 Idle	1951 All bulls
St. Paul Island									
Ardiguen	114	14	128	105	10	115	102	12	114
Gorbatch	828	422	1,250	845	525	1,370	802	598	1,400
Kitovi	509	62	571	512	45	557	500	79	579
Little Polovina	203	34	237	270	55	325	252	75	327
Little Zapadni	518	142	660	498	111	609	482	122	604
Lukanin	178	25	203	184	60	244	179	36	215
Morjovi	468	138	606	579	195	774	686	317	1,003
Polovina	294	178	472	312	190	502	324	275	599
Polovina Cliffs	512	112	624	649	93	742	788	187	975
Reef	1,806	835	2,641	1,587	701	2,288	1,618	826	2,444
Sivutch	150	50	200	150	50	200			
Tolstoi	1,050	204	1,254	1,055	276	1,331	943	273	1,216
Vostochni	1,572	358	1,930	1,510	494	2,004	1,621	475	2,096
Zapadni	960	237	1,197	1,028	287	1,315	995	266	1,261
Zapadni Reef	142	50	192	158	60	218	142	40	182
Subtotal	9,304	2,861	12,165	9,442	3,152	12,594	9,434	3,581	13,015
St. George Island									
East Cliffs	222	95	317	217	90	307	220	70	290
East Reef	113	35	148	110	35	145	124	45	169
North	571	137	708	770	141	911	646	154	800
South	202	52	254	214	60	274	206	40	246
Staraya Artil	363	165	528	386	178	564	372	195	567
Zapadni	274	68	342	262	70	332	257	45	302
Subtotal	1,745	552	2,297	1,959	574	2,533	1,825	549	2,374
Both islands	11,049	3,413	14,462	11,401	3,726	15,127	11,259	4,130	15,389

Table 4.--Comparison of St. Paul and St. George Islands with respect to number of harem bulls and number of seals killed, 1926-51.

[See headnote, table 2]

Year	Number of harem bulls, both islands	Percent harem bulls on St. Paul	Number of all seals killed, both islands	Percent seals killed on St. Paul
1926	4,034	86.2	22,131	73.3
1927	4,643	84.3	24,942	76.2
1928	6,050	83.6	31,099	74.0
1929	7,187	83.5	40,068	82.9
1930	8,312	82.1	42,500	80.9
1931	9,233	81.8	49,524	80.7
1932	10,088	81.9	49,336	80.0
1933	10,213	81.6	54,550	81.5
1934	10,770	82.1	53,468	80.4
1935	11,547	81.8	57,296	80.0
1936	------	----	------	----
1937	13,100	81.6	55,180	79.9
1938	------	----	------	----
1939	10,980	83.1	60,473	78.8
1940	11,650	82.9	65,263	79.1
1941	12,031	83.9	95,013	83.5
1942	------	----	------	----
1943	13,055	83.9	117,164	81.4
1944	13,374	82.8	47,652	83.6
1945	13,184	81.5	76,964	76.2
1946	12,996	81.3	64,523	81.3
1947	11,968	84.9	61,447	81.0
1948	12,200	85.1	70,142	83.1
1949	11,049	84.2	70,891	81.0
1950	11,401	82.8	60,090	81.0
1951	11,259	83.8	60,689	83.3
Total	240,324		1,330,405	
Mean	10,449	82.9	57,844	80.5

Table 5.--Number of harem bulls on the Pribilofs, 1911-51; comparison of empirical data with estimates based on fitting a logistic curve.

[See headnote, table 2]

Year	Empirical (counted)	Theoretical	Year	Empirical (counted)	Theoretical
1911	1,356	-----	1931	9,233	9,195
1912	1,358	-----	1932	10,088	9,867
1913	1,403	-----	1933	10,213	10,422
1914	1,559	-----	1934	10,770	10,869
1915	2,151	-----	1935	11,547	11,220
1916	3,500	-----	1936	------	11,490
1917	4,850	-----	1937	13,100	11,696
1918	5,344	-----	1938	------	11,851
1919	5,158	-----	1939	10,980	11,967
1920	4,066	-----	1940	11,650	12,053
1921	3,909	-----	1941	12,031	12,116
1922	3,562	-----	1942	------	12,163
1923	3,412	-----	1943	13,055	12,198
1924	3,516	1/ 3,032	1944	13,374	12,222
1925	3,526	3,808	1945	13,184	12,241
1926	4,034	4,680	1946	12,996	12,254
1927	4,643	5,621	1947	11,968	12,264
1928	6,050	6,587	1948	12,200	12,272
1929	7,187	7,531	1949	11,049	12,277
1930	8,312	8,411	1950	11,401	12,281
			1951	11,259	12,283

1/ The logistic curve fits the observed increase (field count) of bulls from about 1924 on.

It is from the hauling grounds that the commercial harvest is taken.

Statistics of the commercial kill

The commercial sealing season begins about 20 June and ends not earlier than 27 July. The beginning is determined by the arrival of bachelor seals in commercially important numbers, the end by two considerations. First, in order to reserve male breeding stock, the season is closed before all the bachelors in the commercial age classes have arrived. Second, during the last few days of July the number of females and 2-year-old bachelors on the hauling grounds, and thus on the killing fields, increases rapidly. These unwanted animals interfere with sealing operations. In general, Pribilof sealing procedures have remained quite uniform since 1918.

Figure 6. A young harem bull. A tagged 7-year-old bull holding a small harem at the edge of Tolstoi rookery. Note the metal tag at the base of his right front flipper. Few males hold harems before the age of 10 or 12, at which time they become large enough to force their way on to the breeding grounds (KWK 48 28).

The objective of the sealers is to kill males 41 to 45 inches in length. From 1913 to 1918 age-length standards were established for male seals ages 1 to 6 by means of measurements taken by G. Dallas Hanna from known-age seals branded as pups in 1912 (U. S. Bureau of Fisheries, 1918, p. 96. See appendix D). The length of every male seal killed in the commercial harvest since 1918 is on record. The records include more than 1,500,000 seals, by day and place of kill, and have proved useful in the present study as indexes of the relative abundance of bachelors from one year to the next.

Recent studies of the size-to-age relation in seals reveal that the age-length standards established before 1918 are no longer a true indication of age. For example, males measuring 41 to 45 inches in length have been considered 3-year-olds. Age studies between 1949 and 1952, based

on approximately 2,800 tooth readings for age as discussed previously, show that about one-third of the seals in this length group are actually 4-year-olds and a few are 2's and 5's. Similarly, studies of 4,196 tagged, known-age seals recovered on the killing fields indicate a discrepancy in the age-length standards. The biologists now use the term "group-III males" rather than "3-year-old males" in referring to the 41- to 45-inch length class (appendix D).

Figure 7. Measuring the length of a bachelor seal. For each male seal killed during the commercial sealing operations the length from tip of snout to base of tail, to the nearest inch, is recorded. The clubbers attempt to kill seals within the limits 41 to 45 inches, since animals within these limits, collectively designated as group III in this report, furnish the skins best adapted to commercial use. (VBS 2061).

The annual kill of group-III males since the effective date of the Treaty of 1911 is shown in table 6 and figure 13. Also shown in table 6 is the theoretical group-III kill, obtained from a logistic curve fitted to the observed data. As is the case in fitting a logistic curve to the harem-bull counts (table 5), the agreement is reasonable. The kill by decades of all seals since the discovery of the Pribilofs is shown in table 17 and is discussed in appendix A. The kill of all seals on the Pribilofs

and the percent killed on St. Paul were shown in table 4.

Since the group-III kill is a composite of several age groups, it is important in a population study to evaluate the kill by age groups. The age composition of annual kills in eight postwar years are shown in table 7. This table is based on the estimates of age composition obtained from tooth-sample age determinations, discussed in appendix D.

Table 6.--Number of group-III male seals killed annually on the Pribilofs, 1918-51. Comparison of empirical data with estimates based on fitting a logistic curve.

[Males measuring 41 to 45 inches in length taken during the regular sealing season ending not later than 10 August, and exclusive of seals taken by natives in the fall for food. From 24 August 1912 to 24 August 1917, commercial sealing was prohibited; food killings were abandoned on 18 November 1929. Theoretical estimates are based on fitting a logistic curve.]

Year	Empirical (counted)	Theoretical	Year	Empirical (counted)	Theoretical
1918	16,454	------	1933	52,747	48,247
1919	15,042	------	1934	51,935	50,682
1920	18,831	------	1935	54,890	52,727
1921	19,530	------	1936	49,566	54,414
1922	29,153	------	1937	50,800	55,784
1923	12,992	------	1938	54,140	56,885
1924	16,083	15,987	1939	56,520	57,769
1925	17,612	19,283	1940	59,945	58,450
1926	19,777	22,911	1941	1/ 76,036	58,986
1927	22,699	26,782	1942	1/ 114	59,420
1928	28,539	30,777	1943	68,189	59,745
1929	38,079	34,760	1944	43,267	60,006
1930	41,409	38,598	1945	71,286	60,201
1931	47,767	42,174	1946	58,780	60,352
1932	47,625	45,406	1947	49,911	60,472
			1948	64,784	60,562
			1949	64,309	60,638
			1950	56,123	60,679
			1951	53,904	60,700
		Total		1,428,838	

1/ Islands under military occupation

Table 7.--Number and estimated ages of male seals killed on the Pribilofs, 1945-52.

[Ages estimated from tooth-ridge counts on St. Paul Island in 1950, 1951, and 1952; on St. George in 1951 and 1952.]

Year	All ages (100%)	2-year-olds (1%)	3-year-olds (62%)	4-year-olds (35%)	5-year-olds (2%)
1945 1/	76,390	764	47,362	26,736	1,528
1946	64,028	640	39,697	22,410	1,281
1947	61,153	611	37,915	21,404	1,223
1948	69,893	699	43,334	24,462	1,398
1949	70,654	707	43,805	24,729	1,413
1950	59,921	599	37,151	20,972	1,199
1951	60,504	605	37,513	21,176	1,210
1952	63,670	637	39,475	22,285	1,273
Total	526,213	5,262	326,252	184,174	10,525
Mean	65,777	658	40,781	23,022	1,316
Subtotal, 1950-52	184,095	1,841	114,139	64,433	3,682
Mean, 1950-52	61,365	614	38,046	21,478	1,227

1/ Excluding 1 bull.

An analysis of the age composition shows considerable uniformity, on the average, between hauling grounds and between the different years sampled. On the other hand, age composition changes throughout the killing season, the proportion of 3's tending to increase as the season advances. This is in complete conformity with the results from the tagging studies and with observations that 4-year-olds tend to haul out on the islands earlier than 3-year-olds.

As stated previously, sealing methods have been quite uniform for the past 33 years. However, certain irregularities should be mentioned. Before 1928 it was the custom to take a few hundred seals in the fall in "food killings" to supplement the local meat supply. And before 1933 a certain number of bachelors were spared during the killing season as future breeding stock. These were marked by shearing the tops of the heads. During the World War II years 1942-43 sealing practices were upset by military occupation.

After the sealing harvest ceased to increase annually as it had during the 1920's and early 1930's some of those interested in the size of the commercial harvest proposed an explanation, paraphrased as follows: "Perhaps seals of killable age exist today in far greater numbers than

anyone realizes but are, year after year, postponing their time of arrival on the breeding islands until after the sealing season. Many may even remain at sea during their entire bachelor life. As a result, the Government is harvesting a smaller percentage of the herd than it should, while at the same time the herd has actually reached a population of millions." If this were true, the harem-bull population would increase both in actual numbers and in proportion to the commercial kill, but it does not. The harem-bull count represented 20.3 percent of the group-III kill for the period 1931-35, 22.6 percent for the period 1936-48, and 20.5 percent for the period 1946-51 (tables 2 and 6).

Escapement of bachelors from the kill

The escapement includes all bachelors that live through their third and fourth years, the survivors eventually becoming the male breeding element of the herd. Escapement may be divided into two categories: (1) Postseason escapement, including not only the bachelors that arrive on land after the killing season but also the fraction that may remain at sea; and (2) through-the-season escapement, including animals too large or too small to be selected in the kill.

Field observations and tag returns show that the homing instinct becomes stronger with increasing age. Few yearling seals return to the Pribilofs, and those that do, arrive in the fall. Two-year-olds are distinctly juvenile and return in midsummer. Three-year-olds, also juvenile with few exceptions, return in early summer. The peak of arrival of succeeding age classes falls progressively earlier in the season, and the assumption appears justified that only the attendance of the juvenile classes on the Pribilofs is incomplete. Present indications are that all 4-year males return to the breeding islands. The fact that the number of breeding bulls does not increase substantiates the assumption that most 3- and all 4-year males return to the breeding islands and are included in the escapement figures. There is no clear proof that on-the-ocean escapement is important, and it is convenient to include it under postseason escapement. The escapement of 3-year and 4-year males from the kill is discussed in appendix E. On the basis of A-tag returns in 1950 and 1951 the following breakdown is obtained:

	Average escapement for 1950-52 of --			
	3-year males		4-year males	
	Number	Percent	Number	Percent
Males killed	38,046	60	21,478	79
Through-the-season escapement	3,805	6	3,262	12
Subtotal: males arriving on killing fields . .	41,851	66	24,740	91
Postseason escapement . . .	21,559	34	2,447	9
Total	63,410[1]	100	27,187[2]	100

1/ 3-year males alive at start of kill, excluding natural mortality during the summer, which is relatively unimportant.

2/ 4-year males alive at start of kill.

Pups

Virtually all seals are born between mid-June and the end of July. The young fur seal is called a pup until it is 5 or 6 months old, at the end of December. Thereafter for 12 months it is called a yearling. The number of pups born each summer is an extremely important census figure for several reasons. (1) It is the only clue to the number of breeding cows. (2) It is an index of the reproductive status of both male and female elements of the herd. (3) Its fluctuations are an indication of changes in the size of the total herd. (4) Its fluctuations could, under a perfected method of rapid field estimates, be a guide to the management in planning commercial sealing operations.

Six different estimates of the numbers of pups born on the Pribilof Islands in the years 1947 through 1951 are presented below. These estimates, based on a variety of data and methods, differ, but are all of a similar order of magnitude. The most objective estimates are those based on tagged seals, ages 3 and 4, recovered in the commercial kill. Because it is believed that tag-recovery estimates are the most reliable, they are given the most weight in arriving at a mean value for number of pups born and are also used in estimating certain mortality rates in the herd.

For the purpose of this study the sex ratio among pups is considered to be 1:1. Among 1,172 fetal seals taken at sea, mostly during April and May, the percentage of males was 52.7 and of females 47.3 (International Fur Seal Investigation, 1954, MS). The sex ratio among 1,000 living pups on 4 August 1950 was 50.5 percent males and 49.5 percent females.

The increase of pups from 1912, when the Treaty of 1911 took effect, to 1924, when pup counting was discontinued as impractical, is shown in table 8.

