COMPARATIVE FEEDING HABITS OF THE

FUR SEAL (*CALLORHINUS URSINUS*), SEA LION

(*EUMETOPIAS JUBATA*) AND HARBOUR SEAL (*PHOCA VITULINA*)

ON THE BRITISH COLUMBIA COAST

by

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ABSTRACT

Feeding habits of fur seals (Callhorinus ursinus), sea lions (Eumetopias jubata) and harbour seals (Phoca vitulina) have been examined along the British Columbia coast. Collections were made out to 35 miles from shore. All pertinent published and unpublished data have been combined with the object of assessing the effect of pinniped predation upon commercially valuable fish stocks. A total of 126 harbour seal stomachs, 2,113 fur seal stomachs and 393 sea lion stomachs were available. Comparative anatomy of the digestive tract was examined and notable differences were found in the relatively longer digestive tract and late eruption of permanent teeth in the sea lion. Published data indicate that fur seals, sea lions, and harbour seals eat an amount of food equal to 6% of their body weight per day with a range of 2% to 11%. All samples were grouped as to season and area of collection and comparative seasonal feeding habits were discussed. The effect of the reproductive period upon feeding habits was examined: there is little evidence regarding fur seal feeding habits on the rookeries except for conflicting observations made on harem bulls; the majority of the sea lion rookery population fasts for a few days only, during pupping; harbour seals on the Skeena River appear to fast for at least part of June. There is no evidence of interspecific competition between the three species studied on the British Columbia coast. Sea lions and harbour seals each year eat an estimated amount equivalent to 1.6% of the annual commercial salmon catch and

2.7% of the annual commercial herring catch. Predation at this level is believed to be of negligible importance in the reduction of existing salmon and herring stocks. Insufficient data from waters greater than 35 miles from shore precludes an assessment of fur seal predation upon ocean salmon. Further offshore collections should be made.

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The collecting of seals and sea lions is difficult, often unpleasant and occasionally dangerous. The cooperation of those mentioned below has increased the number of specimens available for this study: Mr. R. Kelly and crew of the "Pacific Ocean"; Messrs. T. and A. Boroevich and crew of the "St. Joseph"; Mr. D. Berven and crew of the "T. W. Islander"; Mr. W. Secord and Mr. D. Secord; Messrs. D. and W. McNaughton of Pender Harbour; Mr. I. B. MacAskie, Mr. T. Binnersley, Mr. W. Pinckard and Mr. F. Velsen of the Biological Station. The Department of Fisheries has cooperated in the collection of specimens whenever possible.

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INTRODUCTION

The predatory activities of several members of the order Pinnipedia provoke heated arguments whenever inshore fisheries are carried out near seal or sea lion populations. On the one hand commercial fishermen advocate stringent controls, and in some instances complete eradication, of all pinnipeds whose depredations may affect fish catches. "The only good seal (or sea lion) is a dead one" is a favourite expression. On the other hand many naturalists and seal lovers vigorously oppose such control measures. Control is often synonomous with "slaughter" and "extinction" to some members of the latter group.

Three pinnipeds, the northern fur seal (Callorhinus ursinus), the northern sea lion (Eumetopias jubata), and the harbour seal (Phoca vitulina), are found in British Columbia's coastal waters where commercial fishing is carried out. This study is an attempt to describe the seasonal feeding habits of these three pinnipeds with particular reference to the commercially valuable fish species in their diet. The amount of salmon and herring eaten by sea lions and harbour seals has been estimated in Appendix 1.

HISTORY OF PINNIPED FOOD HABIT STUDIES

An extensive body of literature deals with pinniped feeding habits, much of it about the problem of predation upon commercially valuable fish species. The following summary includes the major pinniped food habit studies carried out in waters of western Europe, North America and Japan. Food items have been described either by their common names, or by both common and scientific names in the studies reviewed. For the sake of consistency common names have been used in this study. Appendix Table I includes scientific and common names of all food items referred to.

A. Feeding habits of seals outside British Columbia's coastal waters

Rae (1960) summarized the major studies carried out in western Europe and the British Isles. Hjort and Kripowitsch (1907) and Wollebaek (1907) concluded that seals on the Norwegian coast were destroying more salmon than were caught by fishermen in that area, during the early part of the twentieth century. Havinga (1933) estimated that commercially valuable fish comprised 75% of the food of harbour seals (*Phoca vitulina*) in Dutch waters. Rae (1960) examined the predatory activity of both the harbour seal and the grey seal (*Halichoerus grypus*) in the British Isles. He concluded that these two species annually consumed an amount of fish equivalent to one-fifth the total annual British catch from inshore or home waters.

Food items eaten by pinnipeds on both the Atlantic and Pacific coasts of North America (excluding British Columbia), and in the western Pacific, are summarized in Appendix Table II. This table illustrates the wide range of foods available. Despite the large number of food items, however, each pinniped usually concentrates on a relatively few items in any given area.

The fur seal (*Callorhinus ursinus*) has been studied extensively in both the eastern and western Pacific. Most collections have been made under the terms of two international programs of investigation: (a) In 1952 a one-year program was undertaken by Japan, the United States and Canada to study the distribution, migration and food habits of the fur seal. (b) In 1957 representatives from Russia, Japan, the United States and Canada signed an "Interim Convention on Conservation of the North Pacific Fur Seals". This convention, effective for six years, was designed to investigate the numbers, migration routes and wintering areas of the seals, their feeding habits and effects upon commercial fish stocks and fishing gear.