Size of the pup class in 1947 as derived from tag recoveries in 1950 and 1951.

In 1947, metal tags marked in the "A" series were placed on the left front flippers of 19,183 seal pups of both sexes (fig. 8). Also, a quarter-inch hole was punched in the web of the left hind flipper between the first and second digits. In 1948, metal tags of the "B" series were placed on the left front flipper of 19,532 seal pups of both sexes. The primary objective of the marking program was the recovery of tagged seals at age 3 and 4 in the commercial kill, to permit calculations of the size of the pup crop in the year of tagging. Other objectives were information on mortality rates, migration, homing instinct, and growth.

Tag-and-sample method.—The procedure of tagging animals and subsequently sampling them to obtain a population estimate has been

extensively used. With fur seals, unfortunately, the method requires 3 years for results. If data to be used in forecasting the commercial kill from the pup class of any given year were required, it would be necessary to resort to a more direct method, say, rapid field estimating or sample counting on selected index rookeries.

Table 8.--Number of pups counted on the Pribilofs, 1912-24.

[Scattered and incomplete counts were made before 1912 and are not comparable with later series. For example, see Jordan 1898, part 1, pp. 92 and 96.]

Year	St. Paul Island counted out of 16 rookeries[1]	Number of pups on all St. Paul rookeries[2]	St. George Island counted out of 6 rookeries[3]	Number of pups on all St. George rookeries	Number of pups on all Pribilof rookeries[2]
1912	all	70,035	all	11,949	81,984
1913	all	79,458	all	12,811	92,269
1914	all	79,383	all	13,867	93,250
1915	all	88,137	all	15,390	103,527
1916	all	98,855	all	18,122	116,977
1917	8	108,689	3	19,335	128,024
1918	4	122,617	3	20,298	142,915
1919	5	133,914	4	23,258	157,172
1920	5	143,275	3	24,252	167,527
1921	5	149,865	3	26,790	176,655
1922	all	158,886	all	27,028	185,914
1924	5	172,528	3	35,868	208,396

1/ Pups were counted on tiny Lagoon rookery from 1912 to its disappearance in 1942, leaving 15 rookeries on St. Paul Island.

2/ Total living and dead; where counts were made on part of the rookeries, estimates were projected to the uncounted ones.

3/ In 1915 South rookery was first listed by name although a few seal pups had been seen there as early as 1912. In 1915 Little East rookery was abandoned and the name was dropped. The total effect was to leave 6 rookeries on St. George.

Normally when a single tagging operation is conducted, the population estimate is based on the Petersen formula (Ricker, 1948, p. 39). This assumes that a random sample is taken of the population so that the unknown percentage of the population marked may be equated to the known percentage of marks or tags obtained in the sample. Here the population estimate is based on the number of male pups alive at the time of tagging on St. Paul in 1947. Several complicating factors immediately arise.

The "sample" is the commercial kill. Since only 3-year-olds could bear A-tags in 1950 and only 4-year-olds could be so tagged in 1951, it is necessary to estimate the number of 3-year-olds in the 1950 kill and the number of 4-year-olds in the 1951 kill. The sample is a composite of these two totals. A further adjustment must be made for the fact that in 1950 and 1951 the sealers were instructed to kill for tags -- see the headnote to table 19.

Figure 8. Pup tagging. A seal pup is held on the table while a metal tag is clamped to the left foreflipper and a perforation is made in the web of the left hindflipper. Pups awaiting tagging are restrained by a portable corral. Polovina rookery 24 September 1947 (KWK 47-35-11).

The most important complication is caused by the homing instinct of the fur seal. This is well illustrated by table 29. Since varying numbers of tags were placed on the different rookeries, the sample is not necessarily random with respect to tag recoveries, and the Petersen formula will be invalid. This problem of heterogeneity in tagging and sampling operations has been discussed by Schaefer (1951). A method of estimating the population size under these circumstances has been given by Chapman and Junge (1953, MS). The method has been applied to the A-tag returns to yield the following results. Calculations and discussions are given in appendix F, and a brief summary here.

Estimated number of pups alive on St. Paul Island by hauling-ground groups, September-October 1947.--Calculations were made for the five rookery groups: Northeast Point, the Polovinas, Reef-Gorbatch, Tolstoi,

and Lukanin-Kitovi, and the Zapadnis (see page 67). The estimates of the numbers of pups alive on the rookeries adjacent to hauling-ground groups used in the calculations are individually subject to large sampling errors, particularly because of some of the corrections that enter the calculations. However, the errors in the subtotals become less important in the overall total, and the estimate of 393,953 pups alive on the five rookery groups at the time of the 1947 tagging is considered valid (see page 69).

The 1948 population could, in similar fashion, be estimated from the return of B-series tags applied in that year, were it not for two obstacles. First, the B-tags were applied on only three rookeries, Polovina, Reef, and Zapadni, with relatively few on Zapadni; and past experience has shown that Reef-born seals tend to return, because of unsatisfactory hauling grounds near their home rookery, to Tolstoi, Lukanin-Kitovi, and Northeast Point hauling grounds. These are precisely the ones that must be omitted in the estimate procedure. Second, the B-tag returns are as yet incomplete, until the 1952 and 1953 data are analyzed.

Estimated number of pups born on the Pribilofs in 1947.--The foregoing estimates apply to St. Paul Island only and to the pups alive during the tagging period, 24 September - 10 October. Also excluded are Ardiguen and Sivutch rookeries where tagging was not done. First, it is desirable to round out the above estimate and, since any overlooked lost-tag scars will tend to inflate the estimate, it is preferable to round it downward. Second, it is estimated by rough interpolation that about 50,000 pups had died on St. Paul in 1947 before the midpoint of the tagging season (table 11). Thus the estimated number of pups born on St. Paul is 390,000 plus 50,000 or 440,000.

To estimate the number born on the Pribilofs, the harem-bull count is used as a basis for extrapolation. On the basis of bull counts in 1947, St. Paul, excluding Sivutch and Ardiguen rookeries, appeared to have 82.3 percent of the Pribilof population. Consequently, the estimated number of pups born on the Pribilofs in 1947 rounded to the nearest ten thousand is 530,000.

Sample counts and rapid field estimates of living pups, and counts of dead pups.

From 1912 to 1924, when the herd was small, a counting method successfully employed was to drive the pups past observers (fig. 9). The method was used briefly in 1940, in 1949, and again in 1951 in an attempt to get accurate sample counts on small rookeries. Because the pups are badly frightened, gather in compact groups, and are difficult to handle, the method is considered a last resort. However, it appears to be sufficiently accurate to merit some consideration. Sample counts obtained in this way have been linked with the harem-bull counts and to ground-area measurements obtained from aerial photographs to obtain two additional estimates.

Figure 9. A sample count of living pups, Polovina rookery, 8 August 1949. Several thousand animals were rounded up; the adults were allowed to escape into the sea; the pups were driven in small numbers past two observers. Virtually no pups had taken to the water by this date (VBS 2683).

The "rapid field estimate," whereby observers from a vantage point estimate the number of pups spread over the rookery before them, was tried in 1950 (fig. 10). This method has the great advantage of speed, for 5 to 10 thousand pups can be estimated in an hour. However, its success depends largely on the ability of the observer to estimate numbers, and it must be considered the least accurate of all methods. The best period for rapid field estimating is the first 10 days of August, when breeding activity has waned and before the pups have taken to the water.

Dead-pup counts, abandoned in 1924, were resumed in 1941 by Wilke and Banner and again in 1949, 1950, and 1951. To obtain counts, the rookeries are visited in late August and dead pups are systematically counted (fig. 11). Earlier in the season, substantial numbers of pups destined to die are still alive; later many of those that died early in the season have disintegrated or washed away in the surf. The counting crew marks each carcass with a pinch of white plaster, simultaneously recording it on a mechanical hand tally. A crew of four can count approximately 2,000 pup carcasses an hour. The count probably includes 95 percent of the actual number.

Estimate of the number of pups born in 1949 from sample counts of pups used with complete counts of harem bulls.--On carefully counted sample areas it was found that the average ratio of pups to harem bulls was 42 to 1. On the basis of accurate harem-bull counts, the ratio was extended to include all rookeries. Corrections were made for the variable abundance of seals on different types of terrain. In spite of this correction factor, the method is believed to provide results that are useful only as a check on other methods. The procedure was as follows: (1) Careful estimates of living pups and counts of dead pups were made on 6 sample rookeries (table 9). (2) Using the harem-bull count for 1949, (table 3) a pups-per-bull ratio was calculated for each sample rookery. (3) The sample rookeries were classified according to slope of land, abundance of rocks, and general compactness of the harems. Each uncounted rookery was then allocated to the category of the counted sample rookery that it most closely resembled, and the pups-to-bull ratio of the counted rookery was extended by means of the bull count to those rookeries where pups were not counted.

Figure 10. A "rapid field estimate" of living pups. Gorbatch rookery. A typical late July and early August view of pups sleeping closely massed. This photo illustrates the difficulty of estimating the number of pups, especially when they are distributed along 8 miles of Pribilof breeding beaches (KWK 48 96).

As of 10 August 1949, the estimated number of living and dead pups was, in round numbers, 470,000 (table 9). (As a practical consideration this is equivalent to the number of pups born.) In terms of breeding cows the estimate is not far from the "total of 480,000 cows, a number scarcely exceeded in the history of the herd" to which Osgood, Preble, and Parker referred (1915, p. 50). They postulated an annual replacement of 2,000 bulls, a total harem-bull class of 12,000, and an average harem of 40. With the facts available to them in 1914, when the herd was only one-fifth its present size, it is interesting that their predictions were so close to our present understanding of herd size.

Figure 11. A count of dead pups, Vostochni rookery, 11 August 1948. The biologists counted 21,600 dead pups on 1-1/2 miles of shoreline here. White plaster, used to mark each carcass as it is counted, is visible on some of the dead pups. Hookworm disease is the immediate cause of death of most pups dying on land; an estimated 1 percent die of starvation. Crowding may account for the increased mortality rate among pups in recent years (VBS 2441).

Estimate of the number of pups born in 1949 from sample counts used with ground-area measurements.—At the height of the breeding season in July, individual seals and family groups, or harems, are spaced rather uniformly on the rookeries. The breeding areas are well defined and rather uniformly occupied from year to year. Noting this, Charles Bryant in 1869 attempted to estimate the number of seals by mapping and crudely measuring

the ground they occupied. His work and that of naturalists who followed him is summarized by Jordan (1898, part 1, p. 88) and by Hanna (U. S. Bureau of Fisheries, 1917, p. 111). Attempts to estimate seals have always been handicapped by the rough terrain and the prevailing misty weather on the Pribilof Islands.

The development of aerial photography and the construction of an air field on St. Paul Island in 1943 brought hope that a new census method might be developed. Several opportunities to photograph sample rookery areas from the air were offered at various times by visiting planes (appendix G). In 1948 a Fish and Wildlife Service twin-engine plane equipped with an aerial camera was flown to the islands. All rookeries were photographed. Of the 376, 7x7-inch negatives produced, about 100 were found useful in calculating the pups per unit of rookery area.

The negatives were not sharp enough to permit a count of individual seals, but they did show the outline of massed seals on the rookeries (fig. 12). The technique was as follows: (1) On photographs, with the help of a planimeter, the biologists were able to measure the dark patches representing areas occupied by seals. (2) They then counted, on foot, the living and dead pups on 6 sample rookeries. (3) They

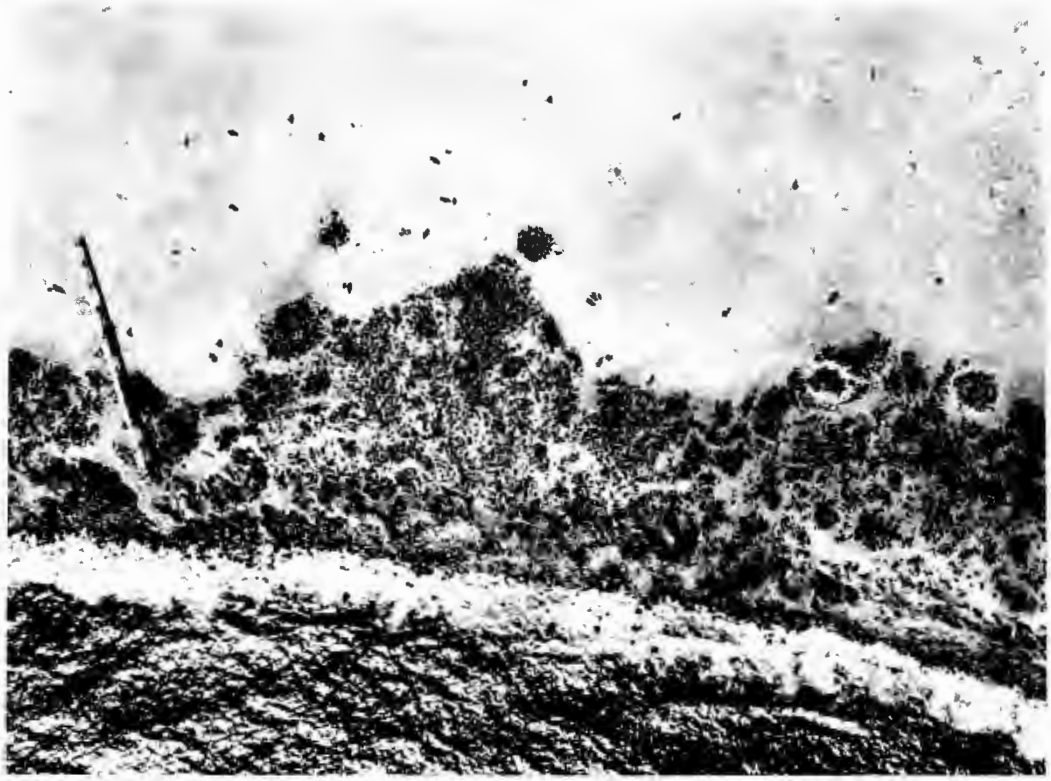


Figure 12. Aerial photograph of a portion of Polovina rookery. This illustrates the definite outlines of the breeding area at the height of the season. Bering Sea in foreground; harems in the middle; bare ground with thinly scattered idle bulls at top; an elevated walkway at left. Photo taken from an altitude of 1,000 feet on 14 July 1948 (VBS and KWK aerial photo 29).

Table 9.--Size of pup class in 1949 as derived from sample counts of pups with complete counts of harem bulls.

Rookery	Number of harem bulls[1]	Pups-per-bull ratio (average harem)	Number of pups born[2]	Number of dead pups counted[2]
St. Paul Island				
Gorbatch	828	71.43	59,144	
Polovina*	294	71.43	21,000*	1,779*
Little Zapadni	518	48.59	25,170	
Reef	1,806[3]	48.59	87,753	
Sivutch	150[3]	48.59	7,289	
Vostochni	1,572	48.59	76,383	
Zapadni	960	48.59	46,646	
Zapadni Reef*	142	48.59	6,900*	575*
Little Polovina*	203	44.33	9,000*	1,600*
Polovina Cliffs	512	44.33	22,697	
Morjovi*	468	33.76	15,800*	2,600*
Ardiguen	114	26.97	3,075	
Lukanin*	178	26.97	4,800*	635*
Tolstoi	1,050	17.88	18,774	
Kitovi*	509	17.88	9,100*	800*
Subtotal	9,304	44.45	413,531	7,989
St. George Island				
East Reef	113	48.59	5,491	
Staraya Artil	363	44.33	16,092	
Zapadni	274	44.33	12,146	
East Cliffs	222	26.97	5,987	
South	202	26.97	5,448	
North	571	17.88	10,209	
Subtotal	1,745	31.73	55,373	
Total, both islands	11,049	42.44	468,904	

1/ Counted 16-19 July 1949.

2/ * Living and dead pups counted 9-11 August 1949 on the 6 rookeries.

3/ Estimated from aerial photos made on 15 July 1948.

Table 10.--Size of pup class in 1949 as derived from sample counts of pups with ground-area measurements.

Rookery	Ground-area, (square meters) 1/	Square meters per pup	Number of pups born 2/
St. Paul Island			
Gorbatch	19,040	0.4019	47,375
Polovina*	8,440	0.4019	21,000*
Little Zapadni	16,403	0.4472	36,679
Reef	42,136	0.4472	94,222
Sivutch	7,621	0.4472	17,041
Vostochni	51,552	0.4472	115,277
Zapadni	26,580	0.4472	59,436
Zapadni Reef*	3,086	0.4472	6,900*
Little Polovina*	5,402	0.6002	9,000*
Polovina Cliffs	18,261	0.6002	30,425
Ardiguen	2,236	0.7458	2,998
Lukanin*	3,580	0.7458	4,800*
Tolstoi	28,066	1.1766	23,853
Kitovi*	10,707	1.1766	9,100*
Morjovi*	26,359	1.6683	15,800*
Subtotal	269,469	0.5456	493,906
St. George Island			
East Reef	3,284	0.4472	7,343
Staraya Artil	14,666	0.6002	24,435
Zapadni	9,597	0.6002	15,990
East Cliffs	5,932	0.7458	7,954
South	4,322	0.7458	5,795
North	24,080	1.1766	20,466
Subtotal	61,881	0.7548	81,983
Total, both islands	331,350	0.5754	575,889

1/ Calculated from aerial photos made on 13-15 July 1948.

2/* Living and dead pups counted 9-11 August 1949 on the 6 sample rookeries.

calculated for each of these rookeries a square-meters-per-pup value, and arranged the photos of the 6 rookeries in order of decreasing pup density. (4) They sorted the photos of the remaining 15 rookeries where no pup counts had been made and matched them with the photos of counted sample rookeries on the basis of topography. For example, Gorbatch was matched with Polovina rookery, since each is a smooth, open area lying above a narrow, rocky beach line. (5) Finally, they estimated the entire pup population on the basis of the square-meters-per-pup value for each rookery (table 10).

In computing ground area from aerial photographs, distortion due to parallax as well as differences in land elevation introduced errors which could be eliminated in part only. Although the aerial photographs were made in 1948 and the sample pup counts in 1949, the similarity of the rookery patterns from one season to the next is such that the error from this source is probably less than that introduced by some of the other assumptions involved. Secondary importance is assigned to population figures derived from the photogrammetric studies. The total number of pups born in 1949 as computed by this method was found to be, in round numbers, 580,000.

Rapid field estimate of living pups, 1951.--After a preliminary trial in 1950, the results of which were questionable, the experiment was repeated in 1951, as follows:

Living pups by rapid field estimate, St. Paul only . . .	226,700
Correction factor obtained by carefully counting Zapadni Reef as a sample, add 25%	50,700
Total living pups on St. Paul	280,400
Dead pups counted on St. Paul (including those calculated for Sivutch rookery)	72,700
Correction of 5% for those overlooked	3,635
Total pups dead	76,300
Total pups born on St. Paul Island	359,400
Total pups born on Pribilofs (utilizing the fact that the St. Paul harem bull count equals 82.9 percent of all Pribilof count)	433,534
Rounded to	440,000
(This is rounded upward to the nearest ten thousand. Experience shows that field counting is likely to be an underestimate.)	

Counts of dead pups.--Mortality on land, both natural and artificial, is quite easily evaluated, while mortality at sea is largely unknown (fig. 11). In the pelagic-sealing days before 1910, when nursing mothers were killed at sea, the mortality rate among pups was 7 to 8 percent (table 11). During the years of rapid herd growth, from 1914 to 1925, the mortality ranged from 1.7 to 3.1 percent. Now that the herd has reached its ceiling, the mortality rate has increased to about 14.6 percent (average, 1949-51), and the mortality to a total of 60,000 to 80,000 pups each summer. The mortality rate may be as high as 39 percent on individual rookeries (table 12). The majority of deaths are from hookworm

Table 11.--Mortality of pups on the Pribilofs in selected years from 1896 to 1951.

[Underlined figures are partial counts]

Year	Number of dead pups	Number of living pups	Number of pups born	Percent dead pups of those born
1896[1]	11,045	146,360	157,405	7.0
1908[2]	3,003	38,447	41,450	7.2
1909[2]	3,786	41,978	45,764	8.3
1914[3]	1,743	91,507	93,250	1.9
1915[4]	1,811	101,716	103,527	1.7
1916	2,482	114,495	116,977	2.1
1917	3,850	124,174	128,024	3.0
1918	4,302	138,613	142,915	3.0
1919	4,834	152,338	157,172	3.1
1920	4,219	163,308	167,527	2.5
1921	4,397	172,258	176,655	2.5
1922	3,223	182,691	185,914	1.7
1924	5,109	203,287	208,396	2.5
1941[5]	19,000	421,000	440,000	4.3
1949[6]	7,989	58,611	66,600	12.0
1950[7]	54,520	385,480	440,000	12.4
1951[8]	76,300	363,700	440,000	17.3

1/ From Jordan and others, 1898, part 1, p. 95; 1899, part 3, p. 97; based on partial counts.

2/ St. Paul Island only; data from U. S. Bureau of Fisheries, 1909, pp. 41-42. The living pups were estimated, not counted. We reduced the published value of 50,000 births for the Pribilofs in 1908 to 41,450, representing the births for St. Paul only.

3/ From Osgood, Preble, and Parker, 1915, p. 71; based on complete counts.

4/ Data for 1915-24 from U. S. Bureau of Fisheries annual reports, Alaska fur-seal industry; based on complete counts 1915, 1916, and 1922; partial counts other years.

5/ St. Paul Island only; dead-pup counts of 1941 with living-pup estimate of 1947.

6/ St. Paul Island, 6 rookeries only; dead-pup count and sample count of living pups, 1949.

7/ St. Paul Island only; dead-pup count of 1950 with living-pup estimate of 1947.

8/ St. Paul Island only; dead-pup count of 1951 with living-pup estimate of 1947.

Table 12.--Mortality of pups on the Pribilof Islands in 1950, by rookeries.

Rookery	A[1] Number of dead pups counted	B Number of harems counted	C Percentage contribution of each rookery to the harem count from column B	D Number of pups born, based on column C percentages and 530,000 total pups	E Estimated percent mortality
St. Paul Island					
Ardiguen	170	105	0.92	4,876	3
Gorbatch	2,810	845	7.41	39,273	7
Kitovi	1,160	512	4.49	23,797	5
Little Polovina	1,740	270	2.37	12,561	14
Little Zapadni	2,120	498	4.37	23,161	9
Lukanin	770	184	1.61	8,533	9
Morjovi	3,000	579	5.08	26,924	11
Polovina	5,660	312	2.74	14,522	39
Polovina Cliffs	3,800	649	5.69	30,157	13
Reef	9,520	1,587	13.92	73,776	13
Sivutch[2]		150	1.32	6,996	16
Tolstoi	4,230	1,055	9.25	49,025	9
Vostochni	13,120	1,510	13.24	70,172	19
Zapadni	4,660	1,028	9.02	47,806	10
Zapadni Reef	660	158	1.39	7,367	9
Subtotal	54,520	9,442	82.82	438,946	12.4
St. George Island					
East Cliff		217	1.90	10,070	
East Reef	360	110	0.96	5,088	7
North		770	6.75	35,775	
South		214	1.88	9,964	
Staraya Artil		386	3.39	17,967	
Zapadni		262	2.30	12,190	
Subtotal	360	1,959	17.18	91,054	
Total, both islands	54,880	11,401	100.0	530,000	

1/ Explanation of columns

A--Dead pups counted on all St. Paul rookeries except Sivutch, 26-30 August; on St. George, counted on East Reef only, 2 August.

B--Annual harem-bull count for 1950, 15-25 July.

C--For each rookery the percentage equals column B ÷ 11,401 x 100.

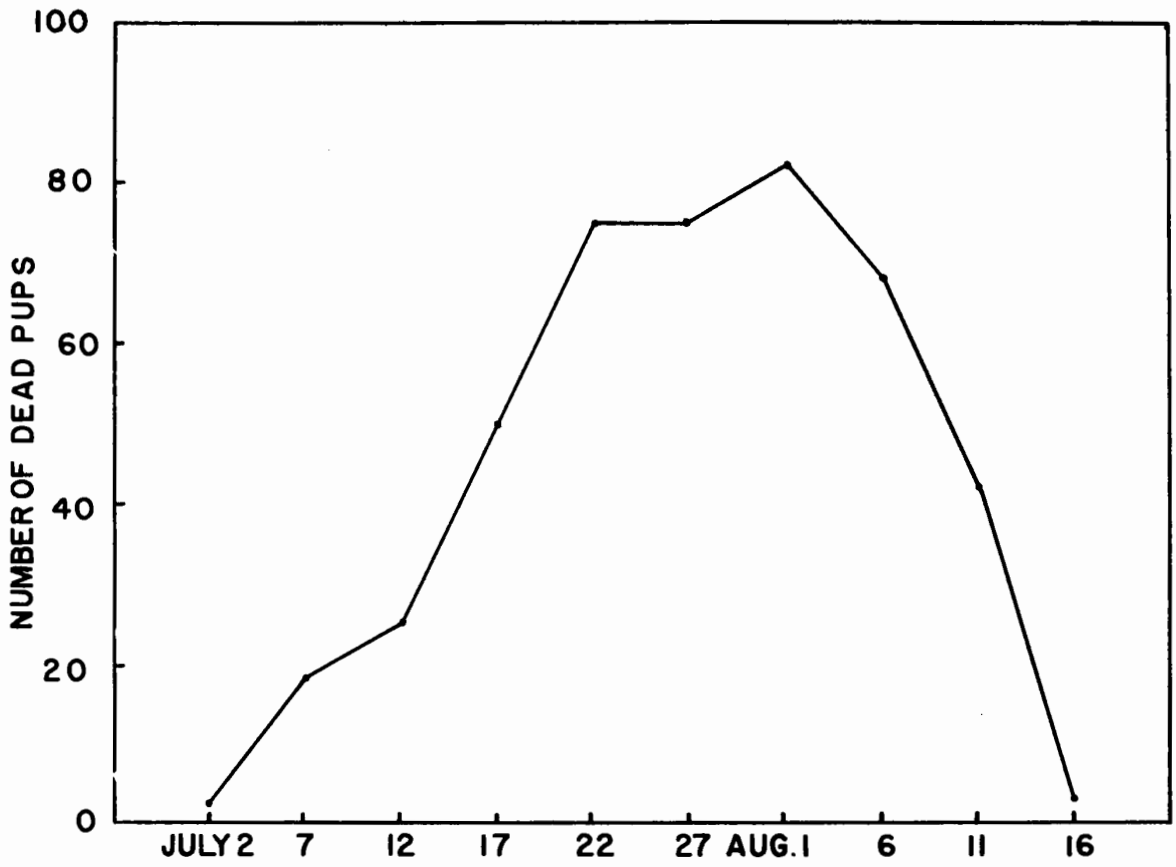
D--The value 530,000 total pups born on the Pribilofs is derived from tag returns.

E--Column A/column D x 100, or pup mortality on land as of 26-30 August.

2/ Estimated on the basis of aerial photos taken 15 July 1948. To Sivutch there are assigned 150 harem bulls, 50 idle bulls, and 6,996 pups, with an estimated pup mortality of 15.7 percent.

Table 13 (with graph).--Mortality rate of pups on a portion of Vostochni rookery, by 5-day intervals in 1951.

Date	Cumulative total of dead pups	Increment at 5-day intervals
June 25	0	
July 2	2	2
7	20	18
12	45	25
17	95	50
22	160	75
27	235	75
Aug. 1	317	82
6	385	68
11	427	42
16	430	3



disease. A few pups die of starvation when their mothers fail to return from a foraging expedition at sea, or when they do return, fail to find their young. Contrary to popular belief, few pups die as a result of trampling by adults.

The greatest natural die-off takes place among the pups when they are a few weeks old. In order to study the day-by-day rate of mortality a study area was selected on St. Paul Island in 1951. Before the arrival of seals, a 15,000-square-foot plot, bounded by painted rocks and bisected by an elevated walkway, was laid out on Vostochni rookery. With the first pup born a systematic survey of the area was begun, and the accumulated carcasses were counted at 5-day intervals throughout the season (table 13).

Estimate of the number of pups born annually, from the trend of the commercial harvest

As noted earlier, the commercial harvest in a given year is a direct product of the pup recruitment of 3 and 4 years earlier and, to a very minor extent, of 2 and 5 years earlier. Under a uniform system of harvesting, the number of seals killed should bear a fairly constant relation to the size of the pup class. Observing that the commercial kill has shown an increase over the past 28 years, (1923-51), the writers have attempted to draw a parallel in the increase of the annual birth rate of pups. A smooth curve has been fitted to the increase in kill (table 6). The mean kill in a present-day reference period (1947-51) is 1.5807 times the mean kill in an earlier reference period (1928-32). Therefore, the size of the pup class today is estimated to be 528,036 (that is, mean count of pups 1928-32, or 334,052, times 1.5807). But the mortality rate is higher today than it was in 1928-32, from direct evidence of carcass counts (table 11). Thus, the percentage of pups that live to killable age is now less than it was. On the basis of 2 to 3 percent mortality during the reference period and 12 to 17 percent during the modern period (table 11), there has been roughly a 10-percent increase in mortality. Applying this correction, the mean birth rate becomes approximately 590,000.

The reference period 1928-32 has been selected for three reasons. First, the size and growth rate of the pup class then had been fairly well established through actual counts between 1912 and 1924. Second, the annual kills were about as predicted, indicating that computations of herd size were correct. Third, after the closed season of 1912-17, when the only seals killed were those taken for food, commercial harvesting was resumed. By the time of the reference period the effects of the sealing holiday would have been reduced to negligible proportions.

Estimate of the number of pups born annually, from the trend of the harem-bull count

Assuming, again, a uniform system of harvesting, and its corollary, a uniform system of sparing male breeders, the number of harem bulls should

bear a fairly constant relation to the size of the pup class. A smooth curve has been fitted to the increase in harem bulls (table 5). The mean number of bulls in the reference period 1947-51 is 1.4757 times the number in 1928-32. Therefore, the size of the pup recruitment today is estimated to be 492,961 (that is, mean count of pups 1928-32, or 334,052, times 1.4757). Applying the same correction for increased mortality, the figure becomes approximately 550,000.

Cows

According to custom, any female seal 2 years old or older is called a cow. For example, a female pup born in the summer of 1950 would become a yearling on 1 January 1951 and a 2-year cow on 1 January 1952. Since the cows are the largest and most transient component of the herd on the breeding grounds (they number over half a million and shift constantly between the land and sea), no direct method of counting them has been developed. They are here calculated from (a) the estimated number of pups born, which is equal to the total successfully breeding cows, and (b) the percentage of nonpregnant cows as determined from a sample of 894 cows of breeding age.

The pregnancy rate is based on specimens taken at sea and on the Pribilof Islands. The female fur seal may become pregnant for the first time at the end of her third year. A traditional belief (Lucas, in Jordan 1899, p. 48) that impregnation occurs at the end of the second year has never been substantiated (Enders, Pearson, and Pearson, 1946, p. 214; also specimens collected in 1952 and 1953). Females sampled at sea along the northwest coast of America and on the Pribilofs indicated that relatively few (about 7 percent) become pregnant at the end of their third year, an increased number (about 57 percent) at the end of their fourth year, and the greatest number (about 79 percent) in the age classes above the fifth year (International Fur Seal Investigations, 1954, MS). Of the 894 females sampled in their fourth year or older the mean rate of pregnancy was 69 percent (the percentages given by age groups are listed in table 15). Since a cow bears one pup, the number of pups produced each summer on the Pribilofs is the best clue to the number of breeding females. The age when a female ceases to reproduce is unknown. The oldest cows seen on the breeding grounds were 21 years of age (U. S. Bureau of Fisheries, 1923, p. 136).

Among four groups of seals for which data are available, the pregnancy rate of Pribilof fur seals is the lowest.

	Percent pregnant
Pribilof fur seals, *Callorhinus ursinus*, 894 specimens	69
Asian fur seals (including an estimated 27% migrants from the Pribilofs) *Callorhinus ursinus*, 1,052 specimens from Japanese waters (International Fur Seal Investigation, 1954, MS)	80
South African fur seals, *Arctocephalus pusillus*, about 300 specimens (Rand, 1952)	70
North Atlantic harp seals, *Phoca groenlandica*, 70 specimens (Fisher, 1952)	80

The difference between pregnancy rates of Pribilof and Asian fur seals is striking in age 4, the earliest year of puberty: Pribilof, 7 percent (in 101 specimens); Asian, 37 percent (in 288 specimens). Furthermore, the pregnancy rate is lower in Pribilof females of all other age classes. A breakdown by age classes is available only for Callorhinus in the four groups above. The extent to which the samples represent an entire breeding population is open to question, and further investigation is planned.

We conclude that the present ratio of cows to bulls on the Pribilofs has increased beyond the point of maximum reproductive success. As a gregarious animal, the fur seal would be expected to follow in a general way the breeding behavior of other gregarious species. Of those that have been studied, for example, gulls, red deer, and Atlantic seals, it is said "reduction of gregariousness, and therefore of males, to a low level results in much less thorough overt, pre-coital sexual behavior, and females are apt to be left barren. Indeed, in some species of animals there is a threshold of numbers below which breeding will not take place" (Darling, 1951, p. 250). The Pribilof herd is the only group of seals studied with respect to pregnancy from which a large and consistent portion of the male life is removed annually. Mortality among males up to age 5 from natural and artificial causes combined is 98.6 percent.

Therefore, significance may be attached to the low rate of pregnancy here as compared to that among Asian fur seals and Atlantic harp seals. The reproductive success on the Pribilofs would presumably rise if the number of adult males were allowed to increase or if a portion of the female population were removed through commercial killing. The decrease in the number of pups born because of the decrease in the breeding stock should be compensated for by the increase of reproductive success and the decrease in pup mortality, provided the killing of cows were carried on within conservative and reasonable limits. Perhaps an annual kill of cows should be considered. Since the reservoir of physically mature males in the Pribilof herd appears to be at a relatively low level, the male breeding capacity may be substantially spent during the early and middle parts of the breeding season. This would explain why most young females, habitually arriving on the breeding islands late in the season, are neglected. Even among older cows the optimum breeding potential is not realized. Hanna (appendix B) was unable to find marked 7-year-old males on the breeding ground. Today, 7-year-olds are observed holding harems. The fact that a half-grown bull is allowed on the breeding ground today and was not in the twenties may be additional evidence that the population of fully mature bulls is not sufficiently large to serve the present cow population.

It appears that today the number of bulls is the determining factor for the number of pups born each year on the Pribilofs. If the killing of cows should be undertaken on a modest scale and under careful control, the following three results might eventually be expected: (1) A rise in the pregnancy rate, especially among young cows. (2) A reduction in the overcrowding that now exists (and is known to exist in other wild-mammal populations that have reached ceiling level). The

immediate effect would be greater survival of pups to killable ages of 3 and 4 years. An accurate prediction of the results of harvesting females is difficult because of two opposing factors which would come into operation--increase in pregnancy rate and decrease in actual number of breeding females. (3) An increase in the harvest of seal skins.

The observed mortality among cows under present conditions is low. Commercial sealing on the Pribilofs annually accounts for about 200 cows killed by mistake. A few, probably less than 500, die in parturition each season. Mortality rates as presented in table 15 are based to a large extent on the rates for males, which are based on tag recoveries on the killing fields.

Yearlings

The yearlings are the last group to arrive on the Pribilofs each summer, being preceded about 2 months by the 2-year-olds. Both classes are present on the breeding islands in greatest numbers during September and October. Field observations lead to the belief that many yearlings and 2-year-olds remain at sea throughout the year. Because of the largely unknown migratory habits of the yearlings and 2-year-olds, any direct count of them is impossible. Their numbers are estimated very roughly from the recoveries of tagged 3-year-olds (tables 14 and 15).

Mortality at sea is believed to strike the yearling class harder than any other. The transition from a milk diet on the Pribilofs to a diet of fish and squid in the stormy waters of the North Pacific in the fall is abrupt, and about half of the yearlings are believed to succumb in making the adjustment. Starvation during prolonged storms is a direct cause of death. An estimated 700 yearlings washed ashore along the Washington and Oregon coasts in the severe winter of 1949-50 (Scheffer, 1950d). Evidence from tag recoveries and dead-pup counts indicates that, between the time of tagging, when the seals are about 3 months old, and the start of the commercial kill 3 years later, about 60 percent are lost (tables 11 and 14). Seals with missing and badly scarred flippers seen on the Pribilofs suggest losses to sharks and killer whales. The only authentic observations of killer whales attacking seals were made during the late 1800's and early 1900's near the Pribilofs (Preble and McAtee, 1923, p. 117). In recent years, killer whales have rarely been seen near the breeding islands.

PRESENT SIZE OF THE HERD

The foregoing sections have dealt with methods and results of computing the size of component groups of the seal herd. The estimates believed to be most reliable for each group are now used in conjunction

with the best information available on length of life, age, mortality rates, and pregnancy rates to calculate the approximate total size of the Pribilof seal herd and of its sex and age classes. Sufficient data from one year have never been available to permit a calculation of the seal population for any specific year. The present summary gives the approximate average size of the herd and its components in the period 1947-51. Sealing statistics and harem-bull counts indicate that during the early 1930's herd growth was leveling off rapidly. Before 1940 the point was reached at which the factors governing life and death in the seal herd approached equilibrium. Although the population naturally fluctuates, it has passed the stage of rapid active growth. It is important to note that a 1947-51 appraisal of the Pribilof herd is valid for this period only, for the herd will not have arrived at complete equilibrium until the late sixties, by which time its oldest member (perhaps 30 years of age) will have been born after the leveling-off period of the late thirties. For example, many seals living in 1951 were born when the pup mortality rate was certainly lower and when the pregnancy rate was probably higher than today.

Life tables

The life table (14) for male seals is based on four values that determine its shape and magnitude. Between these values, or check points, it has been necessary to interpolate rather freely. The values are--

1. 265,000 male pups born in 1947; from 530,000 total pups born (tag recovery method) and a sex ratio of 1:1.

2. 61,365 bachelors, combined ages 2, 3, and 4, killed annually during the study period 1950-52 (table 7).

3. 5,709 estimated average escapement of 4-year males through and after the kill (appendix E).

4. 16,017 bulls counted annually during the postwar period 1945-51 (table 2); mean of harem bulls 12,008, of idle bulls 4,009.

The essential procedure has been to work forward and backward from the 4-year age group. The estimated escapement of 4's is consistent with other observed factors, in particular the total bull count. Only by assuming that the mortality in the 4-to-10-year range is very much larger than that postulated here can it be asserted that the escapement from the kill exceeds 6,000. An escapement below 1,000 is likewise unreasonable. Consequently, it may be assumed that the number of returning 3-year-olds (approximately 70,000) postulated in the life table is correct to within 3,000 to 4,000 in either direction.

Table 14.--Life table for male seals.

[Underlined figures represent counted or closely estimated basic data.]

Age 1/	Vernacular name	Seals alive at beginning of year: Number 2/	Seals alive at beginning of year: Percent 3/	Seals killed by man during year: Number 4/	Seals killed by man during year: Percent 5/	Seals alive after kill: Number	Seals alive after kill: Percent 3/	Seals dying naturally during year: Number	Seals dying naturally during year: Percent 6/
0	Pups	265,000	100.0					159,000	60.00
1	Yearlings	106,000	40.0					32,595	30.75
2	Bachelors	73,405	27.7	614	8.4	72,791	27.5	5,823	8.00
3	"	66,968	25.3	38,046	56.8	28,922	10.9	1,735	6.00
4	"	27,187	10.3	21,478	79.0	5,709	2.2	285	5.00
5	"	5,424	2.0	1,227	22.6	4,197	1.6	210	5.00
6	"	3,987	1.5					199	5.00
7 and over	Bulls	16,017						3,788	23.65
Total		563,988		61,365				203,635	

1/ Age in years from the beginning of the pupping season, 15 June.

2/ For the calculations here, the entire pup class is assumed to be born instantly on 15 June.

3/ Percent of the original newborn stock.

4/ Mean annual kills in 1950-52, apportioned on basis of tooth-ridge counts.

5/ Percent of those alive at beginning of year.

6/ Percent of those alive at beginning of year, except, for ages 2 to 5, percent of those alive at end of kill.

The entries in the table from age 4 upward have been obtained by a crude Gompertz-Makeham mortality curve within the limitations that the cumulative number of bulls should be 15,000 to 16,000. The entries from age 0 to 3 represent broad deductions, supported by the reasonable assumption that the greatest mortality is experienced in the first year of life when the seal pups encounter the rigors of winter at sea in the North Pacific.

Tooth-ridges, so far as they have been studied, have not revealed the maximum length of life. Branded seals 18 and 21 years of age have been seen on St. Paul Island breeding grounds (U. S. Bureau of Fisheries, 1923, pp. 136-137, 1930, p. 105, 1938, p. 163). Recent studies of the longevity of several "hair seals" (Phocidae) have been published. Fisher (1952) sectioned the teeth of harp seals (Phoca groenlandica) and found that the annual layers could usually be read up to the age of 20 years, and in one case to 28 years. Sivertsen (1941) reported that a gray seal (Halichoerus grypus) lived for 17 years in captivity and a harbor seal (Phoca vitulina) for 19 years. Matheson (1950) recorded the length of life of several gray seals kept in captivity, one 18 years, one 26 years 3 months, and one 41 or possibly 42 years. Laws (1953) has been able to read tooth rings in the elephant seal (Mirounga leonena) to age 20. Considering all the evidence, we conclude that the Alaska fur seal may attain an age of 30 years.

The life table (15) for female seals is based on the following assumptions and checkpoints:

1. 265,000 female pups born; the same number as males.

2. Mortality rates up to age 3 similar to those for males. Thus, at beginning of age 3, the number of females (67,533) is postulated to be the same as the number of males, except for the few hundred males killed at age 2. Mortality rates are assumed to be fairly low and uniform; 5 percent among young, but sexually mature, cows up to age 10. No attempt has been made to estimate the rate in older cows.

3. Pregnancy rates are based upon reproductive tracts collected on or along the coast of North America, 1948-52. The collections included 101 four-year-old females, 51 five-year-olds, 425 six- to ten-year-olds, and 317 females over 10 years of age.

4. A total of 364,216 female seals over 10 years of age has been predicated simply to bring the total of bearing females (right-hand column) up to 530,000, i.e. equal to the estimated number of pups born. The value 364,216 represents 30 percent of all female seals exclusive of pups.

Table 15.--Life table for female seals.

[Underlined figures represent counted or closely estimated basic data.]

Age [1]	Vernacular name	Seals alive at beginning of year: Number [2]	Seals alive at beginning of year: Percent [3]	Seals dying naturally during year: Number [4]	Seals dying naturally during year: Percent [5]	Pregnancy rate Percent	Number of seals bearing pups
0	Pups	265,000	100.0	159,000	60.0		
1	Yearlings	106,000	40.00	30,005	28.3		
2	Cows, virgin	73,405	27.7	5,872	8.0		
3	" "	67,533	25.5	4,052	6.0		
4	" mature	63,481	23.9	3,174	5.0	7	4,444
5	" "	60,307	22.8	3,015	5.0	57	34,375
6	" "	57,292	21.6	2,865	5.0	82	46,979
7	" "	54,427	20.5	2,721	5.0	82	44,630
8	" "	51,706	19.5	2,585	5.0	82	42,399
9	" "	49,121	18.5	2,456	5.0	82	40,279
10	" "	46,665	17.6	2,333	5.0	82	38,265
Over 10	" "	376,526		46,922	12.5	74	278,629
Total		1,271,463		265,000			530,000

1/ Age in years from the beginning of the pupping season, 15 June.

2/ For the purpose of calculations, the entire pup class is assumed to be born instantly on 15 June.

3/ Percent of the original newborn stock.

4/ Including several hundred accidentally killed.

5/ Percent of those alive at beginning of year.

Some of these assumptions may be seriously questioned, particularly the mortality rates noted in assumption 2 and the total of female seals over 10 years of age, in assumption 4. That the mortality rates up to age 3 are similar in males and females is reasonable, but there is no positive evidence supporting it. From pelagic samples taken off the American coast in the spring of 1952 (International Fur Seal Investigation, 1954, MS), the mortality in the age bracket 4 to 10 is estimated to be 7.8 percent. However, samples taken elsewhere (of Pribilof seals) indicate a lower mortality. In the 1952 pelagic sample the proportion of females over 10 years of age was 59 percent of those aged 4 to 10. To what extent these samples are random in age composition is not known. For example, the yearlings, the largest single age group, are poorly represented in the 1952 pelagic collection. Consequently it is difficult to assess what weight should be given to them.

That there are some uncertainties in the life table for female seals is apparent. These may be due to sampling errors, since even the best of the checkpoints are based on estimates of varying degrees of accuracy. Furthermore, year-to-year fluctuations in the different components of the herd may cause complications. As additional data and observations accumulate, these difficulties will be resolved, and at the same time there will almost certainly be some modifications in the following estimated life table.

On the basis of the life tables, the total Pribilof seal population is approximately 1,840,000. This is a maximum figure never actually attained, for many pups die soon after birth, and while pups are dying and others are being born the commercial kill of bachelors is in progress. After the sealing season and after hookworm mortality has taken its greatest toll, that is, by mid-August, about 1,700,000 seals are alive. Before the birth of pups begins in the following summer the herd population has dropped, through natural mortality, to about 1,300,000. For an average all-year estimate it may be said that the size of the Pribilof fur seal herd is about 1-1/2 million seals.

Estimate of the size of the herd from the trend of the commercial harvest

As a check on the figure of 1-1/2 million derived from various counts in the period 1948-51, two estimates have been obtained from a study of trends in the growth of the seal herd since 1924. The first is based on the trend of the commercial harvest, the second on the trend of the harem-bull count (fig. 13).

To estimate the size of the herd from the observed increase in kill of group-III males it has been necessary to make the following assumptions:

1. Harvesting practices have been uniform during the study period.

2. Up to about 1935 computations for the size of the herd were quite accurate.

3. Because of the uniform harvesting methods the kill of group-III males represents each year about the same fraction of the total herd.

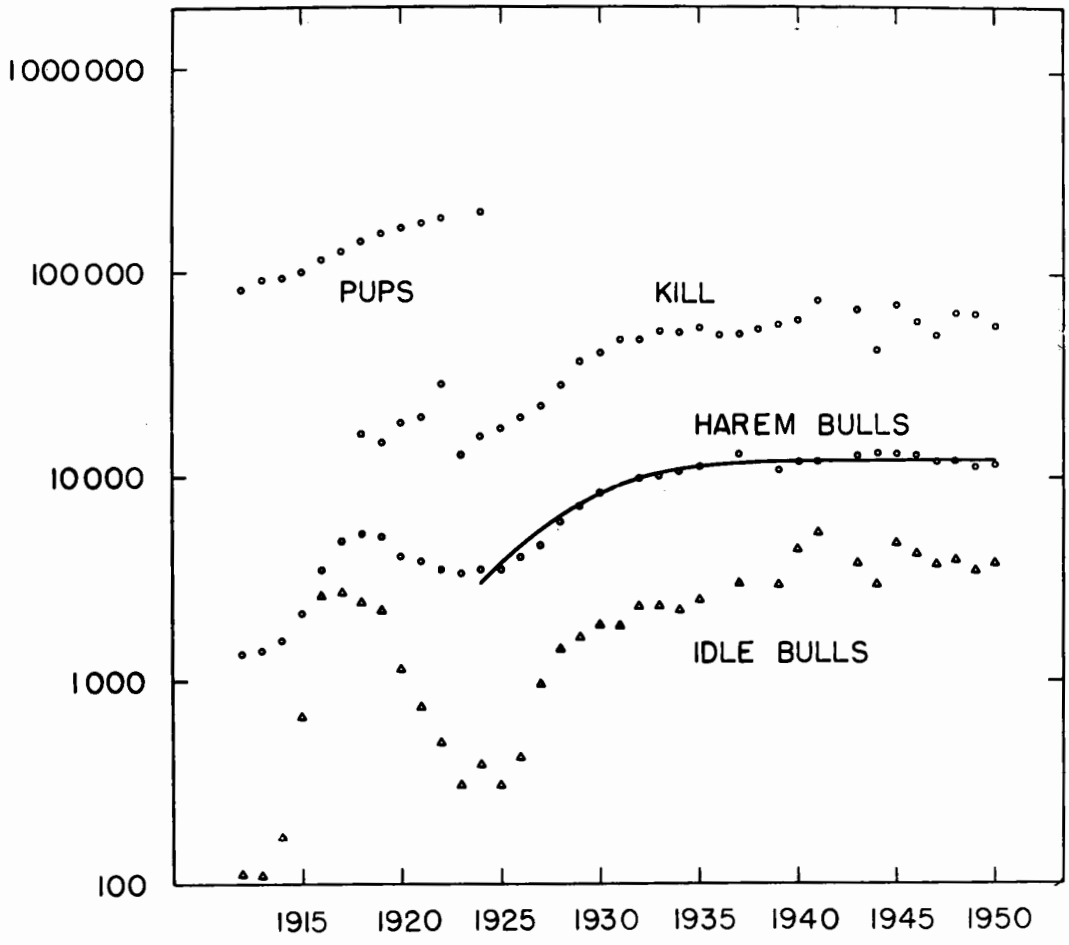


Figure 13. Counted elements of the seal herd, 1912-51. Increase in selected classes (top to bottom): pups counted; group-III males killed; harem-bulls counted, with a logistic curve fitted to the data for years 1924-51; idle bulls counted. (See tables 2, 5, 6, and 8).

After the middle thirties, the kill began to lag behind the computed growth of the herd. A logistic curve fitted to the kills of group-III males during the period 1924 to 1951 (table 6) indicates that under present management practices the annual kill is now fluctuating around a mean of 60,600.

Following a line of reasoning similar to that used in computing the size of the pup crop from the commercial kill, the present size of the herd is estimated to be: mean size of the herd 1928-32, or 1,047,037, times 1.5807 equals 1,655,051 or, rounded, 1,660,000.

It should be pointed out that the herd size in 1928-32 was computed on an assumed pregnancy rate of 100 percent, whereas it is now estimated to be approximately 70 percent and probably was nearer 80 percent at that time. Furthermore other errors are introduced by the increase in pup mortality in recent years. Both of these factors tend to make the estimate determined from the trend of the commercial kill too low; hence the estimate is quite in line with the one noted in the previous section (1,840,000).

Estimate of the size of the herd from the trend of the harem-bull count

In the preceding section we have used the increase (mean 1928-32 to mean 1947-51) of bachelors available during the harvest season as a rough index of the increase in total size of the herd. The increase in harem bulls can be used similarly, since the number of harem bulls is directly related to the escapement from the harvest. But the number of harem bulls is also related to the number of mature cows on land since, by definition, a harem bull is a bull holding one or more cows. The extent to which the number of cows affects the standing size of the harem-bull class is not known, for the cow-to-bull relation is exceedingly complex. For the moment, the assumptions are made (1) that uniform sealing practices since 1924 have perpetuated a uniform annual percentage escapement and (2) that the harem-bull class has remained in approximately the same relation to the cow class during these years. In table 5 the smoothed increase in harem bulls from 1924 to 1951 is shown. The present size of the herd is estimated to be: mean size of herd 1928-32, or 1,047,037, times 1.4757 equals 1,545,113 or, rounded, 1,550,000.

Again there are known errors, for which it is impossible to correct quantitatively. An error in the assumed pregnancy rate in the 1928-32 computations would enter here also, while changes in pup mortality and harem size (appendix C) would affect the estimate.

APPENDIX A

Effect of sealing on fluctuations in herd size, 1786 - 1951

Historical

The question has been raised, "Why does the Government now take only about 60,000 to 70,000 seals annually when it is an historical fact that approximately 115,000 seals were taken each year during the 20-year period, 1871 to 1890? Since the herd has now recovered, shouldn't it yield at least 100,000 seals a year?" Consideration of the recorded fluctuations of the herd provides the answer.

In 1786-87, when the Pribilofs were discovered, the size of the seal population under primitive conditions was probably 2,500,000. This figure is based upon the modern size of the herd, with an allowance for several small extinct rookeries, and upon the estimated number of males which, were they spared by man, would live to swell the herd population. Sims (1906, p. 38) made the same estimate of 2,500,000 for the size of the herd at the time of its discovery. The early history of sealing under Russian management from 1786 to 1837 is presented by Veniaminof (in Elliott, 1881, pp. 140-145). Interpretations are presented by Elliott, by Sims (1906), by Jordan (1898, pt. 1, pp. 23-28), and by Osgood, Preble, and Parker (1915, pp. 21-22).

From the start and until about 1835, sealing operations were extravagant, wasteful, and largely unrecorded. The reported take of skins (table 16) is certainly far too low. From time to time Russian overseers recognized the dangers of overexploitation and placed a temporary ban on killing. By 1834, the herd had dwindled to the lowest point under Russian jurisdiction, possibly to less than a million animals. The stringent ban on killing (the "zapooski") was applied in 1835. After a rest of 7 years, when fewer than 10,000 skins were taken annually, the kill was gradually increased. In 1867, the last year of Russian occupation, 75,000 seals were killed. After the initial period of unrestricted killing the take of seals throughout the Russian regime appears to have been conservative. Even during the period 1835 to 1867 for which the statistics are considered most reliable, the mean annual kill was only 20,000, less than one-third the present yearly crop.

During the first year of American occupation (1868), the take was 242,000 seals! The next year it was 87,000. This slaughter inaugurated a long period of poorly controlled sealing on land and at sea, which was to end 40 years later with the herd at less than one-tenth of its primitive size. From 1870 to 1889 the Alaska Commercial Company, and from 1890 to 1909 the North American Commercial Company, leased the privilege of taking sealskins on the Pribilof Islands. During this 40-year period, pelagic sealing reached its greatest intensity. In 1897, Jordan (1898, part 1, p. 100) estimated the herd size at 400,000, a figure which seems

reasonable in the light of modern knowledge. By 1911, when the Government assumed direct control of the seal herd, the combined assault on land and sea had reduced it to approximately 215,000 animals.

From 1912 to sometime in the late 1930's the herd, as well as the annual take of seals, increased. As this report demonstrates, the herd has now leveled off at approximately 1-1/2 million seals and the annual take at 66,000. From the foregoing discussion it is obvious that annual kills of over 100,000 seals during the period 1870 to 1890 were at the expense of the breeding stock. Future kills may possibly be increased slightly by improved methods of harvesting, but no long-range advantage can be gained by greatly depleting the breeding stock.

Modern pelagic sealing

Pelagic sealing is nonselective. It results in the taking of a high percentage of pregnant females. While the selective killing of 60 to 70 thousand male seals on the Pribilofs has little effect on the breeding reserve, the same is not true for a sustained annual take of 60 to 70 thousand seals at sea.

Figure 14. Pelagic sealing for research purposes off Japan in 1952. The Japanese use 10- and 12-gage shotguns loaded with 0 or 00 buckshot to kill seals as they "porpoise" ahead of the ship. Dead seals are recovered by a gaff on a bamboo pole. As many as 100 seals can be taken in a day by a Japanese harpoon ship or "tsukimbo-sen" of this type. Pelagic sealing on a large scale especially between 1880 and 1910 reduced the Pribilof fur-seal herd to the verge of extermination (KWK 52 723).

Pelagic sealers are even today taking a few Pribilof seals. Japanese fishermen working off northern Honshu and Hokkaido during World War II and since have probably taken 2 to 3 thousand seals annually, (fig. 14) of which about one-third were estimated to be migrants from the Pribilofs (International Fur Seal Investigation, 1954, MS). Commercial sealing was banned during the Allied occupation, 1945-52, and has subsequently been declared illegal by the Japanese government. Thus no authentic records of the take exist. Many seal skins are in evidence as clothing in the coastal Japanese villages. In past years, under terms of the Treaty of 1911, Indians of the northwest coast of America annually took a few hundred migrating seals (fig. 15). Since 1940, coastal sealing activities have virtually disappeared.

Pelagic sealing today has no noticeable effect on the Pribilof herd. However, if it were to become legalized in certain parts of the North Pacific Ocean, and if 100 or more harpoon boats comparable to those now used by the Japanese for shark, porpoise, and seal hunting were to participate in pelagic sealing, the effect on the Pribilof seal herd could be serious within a few years.

Figure 15. Pelagic sealing by aborigines off Southeast Alaska in 1950. A Tlingit Indian pulls in a speared and exhausted fur seal. Aboriginal sealing is a dying art; less than 1,000 animals have been taken on the American coast in the past decade. Aboriginal sealing under treaty rights has little effect on the Pribilof herd (KWK 50 465).

Table 16.--Reported take of Pribilof seals from 1786 to 1950, by decades.

Decade	St. Paul Island	St. George Island	Both islands	At sea 2/	Total take
1786-90 3/	-------	-------	208,879	------	208,879
1791-1800	-------	-------	420,099	------	420,099
1801-10	-------	-------	422,440	------	422,440
1811-20	-------	-------	428,460	------	428,460
1821-30	-------	-------	271,860	------	271,860
1831-40	-------	-------	104,615	------	104,615
1841-50	-------	-------	130,814	------	130,814
1851-60	-------	-------	186,087	------	186,087
1861-70	-------	-------	624,766	17,483	642,249
1871-80	851,294	191,226	1,042,520	71,926	1,114,446
1881-90	777,403	161,700	939,103	238,484	1,177,587
1891-1900			165,252	421,300	586,552
1901-10	135,582	27,529	163,111	208,611	371,722
1911-20	100,038	27,373	197,411	20,834	218,245
1921-30	212,473	56,103	268,576	39,401	307,977
1931-40	445,645	110,255	555,900	11,698	567,598
1941-50	539,954	124,082	664,036	1,106	665,142
Total	3,062,389	698,268	6,793,929	1,030,843	7,824,772 4/

1/ After 15 December 1911 the privilege of taking seals at sea was reserved to aborigines.

2/ Five years only; the Pribilofs were discovered in 1786 and 1787.

3/ Mean reported annual take over the entire 164-year period, 47,712 seals.

The published records of the fur seal industry up to 1910 are scattered and inaccurate. By act of 21 April 1910, the U. S. Commissioner of Fisheries was made directly and solely responsible for the management of the seal herd, and since then the statistics have steadily improved in quality. Main sources of confusion were (1) the count of seals killed compared with the count of skins shipped and skins received in London, (2) summer killings compared with fall food-killings, and (3) varying periods covered by the annual reports. Fairly good accounts of the seal harvest under Russian control (1786-1867) are given by Sims (1906); under lessees' control (1870-1910) by Fraser (1911); and under modern management (1911-50) by the U. S. Bureau of Fisheries and the Fish and Wildlife Service. Fraser gives consistent figures for a long period but does not give a breakdown of the take by islands. The source materials of table 16 are as follows:

The land take between 1786 and 1905 is from Sims (pp. 33-35), except that his figures for 1786-1820 have been redistributed by decades.

The land take for 1906 and 1907 is from Lembkey (1908, pp. 36, 63, 98, and 115).

The land take between 1908 and 1947 is from published reports of the Alaska fur-seal industry (see U. S. Bureau of Fisheries). There seems to have been no published report for 1908, although the total take is given in the annual report for 1909 (p.44). We have prorated the 1908 take to the two islands on the basis of a manuscript giving the summer killings only.

The pelagic take between 1868 and 1905 is from Sims (p. 35); between 1906 and 1948, from annual reports of the fur-seal industry; for 1949 to 1950, estimated.

Excluded from the table are the numbers of seals killed for museum purposes since 1940, in the aggregate less than 100.

APPENDIX B

Fecundity of males

The testes and the reproductive behavior of males have been studied with two objectives in mind: (1) the age of sexual maturity, and (2) the potency rate among adults. The results are summarized as follows:

Age of sexual maturity

1. Smears were made from the testes of 10 known-age 3-year-olds collected on 27 July 1950. Dr. Oliver P. Pearson found sperm in four of them. Testes weighing less than 30 grams contained no sperm, while those weighing 30 grams or over did (letter of 3 October 1950).

2. Testes from seals in the critical ages 3, 4, and 5 were studied and described by Dr. Richard J. Blandau (letter of 29 December 1950):

Three-year-old testes, totaling 25 pairs, weighed from 10 to 74 grams (mean 31.6). "From the survey of the whole 3-year-old group, I would conclude that all of the animals with the possible exception of ... [the largest, 74 grams] would not be able to reproduce."

Four-year-old testes, totaling 10 pairs, weighed from 50 to 86 grams (mean 67.1). Dr. Blandau "would doubt that the 4-year-old seal has reached reproductive maturity."

One pair of 5-year-old testes (91 grams) showed as much spermatogenic activity as did the testes of adult bulls.

3. A study of several hundred seals ranging in age from pups to bulls revealed that testes grow in weight most rapidly in the fourth and fifth years, especially the fourth (Scheffer, 1950d, p. 389).

4. G. Dallas Hanna, studying the branded animals of 1912, saw no 6-year, or even 7-year, males on the breeding grounds (U. S. Bureau of Fisheries, 1918, p. 126; 1919, p. 114). We have seen a few marked 7-year-olds in charge of harems.

5. Field observations of branded animals clearly demonstrate that even a 10-year-old is not as large, nor as active in breeding, as he will eventually become.

Potency

1. The testes of 11 bulls 10 years of age or older were collected at three intervals during the 1951 breeding season. They included 4 prospective harem bulls collected on the breeding area on 30 June, 4 active harem bulls collected 11-16 July, and 3 idle bulls collected 16-18 July. The testes

were sectioned and studied microscopically by Dr. Blandau, who drew the following conclusions (letter of 29 November 1951):

"There is remarkable uniformity in the level of spermatogenesis and spermiogenesis from one testis to the next. All the organs show active production of sperm. . . Since nothing is known concerning the rate of progression of sperm through the epididymis in this animal failure to find sperm in all tubules is probably of no significance. All epididymides showed some sperm in them. Estimations of adequacy of numbers could be only grossly estimated. . . the only conclusion that can be reached is that the animals in this age group do produce sperm and that the sperm are delivered into the epididymis and ductus deferens. These slides show no conclusive evidence that the males cannot reproduce. The condition of the tubules in the 10+-year-olds compares favorably with the 5-year-old specimens I examined earlier."

2. Among six sets of idle-bull testes examined earlier by Dr. Blandau, only one, an obviously emaciated animal, contained no active sperm.

APPENDIX C

Size of the average harem

The "average harem" has been defined as: (total number of pups born) / (count of harems, i.e., harem bulls, in mid-July). It was first seriously studied in 1912. From 1912 to 1924, computations of the size of the average harem were based on the firm evidence of complete and partial counts of pups and bulls (U. S. Fish and Wildlife Service, 1947, p. 75). Between 1912 and 1916 the average harem decreased steadily in size as a result of the closed season on commercial sealing and the resulting increase of males (table 17). The all-time low of 26 and 27 reached in 1917 and 1918 probably represents the natural primitive size of the average harem. In the 10-year period 1927-36, when commercial sealing had been carried on quite uniformly for two decades, the average harem was fluctuating around a mean of 43. Then, as the computation system failed to adapt itself to a changing herd, the estimated average harem began to rise. By 1947 (on paper) it had reached 95, a figure at variance with field observations.

All present evidence suggests that a realistic estimate of size today should be not less than 40 nor more than 50. The results of the current study are listed below:

Estimated average harem

1947-48. St. Paul Island, except Ardiguen and Sivutch rookeries, from A-tag recoveries; 440,000 pups ÷ 9,645 bulls . . 46

1949. St. Paul Island, 6 out of 15 rookeries, from actual count of pups; 66,600 ÷ 1,794 bulls 37

1951. St. Paul Island, from rapid field estimate of pups; 359,400 pups ÷ 9,434 bulls 38

1940. Zapadni Reef rookery (a small breeding ground which has continued to grow, doubling its size between 1940 and 1949), from actual count of pups; 3,250 pups ÷ 68 bulls 48

1949. Zapadni Reef rookery, from actual counts of pups; 6,725 pups ÷ 142 bulls 47

1951. Zapadni Reef rookery, from actual count of pups; 6,303 pups ÷ 142 bulls 44

1951. Kitovi rookery, "amphitheater" area only, from daily observations (Bartholomew, 1951, MS); 780 pups ÷ 20 bulls 39

1951. Kitovi rookery, from rapid field estimate of pups; 16,877 pups ÷ 500 bulls 34

1947-51. All-Pribilof, from the trend of the commercial harvest; 590,000 pups ÷ 11,575 bulls 51

1947-51. All-Pribilof, from the trend of the harem bull count; 550,000 pups ÷ 11,575 bulls 48

Table 17.--Published estimates of the size of the average harem, 1912-47.

[Where underlined, the average harem was based on a complete count of pups (partial counts only were made in 1917 to 1921); elsewhere on an estimated annual increase in numbers of pups over the base period 1912-22. The increase was assumed to be 8 percent up to 1942, 7 percent from 1942 to 1946, and 6 percent in 1947 (U. S. Fish and Wildlife Service, 1947, p. 75).]

Year	Average harem	Year	Average harem	Year	Average harem
1912	60	1927	57	1942	66
1913	66	1928	47	1943	67
1914	60	1929	43	1944	70
1915	48	1930	40	1945	76
1916	33	1931	39	1946	82
1917	26	1932	38	1947	95
1918	27	1933	41		
1919	30	1934	42		
1920	41	1935	42		
1921	45	1936	43		
1922	52	1937	43		
1923	58	1938	47		
1924	59	1939	60		
1925	64	1940	62		
1926	61	1941	64		

APPENDIX D

Age criteria for bachelor fur seals

Early in the development of the sealing industry under United States Government management, it was found advisable to establish standards for the age and size of each animal killed, and to preserve for study purposes the records of those measurements. The objectives were, first, to impress the native clubbers with the need for care in selecting animals of the proper commercial size and, second, to obtain a rough age-class breakdown of the kill for the purpose of population computations. It was the practice in the late 1800's and up 1914 to age each seal killed on the basis of skin weight; from 1915 to 1917 on the basis of body length as measured by steel tape; from 1918 to the present on the basis of body length as measured by wooden calipers.

Special Investigator George A. Clark conducted branding operations on the Pribilofs in 1912. His object was to obtain precise information on the size and growth rate of seals of positively known age. He branded, as pups, 1,944 males, 1,796 females, and 1,488 of unrecorded sex. In subsequent years G. Dallas Hanna recovered and measured 363 branded seals of this series (table 18). On the basis of body measurements he established age-length standards for yearling and bachelor seals.

Table 18.--Specimens examined from the 1912 series of brandings.

Age (years)	Number of specimens		Length standards established for males (inches)
	Male	Female	
1	3	---	up to 36-3/4
2	16	2	37 to 40-3/4
3	120	---	41 to 45-3/4
4	96	---	46 to 51-3/4
5	46	---	52 to 57-3/4
6	37	---	58 to 63-3/4
7	25	---	----------
8	15	---	----------
9	2	---	----------
10	1	---	----------
Total.	361	2	

Measurements in commercial sealing statistics are now reported to the nearest inch. Studies of several thousand tagged animals taken

during the last 10 years show that there is considerable overlapping in length among age classes, so that the 1913-18 standards are applicable only in a general way so far as true ages are concerned. Their value in commercial sealing operations is not impaired, however, by the fact that they poorly represent true age classes. The sealers are under instructions to kill 41- to 45-inch males and their judgment of size is constantly checked by measuring each seal killed. The take conforms closely to the commercial standards, about 90 percent falling within the required limits.

Since it will be conclusively shown in subsequent pages that the length standards are poor criteria of age, we have consistently referred to the outmoded age-length classes of the commercial harvest as numbered groups:

Group	I	up to 36 inches
Group	II	37 to 40 inches
Group	III	41 to 45 inches
Group	IV	46 to 51 inches
Group	V	52 to 57 inches
Group	VI	58 to 63 inches

For example, the seals referred to as "3-year-olds" in the commercial sealing statistics are called group-III seals in the present report. When we mention age, it has been ascertained either through tag recoveries or through tooth-ridge counts.

Table 19.--Percentages of 2-, 3-, and 4-year tagged males falling within length groups I to V, killed in 1950, 1951, and 1952.

[Seal pups tagged in A-, B-, and CS-series in 1947, 1948, and 1949 were killed in their third or fourth years; total killed, 4,196. Instructions to the sealers were: in 1949 to spare all tagged animals; in 1950 to kill all tagged animals regardless of size; in 1951 to kill all tagged animals except those bearing a hind flipper CS-tag (2-year-olds); in 1952 to ignore tags and kill only for size.]

	Seals killed											
	Age 2		Age 3						Age 4			
Length	1950		1950		1951		1952		1951		1952	
group	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
I	10	9										
II	93	80	154	13	169	14	22	3	1	<1		
III	13	11	1,071	86	1,014	84	787	96	303	65	290	82
IV			15	1	22	2	8	1	157	34	64	18
V									3	<1		
Total	116		1,240		1,205		817		464		354	

Field length measurements of tagged, known-age seals

Tag recoveries do not reveal the ratio of true age-class composition taken in the entire kill, whereas the tooth-age readings do. There are two reasons. First, all tagged animals (with certain exceptions, see headnote, table 19) appearing each year on the killing fields are taken simply because they bear a tag, and regardless of size. Thus the ratio of tagged to untagged animals is upset. Second, the grouping of tagged animals into length classes is subject to the human error of the scaler and even to conscious bias on his part.

Human error in measuring seals on the killing field

It may be seen that the length frequencies of 1,243 tagged 3-year-olds (table 23) recovered and measured during sealing operations in 1950 do not fit closely a normal curve (chi-square is 51.8). The greatest divergence from normal is at the lower limit (41 inches) of group III. Of the 40-inch seals there were too few, and of the 41-inch too many. As a control, the biologists measured the length of the right hindflipper of 147 tagged 3-year-olds and found that the distribution did resemble the normal curve (table 20). (Chi-square is 4.4; a deviation this large or larger would occur 50 percent of the time by chance alone). The discrepancy in body length measurements was attributed to bias on the part of the scaler who unconsciously brought marginal animals within the commercially desirable group-III limits.

Table 20.--Distribution, by length of right hindflipper, of 147 tagged 3-year males recovered on St. Paul Island, 29 June-3 July 1950.

[Mean 343.0 mm., Standard Deviation 18.83 mm., Variation 5.49%]

Flipper length (millimeters)	Number of specimens	Flipper length (millimeters)	Number of specimens
300-309	3	350-359	29
310-319	13	360-369	11
320-329	21	370-379	4
330-339	30	380-389	4
340-349	29	390-399	3

Age classes in the commercial kill as revealed by tooth-age analysis.

Tooth samples were taken at random on the killing field, without reference to body size, and are therefore a good indication of the actual proportion of each age class appearing in the kill.

Age studies based on tooth samples recovered during three seasons from the killing fields indicated that slightly more than one-third of the animals classified as 3-year-olds by the early age-length standards are actually 4-year-olds, and some of them are 2- and 5-year-olds.

Table 21.--Composition of the Pribilof kill, 1950-52.

[Percentage in each age class]

According to body length measurements [1]				According to tooth-age readings			
Age	1950	1951	1952	Mean	1950	1951 [2]	1952	Mean
2	3	3	2	3	1	1	2	1
3	93	89	93	91	65	59	61	62
4	4	8	5	6	33	39	34	35
5	1	1	1	1	1	1	3	2

1/ "Field length" according to the standards of 1918.

2/ In 1951 the sealers were instructed to raise the length limit to include 46-inch animals.

Why the 1913-18 standards do not fit the seals today is an unanswered question. The discrepancy may represent a real decrease in the average size of the bachelor seal in response to an increasingly crowded population, or it may simply represent differences between the sampling and measuring techniques of 1913-18 and today.

APPENDIX E

Escapement of bachelors from the commercial kill

Escapement of 3-year males in 1950

Through-the-season escapement.--The number of 3-year males spared by the clubbers on St. Paul in 1950 as being offsize (under 41 or over 45 inches) may be estimated from the A-tag return in either of two ways: by comparing the length distribution in the kill and in the tagged animals, or by comparing the returns of tagged and tag-lost animals.

Method 1, Comparison of tagged and tag-lost seals: As noted in the headnote to table 19, clubbers made a special effort to take every tagged animal so that the tag recoveries should be representative of the three-year-old class. On the other hand it may be assumed that the tag-lost group is representative of the commercial kill. In 1950 the proportion of tagged to tag-lost animals in the 41- to 45-inch range (in which range all male seals were taken) was $\frac{1071}{406}$ or 2.64 (tables 23 and 24). The "excess kill" in 1950 resulting from the taking of small and large seals simply because they were tagged is 114, obtained as follows:

Table 22.--Seals killed in 1950 outside commercial class because they bore tags.

Length	Number of tag-lost seals	Expected number of tagged seals 1/	Actual number of tagged seals	Difference = normal escapement of tagged group
40 inches and under	19	50	154	104
46 inches and over	2	5	15	10
				114

1/ For example 19 x 2.64 = 50

Table 23.--Number of marked 3-year males recovered on St. Paul Island in 1950, by date and body length of seal.

[Tagged animals only; excluding tag-lost seals]

Field length (inches)	Number of seals recovered during 5-day round with midpoint-- June				July					
	15[1]	20	25	30	5	10	15	20	25	Total
37	---	---	1	---	---	1	---	2	1	5
38	---	---	---	---	---	3	---	3	---	6
39	---	---	---	1	3	5	6	8	4	27
40	---	6	6	4	10	19	16	33	22	[2]116
41	---	7	16	23	42	43	63	77	75	[2]346
42	2	6	10	35	46	48	63	76	74	[2]360
43	---	6	12	19	34	39	40	37	54	[2]241
44	1	3	3	6	8	12	26	12	20	[2] 91
45	---	1	3	5	---	3	7	8	6	[2] 33
46	---	---	---	3	6	1	3	---	2	15
Unknown	---	---	---	---	2	---	1	---	---	3
Total	3	29	51	96	151	174	225	256	258	1,243

1/ 17 June only.

2/ Total, field lengths recorded, 41 through 45 inches, 1,071.

Table 24.--Number of marked 3-year males recovered on St. Paul Island in 1950, by date and body length of seal; tag-lost animals only.

[Tag-lost animals are identified by a tag scar and by a hole which was punched in the hind flipper at time of tagging.]

Field length (inches)	Number of seals recovered during 5-day round with midpoint-- June				July					
	15[1]	20	25	30	5	10	15	20	25	Total
37	---	---	---	---	---	---	---	---	---	0
38	---	---	---	---	---	---	---	---	---	0
39	---	---	---	---	---	---	---	---	1	1
40	---	---	1	1	2	7	1	3	3	[2] 18
41	---	1	3	11	15	18	25	14	22	[2]109
42	1	4	6	16	27	22	28	22	18	[2]144
43	1	2	3	8	8	20	13	17	9	[2] 81
44	1	3	---	---	8	8	16	9	10	[2] 55
45	---	2	---	---	1	2	6	3	3	[2] 17
46	---	---	---	---	---	---	2	---	---	2
Unknown	---	---	---	---	1	---	---	---	---	1
Total	3	12	13	36	62	77	91	68	66	428

1/ 17 June only.

2/ Total, field lengths recorded, 41 through 45 inches, 406.

Table 25.--Number of male seals killed on St. Paul Island in 1950, by length in inches and by round.

Field length (inches)	Number of seals killed during 5-day round with midpoint-- Pre-season	June 20	June 25	June 30	July 5	July 10	July 15	July 20	July 25	Total
Less than 37	---	---	---	---	---	1	---	5	7	13
37	---	---	1	---	1	5	7	13	18	45
38	1	---	1	11	8	7	14	17	18	77
39	---	1	2	13	21	43	34	46	45	205
40	7	45	69	104	122	184	199	187	181	1,098
41	41	269	422	862	1,104	1,576	1,804	1,830	1,723	9,631
42	54	301	629	984	1,632	1,900	2,408	2,055	2,080	12,043
43	62	344	626	1,020	1,480	1,820	2,017	1,846	1,868	11,083
44	41	258	358	758	1,047	1,130	1,598	1,367	1,222	7,779
45	13	232	227	522	505	714	917	883	726	4,739
46	5	56	76	139	197	167	232	208	136	1,216
47	6	13	23	56	73	58	84	70	60	443
48	---	13	6	11	28	17	26	13	13	127
49	---	1	1	5	5	2	4	9	8	35
50	1	3	---	1	4	1	3	2	1	16
51	---	---	1	---	---	---	1	1	---	3
More than 51	---	---	---	---	1	---	5	1	1	8
Total	231	1,536	2,442	4,486	6,228	7,625	9,353	8,553	8,107	48,561

Consequently it may be estimated that the number of 3-year-old seals taken in the kill represents $\frac{1,243-114}{1,243}$ = 91 percent of the total that hauled out on land before July 27.

Method 2, Comparison of tag recoveries and the total kill: This comparison would be similar to Method 1, if the number of 3-year-olds in the kill were known for each size class. What is known is the estimated total number of 3-year-olds in the 1950 kill (31,746 from table 30) and the fact that most of the seals below 41 inches in length, in the commercial kill are 3-year-olds. It is also necessary to use the estimate of oversize escapement of method 1: $\frac{10}{15}$ = .67 of this group apparently escape through the kill. With these assumptions, the procedure is as follows:

Proportion of known-length seals in tagged group below 41 inches = $\frac{154}{1,240} = 0.124$

Proportion of known-length seals in tagged group 41 - 45 inches = $\frac{1,071}{1,240} = 0.864$

Proportion of known-length seals in tagged group above 45 inches = $\frac{15}{1,240} = 0.012$

Proportion of seals in kill below 41 inches (table 25) = $\frac{1,438}{31,746} = 0.0458$

Let x = proportion of the below-41-inch size group taken in the kill

$$\therefore \frac{.124\,x}{.124x + .864 + (33)\ (.012)} = .0458$$

Whence x = 0.34

∴ Proportion escaping out of total hauling-out before the end of the commercial kill
= [1 - 0.34] [0.124] + (0.67)(.012) = 0.09

The exact agreement of this result with that obtained by method 1 is to be regarded as coincidental in view of the sampling errors involved in the estimates. Moreover the fact that some of the 1,438 seals below 41 inches in length in the commercial kill are 2-year-olds will make this method-2 estimate low.

Postseason escapement.--By fitting a curve to the number of seals recovered in each 5-day round during the season, it is possible to estimate the numbers arriving after the season closes. Such estimates can be based on the tag recoveries or on the total kill for any age class, as estimated in turn by means of the tooth-ridge age determinations. The most difficult problem is the choice of a satisfactory curve. Among three families of curves, the normal, the logarithmic-normal, and Pearson's type III, the last fits most closely in some situations when the agreement between the empirical and theoretical curves is judged by Pearson's chi-square test, (sum of differences squared)/(theoretical value). In other cases none of these gives a satisfactory agreement. This is due to the vagaries of the returns, which are governed by weather and other factors and which consequently do not form a smooth series. (Moreover the numbers in the age classes in the total kill are themselves estimates with varying errors.) The fitted curve must then smooth the original data as well as form a basis for extrapolation, to estimate the postseason escapement.

Escapement estimates based on the logarithmic-normal and type-III curves are implausibly large, particularly for the 3-year-old class. On

the other hand, the normal curve gives estimates that are more in accordance with other observations, in particular with the known kill of 4-year-olds.

The procedure and tables of Hald (1952) are used in estimating the parameters of the normal curve. One advantage of this procedure is that the escapement can be estimated without evaluating all of the parameters.

The following four series have been analyzed in this manner to yield estimates of escapement:

Round centered at--	1950 kill[1] of 3-year-olds	1950[2] returns of A-tags	1951 kill[3] of 3-year-olds	1951[4] returns of B-tags
June 20	[5] 745	[5] 47	[6] 519	[6] 10
25	1,265	64	956	33
30	3,083	132	799	69
July 5	4,312	213	2,496	111
10	4,938	251	4,593	161
15	5,787	316	3,567	212
20	5,597	324	7,651	331
25	6,019	324	7,379	336
Total	31,746	1,671	27,960	1,263
Estimated percent escapement (after July 27)	21	24	47	43

1/ From table 30.

2/ From tables 26 and 27 combined.

3/ From table 31.

4/ By similar analysis to the 1950 A-tag returns.

5/ Including preseason.

6/ Two days only (postseason kill not included).

Since these estimates are based on samples of varying sizes and accuracy (the commercial-harvest samples are much larger, but are based on estimates from the age readings), an unweighted average is taken to determine mean escapement, viz., 34 percent. In other words, we estimate that 66 percent of the 3-year-old group appears on land before the end of the commercial harvest, on July 27. The actual percent escapement may also be reduced by a postseason kill, if any.

Total escapement.--Of the 66 percent of male seals 3 years of age appearing on land up to July 27, 91 percent are taken in the commercial harvest, according to the estimate made in the section on the escapement through the season. Thus the commercial kill takes (.91) 66 = 60 percent of the total number of 3-year-old males while it is estimated that on the average 40 percent survive the kill (neglecting any postseason kill).

From table 7 the average 3-year-old kill for 1950-52 is estimated to be 38,046.

$$\therefore \text{ Average returns of 3-year-old males} = \frac{38,046}{.60} = 63,410.$$

Average escapement = 25,364.

Escapement of 4-year males in 1951

Through-the-season escapement.--This escapement may be estimated from A-tag returns in 1951 (table 26). Again all tagged seals observed in the commercial kill were taken, so that this escapement may be based on a comparison of those recoveries with the total kill or with the tag-lost group. However, it is important to recognize that the A-tag returns in 1951 have been modified by the procedure of taking all tagged animals in 1950. In particular an assumption has to be made about the 104 tagged animals below 41 inches in length that we have estimated should have escaped the 1950 kill but for this fact. According to the mortality table it may be estimated that 6 would have died in the intervening year in any case. If it is assumed that animals returning early as threes continue to do so as fours, and further that males below 41 inches as threes will fall in the 41- to 45-inch size range as fours, then it may be estimated that the corrected number of A-tag recoveries in the 41- to 45-inch size range = 298 + 98 = 396.

Similarly, it is assumed that 9 of the 10 oversized A-tagged seals killed in 1950 would otherwise have been recaptured in 1951. Estimated proportion of known-length seals in tagged group above 45 inches if no killing for tags had taken place in 1950

$$= \frac{\text{corrected number over 45 inches}}{\text{40-inch + corrected number}} = \frac{}{\text{41- to 45-inch + corrected number over 45 inches}} =$$

$$\frac{161 + 9}{1 + 396 + 161 + 9} = \frac{170}{567} = .300$$

Proportion of seals in commercial kill above 45 inches

$$= \frac{3,856}{19,661} = 0.196$$

(neglecting the fact that a few of these 3,856 may be 3- and 5-year-olds)

If x = proportion of the above-45-inch group taken in the kill

$$\frac{0.300x}{0.700 + 0.300x} = 0.196$$

$$x = 0.57$$

Table 26.--Number of marked 4-year males recovered on St. Paul Island in 1951, by date and body length of seal.

[Tagged animals only; excluding tag-lost seals.]

Field length (inches)	Number of seals killed during 5-day round with midpoint-- June 20[1]	June 25[2]	June 30	July 5	July 10	July 15	July 20	July 25	July 30[3]	Total
40	---	---	---	---	1	---	---	---	---	1
41	---	---	2	1	3	1	---	1	---	8[4]
42	2	1	4	9	5	1	7	2	1	32[4]
43	1	7	6	12	15	12	16	6	2	77[4]
44	2	4	9	12	18	12	18	7	4	86[4]
45	2	2	9	12	16	18	18	15	3	95[4]
46	3	2	3	8	10	14	14	14	2	70[5]
47	1	---	2	6	5	5	12	8	2	41[5]
48	---	---	1	2	9	1	3	10	1	27[5]
49	---	---	1	3	3	1	1	4	1	14[5]
50	---	1	1	---	---	1	1	1	---	5[5]
51	---	---	---	---	---	1	---	1	---	2[5]
52	---	---	---	---	1	---	---	1	---	2[5]
Unknown	---	---	---	---	1	---	---	---	---	1
Total	11	17	38	65	87	67	90	70	16	461

1/ 20 and 22 June only.

2/ No kill on 23 June.

3/ 28 and 29 July only.

4/ Total, recorded 41 through 45 inches, 298.

5/ Total, recorded, 46 through 52 inches, 161.

Table 27.--Number of marked 4-year males recovered on St. Paul Island in 1951, by date and body length of seal.

[Tag-lost animals only; tag-lost animals are identified by a tag scar and by a hole which was punched in the hind flipper at time of tagging.]

Field length (inches)	Number of seals recovered during 5-day round with midpoint-- June 20[1]	June 25[2]	June 30	July 5	July 10	July 15	July 20	July 25	July 30[3]	Total
40	---	---	---	---	1	---	---	---	---	1
41	---	---	1	5	2	---	---	---	---	8[4]
42	---	---	---	11	3	3	2	---	1	20[4]
43	---	1	9	10	12	7	9	6	1	55[4]
44	---	2	5	19	18	10	15	5	1	75[4]
45	---	1	2	10	10	4	13	5	2	47[4]
46	---	1	2	7	1	4	5	2	3	25[4]
47	---	---	1	4	4	1	3	2	1	16[4]
48	---	---	---	1	---	---	1	1	---	3
49	---	---	---	1	---	---	2	1	---	4
50	---	---	---	---	---	---	---	---	---	---
Total	---	5	20	68	51	29	50	22	9	254

1/ 20 and 22 June only; no search made for tag-lost seals.

2/ No kill on 23 June.

3/ 28 and 29 July only.

4/ Total recorded, 41 through 47 inches, 230

Proportion escaping = (1 - 0.57)(0.300) = 0.13

It is estimated that 87 percent of the 4-year-olds hauling out on land during the killing season are taken in the kill.

It should further be pointed out that the escapement may be higher in other years, since in 1951 clubbers were instructed to take 41- to 46-inch length seals whereas normally only 41- to 45-inch seals are taken. While it is true that in any year many 46-inch seals are taken and certainly in 1951 not all 46-inch seals were taken, it is probable that some reduction in 4-year-old escapement could be attributed to this factor.

Postseason escapement.--The same method of fitting normal curves to the various returns is applied here. The returns to which they were applied and the results are as follows:

Round centered at--	Kill of 4-year-olds in-- 1950	1951	1952
June 20	974	493	(1/)
25	1,112	1,241	(1/)
30	1,311	2,513	(1/)
July 5	1,916	3,308	3,026
10	2,687	3,207	4,388
15	3,326	2,945	2,503
20	2,864	3,294	1,854
25	1,853	2,083	1,663
Total	16,043	19,658	
Estimated escapement (after July 27) percent	15	8	4

1/ No complete analysis available.

Averaging these the estimated postseason escapement is 9 percent of the overall total; in other words, 91-percent haulout before the end of the killing season.

. . Combining the two types of escapement it is estimated that:

.91 (87) = 79 percent of the four-year-olds are taken in the kill or that 21 percent of the total escape.

Some of the estimates above may be low for reasons outlined; all, of course, are subject to indeterminate sampling errors. On the other hand, any postseason kill will reduce the total escapement.

Applying this escapement to the 1950-52 average kill of 4-year-old males (estimated in table 7) gives:

$$\text{Estimated return of 4-year-olds} = \frac{21,478}{.79} = 27,187$$

Estimated escapement of 4-year-olds = 27,187 -21,478 = 5,709

Total escapement.--It will be observed that the estimate of escapement of 3-year-olds and the estimate of returns of 4-year-olds

disagree by approximately 3,000 (allowing for mortality during the year). This difference is certainly less than the sampling errors involved. Consequently it is futile to attempt to determine on the basis of the present data whether the estimate of 3-year-old male escapement (25,364) is too low or the estimate of 4-year-old male escapement (5,709) too high or whether perhaps a combination of both of these holds. It will, of course, be important to resolve this in the future, for on the basis of the present estimated 4- and 5-year-old kills and mortality rates, a 3-year-old escapement of 25,000 gives an annual replacement to the bull population (males 7 and over) of only about 1,000. Because this figure seems to be low, the life table for males has been calculated using the estimate of 4-year-old escapement of 5,709 as a checkpoint.

Table 28.--Number of male seals killed on St. Paul Island in 1951 by length in inches and by round

Field length (inches)	Number of seals killed during 5-day round with midpoint-- Pre-season 1/	June 2/		July					Post-season 3/	Total
		25	30	5	10	15	20	25		
37	1	---	---	1	5	2	5	1		15
38	---	2	6	8	6	3	6	9	3	43
39	3	5	16	42	39	28	39	38	7	217
40	25	39	123	254	215	239	322	299	50	1,566
41	200	328	546	1,006	1,412	1,025	1,832	1,989	374	8,712
42	221	386	630	1,182	1,595	1,278	2,116	2,000	564	9,972
43	220	479	754	1,247	1,753	1,506	2,324	2,106	565	10,954
44	177	439	589	983	1,469	1,156	1,977	1,616	466	8,872
45	125	306	468	661	995	804	1,419	1,093	341	6,212
46	42	188	219	312	261	338	586	381	185	2,512
47	14	44	56	110	118	119	199	141	50	851
48	6	18	12	25	60	30	86	60	15	312
49	1	6	4	16	23	9	26	30	4	119
50	1	5	6	5	1	6	7	8	4	43
51	1	1	---	---	1	2	---	2	---	7
More than 51	1	---	1	---	2	1	1	1	---	7
Total	1,038	2,246	3,430	5,852	7,955	6,546	10,945	9,774	2,628	50,414

1/ 2 days only.

2/ 4 days only.

3/ 2 days only.

APPENDIX F

Calculations for the size of the pup class in 1947 from tag recoveries

From actual tag recoveries on 5 areas

The method used to estimate the number of pups is based on the fact that if

t_i were tagged on area i and

n_j were sampled from area j which originally had a population N_j and

s_{ij} tags were recovered on area j that had been applied in area i, then on the average

$$\sum_{j=1}^{5} s_{ij} \frac{N_i}{n_j} = t_i \qquad i = 1 \ldots . 5$$

The values n_j, t_i, s_{ij} are known and hence there are 5 equations in 5 unknowns to solve for the N_j. Summing the five N_j yields the total population estimate.

The five equations based on A-tags and composite returns of 1950 and 1951 are as follows:

$$\frac{420}{17941} N_1 + \frac{34}{8373} N_2 + \frac{3}{7423} N_3 + \frac{6}{6307} N_4 + \frac{18}{11315} N_5 = 5,557$$

$$\frac{88}{17941} N_1 + \frac{280}{8373} N_2 + \frac{6}{7423} N_3 + \frac{5}{6307} N_4 + \frac{10}{11315} N_5 = 5,040$$

$$\frac{67}{17941} N_1 + \frac{33}{8373} N_2 + \frac{127}{7423} N_3 + \frac{36}{6307} N_4 + \frac{92}{11315} N_5 = 3,214$$

$$\frac{18}{17941} N_1 + \frac{6}{8373} N_2 + \frac{5}{7423} N_3 + \frac{33}{6307} N_4 + \frac{30}{11315} N_5 = 876$$

$$\frac{57}{17941} N_1 + \frac{30}{8373} N_2 + \frac{6}{7423} N_3 + \frac{19}{6307} N_4 + \frac{279}{11315} N_5 = 4,496$$

Here

N_1 = number of pups on Northeast Point

N_2 = " " " " The Polovinas

N_3 = " " " " Reef-Gorbatch

N_4 = " " " " Tolstoi and Lukanin-Kitovi

N_5 = " " " " The Zapadnis

and

t_1 = number of tags applied at Northeast Point

t_2 = " " " " " The Polovinas

t_3 = " " " " " Reef-Gorbatch

t_4 = " " " " " Tolstoi and Lukanin-Kitovi

t_5 = " " " " " The Zapadnis

and

n_1 = 17,941 seals killed as 3-year-olds in 1950 and as 4-year-olds in 1951 at Northeast Point

n_2 = 8,373 ditto for the Polovinas

n_3 = 7,423 ditto for Reef-Gorbatch

n_4 = 6,307 ditto for Tolstoi and Lukanin-Kitovi

n_5 = 11,315 ditto for the Zapadnis

Total 51,539

Numerators of the left-hand side of the equations, the s_{ij} are obtained from table 25, combining the recoveries at ages 3 and 4.

The solutions are--

$$N_1 = 206,971$$
$$N_2 = 114,944$$
$$N_3 = 39,877$$
$$N_4 = 39,549$$
$$N_5 = 132,834$$

However, this is based on recovery of tags only; no allowance has been made for deliberate killing for tags or for the recovery of tag-lost animals. In a moment it will be shown that the corrected number of recoveries of tags and tag-lost animals is 2,303; the procedure above is based on 1,708 tags. Consequently each of the estimates must be reduced by the factor

$$\frac{1,708}{2,316}, \text{ or } 0.7375$$

The entire foregoing estimations procedure was applied to the A-tags recovered in 1950 and the A-tags recovered in 1951 separately. The adjusted estimates for the five areas are shown below.

	Northeast Point	The Polovinas	Reef-Gorbatch	Tolstoi and Lukanin-Kitovi	The Zapadnis
1950 returns	138,280	86,316	27,122	29,762	86,262
1951 returns	195,121	83,606	18,289	29,202	128,627
Composite	152,641	84,771	29,409	29,167	97,965
Composite Total = 393,953					

Adjustment for number of tagged seals recovered

Because the sealers were instructed in 1950 and 1951 to kill all tagged animals regardless of size, the kills were not representative with respect to tag recoveries. The tagged animals were killed because they wore tags, while the untagged animals were killed because they were of commercial size, approximately 41 to 45 inches in length. Hence, it is necessary to calculate the number of tagged animals that would have been recovered had they been killed for size, regardless of tags. This has been done in table 22 where the calculations were used to estimate through-the-season escapement.

The estimate of "excess kill" resulting from the taking of small and large seals simply because they were tagged is 114.

Similarly, for 1951, the proportion of tagged to tag-lost 4-year-olds in the 41- to 46-inch class is $\frac{368}{230}$ or 1.60 (tables 26 and 27).

Length (inches)	Number of tag-lost seals	Expected number of tagged seals	Actual number of tagged seals	"Excess kill"
40 and under	1	(insufficient data)	1	0
46	(commercial standards were raised in 1951 to include 46-inch seals)			
47 and over	23	37	91	54

The "excess kill" of small males in 1950, totaling 104, (table 22), presents a special problem. Most of these would have been killed in the following year, except for those that died during the winter of 1950-51. In appendix E in discussing 4-year male escapement it was estimated that 98 of these would have been taken in 1951. Thus, the adjusted number of tag recoveries for 3- and 4-year males of the A-series becomes:

1950 tag recoveries	1,671
1951 tag recoveries	+ 715
1950 excess kill of large seals . . .	- 10
1951 excess kill of small and large seals . . .	- 54
1950 adjustment to 1950 excess kill of small seals = -104 + 98 = . .	- 6
Total	2,316

Table 29.--Number of A-tagged males recovered in 1950 and 1951, by areas where tagged and where recovered.

[Underlined figures represent seals homing to rookery of birth]

Rookery group where tagged	Recovered on— Lukanin-Kitovi	Northeast Point	Polovina	Reef	Tolstoi	Zapadni	Subtotal	St. George	Total
				Recovered 1950 at age 3					
Northeast Point	4	312	31	3	2	17	369	4	373
Polovina	1	68	195	6	2	6	278	3	281
Reef	5	44	25	89	18	65	246	3	249
Tolstoi	---	14	5	5	20	21	65	---	65
Zapadni	2	49	22	3	15	194	285	11	296
Subtotal	12	487	278	106	57	303	1,243	21	1,264
				Recovered 1951 at age 4					
Northeast Point	---	108	3	---	---	1	112	---	112
Polovina	---	20	85	---	2	4	111	2	113
Reef	1	23	8	38	12	27	109	3	112
Tolstoi	1	4	1	---	12	9	27	---	27
Zapadni	---	8	8	3	2	85	106	1	107
Subtotal	2	163	105	41	28	126	465	6	471
Total	14	650	383	147	85	429	1,708	27	1,735

Table 30.--Estimated numbers of 3- and 4-year males killed in 1950 by rounds and hauling ground groups, St. Paul Island.

Rookery	18-22 June No.	%	23-27 June No.	%	28 June 2 July No.	%	3-7 July No.	%	8-12 July No.	%	13-17 July No.	%	18-22 July No.	%	23-27 July No.	%	Pre-season 17 June No.	%	Total No.
3-year-olds:																			
Zapadni	84	45	131	30	698	65	962	70	222	60	1,754	85	1,562	70	1,278	60	---	--	6,691
Tolstoi-Lukanin-Kitovi	48	60	105	50	96	80	365	55	1,518	80	967	65	436	55	514	80	---	--	4,049
Reef	149	25	251	50	292	45	450	80	821	70	599	60	416	40	713	55	---	--	3,691
Polovina	158	50	435	65	530	45	742	60	896	60	731	55	896	55	973	65	---	--	5,361
Northeast Point	214	60	343	55	1,467	100	1,793	75	1,481	55	1,736	50	2,287	80	2,541	100	92	40	11,954
Total	653		1,265		3,083		4,312		4,938		5,787		5,597		6,019		92		31,746
4-year-olds:																			
Zapadni	102	55	304	70	322	30	413	30	148	40	310	15	670	30	746	35	---	--	3,015
Tolstoi-Lukanin-Kitovi	32	40	106	50	18	15	298	45	379	20	521	35	317	40	129	20	---	--	1,800
Reef	419	70	252	50	324	50	112	20	352	30	400	40	572	55	454	35	---	--	2,885
Polovina	157	50	201	30	647	55	495	40	597	40	532	40	733	45	524	35	---	--	3,886
Northeast Point	125	35	249	40	---	--	598	25	1,211	45	1,563	45	572	20	---	--	139	60	4,457
Total	835		1,112		1,311		1,916		2,687		3,326		2,864		1,853		139		16,043

Table 31.—Estimated numbers of 3- and 4-year males killed in 1951 by rounds and hauling ground groups, St. Paul Island

Rookery	24-27 June No.	%	28 June 2 July No.	%	3-7 July No.	%	8-12 July No.	%	13-17 July No.	%	18-22 July No.	%	23-27 July No.	%	Pre-season 20 & 22 June No.	%	Post-season 28-29 July No.	%	Total No.
3-year-olds:																			
Zapadni	282	45	160	30	376	40	1,165	60	587	45	2,107	65	2,322	80	---	--	1,622	85	8,621
Tolstoi-Lukanin-Kitovi	---	--	89	15	169	25	656	75	634	65	1,238	100	536	55	---	--	432	60	3,754
Reef	254	45	113	20	208	25	175	20	385	55	939	55	843	70	310	60	---	--	3,227
Polovina	253	50	121	25	464	55	389	35	478	55	1,310	65	1,340	85	---	--	---	--	4,355
Northeast Point	167	30	316	25	1,279	50	2,208	70	1,483	55	2,057	75	2,338	75	209	40	---	--	10,057
Total	956		799		2,496		4,593		3,567		7,651		7,379		519		2,054		30,014
4-year-olds:																			
Zapadni	315	50	346	65	517	55	776	40	718	55	1,135	35	581	20	---	--	286	15	4,674
Tolstoi-Lukanin-Kitovi	---	--	471	80	509	75	219	25	342	35	---	--	438	45	---	--	288	40	2,267
Reef	310	55	450	80	624	75	655	75	280	40	769	45	361	30	206	40	---	--	3,655
Polovina	227	45	362	75	379	45	611	55	391	45	705	35	236	15	---	--	---	--	2,911
Northeast Point	389	70	884	70	1,279	50	946	30	1,214	45	685	25	467	15	287	55	---	--	6,151
Total	1,241		2,513		3,308		3,207		2,945		3,294		2,083		493		574		19,658

APPENDIX G

Aerial photography on the Pribilofs

Perfection of the airplane as a mapping device brought hope that a new fur-seal census method might be developed. In 1938 Superintendent Harry J. Christoffers left Village Cove, St. Paul Island, in a U. S. Coast Guard seaplane and cruised for a time over the rookeries (U. S. Bureau of Fisheries, 1938, p. 162). He took a few motion pictures and still photographs but found them of no practical value.

On 9 July 1945 one of us (Scheffer) flew with a U. S. Navy photographic mission in an amphibious plane (PBY) over certain rookeries of St. Paul Island. Eighty-three 4- by 5-inch negatives were obtained with a K-20 aerial camera, most of them oblique views. The experiment was useful to the extent that it pointed out the need for larger negatives and complete vertical coverage of the rookeries.

In the summers of 1947, 1948, and 1949, Scheffer and Kenyon took experimental photographs with a 4- by 5-inch camera suspended from a captive balloon (Scheffer, 1950b, illus. on p. 22). They were unable to control twisting and swaying of the camera and eventually decided to postpone experimentation with this device.

From 13 to 15 July 1948, Scheffer and Kenyon flew over all of the rookeries on the Pribilof Islands in a twin-engine land plane equipped with an F-56 camera with an 8.5-inch lens. The runs were made at elevations of 900 to 1,200 feet and at a ground speed of about 90 mph.

Two aerial missions were flown by the U. S. Air Force, neither of which produced useful negatives for this study. On 27 July 1948 the Tenth Rescue Squadron flew a PBY mission from Anchorage, Alaska. On 19, 28, and 29 July 1949, the Second Air Force flew a B-29 mission from Barksdale Air Force Base, Louisiana.

The first attempt to photograph the fur-seal rookeries from a helicopter was made on 19 July 1951 when the Navy icebreaker U.S.S. Burton Island with two helicopters aboard stopped at St. Paul Island. Through the courtesy of Commander J. R. Schwartz, in charge, Lieutenant R. L. Maghan was assigned to take one of us (Kenyon) aloft. Photographs of the seal rookeries were taken with a 3-1/4- by 4-1/4-inch camera from altitudes of 100, 200, and 400 feet. The seals were badly frightened by the violent downdraft and noise from the rotor blades, and stampeded even when the helicopter was at 400 feet. Although the photographs were clear, they did not furnish appreciably better results than were obtained in 1948. It is concluded that at the present time the helicopter is impractical for large-scale photography of fur-seal rookeries at altitudes permitting a count of individual seals.

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