Before 1952, fur seal collections in the western Pacific consisted of 61 stomachs (Taylor et al., 1955). During 1952, under terms of the first international investigation, 1,138 stomachs with food were examined from Japanese waters. Lantern fish and squid contributed 87% by volume to these contents (Taylor et al., 1955). These authors concluded that seal predation upon salmon was of occasional and local significance only, but that further studies should be carried out. Studies since 1958 (Anon., 1961) indicate that off Sanriku and Honshu lantern fish and squid contributed from 70 to 90% by volume annually (3,347 stomachs examined). Three hundred and seventy-two stomachs from the Sea of Japan and the Okhotsk Sea indicated that whiting was the most important food. In the western Bering Sea squid and salmonids formed 75% by volume of the contents of 33 stomachs. Salmon contributed 42% by volume to the contents of 17 stomachs from the salmon fishing grounds of the northwest Pacific. No conclusions have as yet been drawn in the present international investigation about the effect of fur seals upon Japanese and Russian fisheries.

In the eastern Pacific, Alexander (1892) and Lucas (1899) examined 140 fur seal stomachs from the Gulf of Alaska and Bering Sea. Squid, salmon, whiting and rockfish were the most important food items. Schultz and Rafn (1936), May (1937) and Bonham (1941) examined a total of 100 stomachs from the Washington coast and found that squid and herring were the two most important food items. Wilke and Kenyon (1954) found that herring comprised over 99% by volume of the contents of 148 stomachs from West Crawfish Inlet, Alaska.

The first (1952) international program in the eastern Pacific found the following (Taylor et al., 1955): from California to Washington clupeids, smelts, anchovy, hake, whiting and rockfish formed nearly 70% by volume of the contents from 125 stomachs. In the Gulf of Alaska capelin formed over 90% by volume of the contents of 116 stomachs. No conclusions were drawn during the 1952 investigation about the possible effect of fur seals on eastern Pacific fisheries.

Results from the first four years of the second (1957) international investigation, excluding the British Columbia collections, were as follows (Anon., 1961): seals wintering off California feed mainly on anchovy, saury, squid and hake, which comprise between 80 and 90% of the contents examined each year. In Oregon waters anchovy, hake and rockfish predominate in stomachs. The Washington sample indicated that herring, anchovy and rockfish were the important food items contributing 67% by volume to the contents examined. Fiscus et al. (1961) stated that the fur seal could not be considered a serious threat to the commercial fisheries of California, Oregon and Washington.

In Alaska herring, capelin, whiting and sandlance are the important food items and have contributed 93% by volume to the total contents examined. Niggol *et al*. (1960) concluded that fur seal predation upon commercially valuable fish in Alaskan waters was of negligible importance.

Smith (1904) and Starks (1918), reporting on sea lions (*Eumetopias jubata* and *Zalophus californianus*) from California and Oregon, found that squid, skate, shark and rockfish were the most important of the identified foods. Sea lion predation upon salmon at the mouth of the Columbia River caused "much damage".

Imler and Sarber (1947) examined 15 northern sea lion (*Eumetopias jubata*) stomachs from Alaska. Salmon, whiting and flatfish comprised 80% of the contents examined. Thorsteinson and Lensink (1962) found that squid, octopus, rockfish and sandlance predominated in 56 stomachs collected along the Alaska peninsula. Mathisen *et al*. (1962) examined 114 sea lions from Chernabura Island, Alaska. Squid, octopus, greenlings and smelts were the most important food items. Salmon occurred once.

Harbour seals on the Atlantic coast of Canada feed mainly on herring, cod and flatfish, which formed 59% by volume of the contents in a sample of 201 stomachs (Fisher and Mackenzie, 1955). Templeman *et al*. (1957) reported that clupeids, salmonids, smelts, cods and flatfishes were the food items most often observed in harbour seal stomachs from Newfoundland and Labrador. In Washington State the harbour seal is not believed to consume large amounts of salmon, but may often cause financial loss to individual fishermen (Scheffer, 1928; Scheffer and Sperry, 1931;

Scheffer and Slipp, 1944). Crustaceans, herring, cods, flatfish and sculpins formed 65% by occurrence of the contents from 95 stomachs. The harbour seal in Alaska feeds extensively on eulachon in the Copper River area and on herring, salmon, eulachon, cods and flatfish in southeast Alaska (Imler and Sarber, 1947). From observations made on damaged salmon these authors estimated that harbour seals in the Copper River estuary destroyed an amount of salmon equivalent to two to three per cent of that area's total annual salmon catch.

B. Feeding habits of seals in British Columbia waters

1. Fur seals

Fur seal stomachs from British Columbia were first examined in 1933 and 1935 (Clemens and Wilby, 1933; Clemens, Hart and Wilby, 1936). These early studies attempted to assess the role of fur seals in the economy of the ocean off the Canadian Pacific coast. In the 193 stomachs examined, herring formed 84% by volume of the contents and was obviously important in the diet of seals off southern Vancouver Island. These authors suggested that further sampling was required during the entire migratory period. They also stressed the importance of knowing the numbers of migrating seals, how long they remained in British Columbia waters and the daily food requirements of each seal.

Between 1935 and 1958 no fur seal stomachs from British Columbia were examined. Although Canada was a member of the first (1952) international program of investigation mentioned above, collections were not made in Canadian waters. During the second (1957) international investigation Canada agreed to collect between 500 and 750 seals each year in the northeast Pacific. Collecting began in 1958 and during the four years from 1958 to 1961, 1,520 stomachs were examined from British Columbia coastal waters. In order to fulfill Canada's quota commitments an additional 500 seals have been collected during the four years, in Washington or Alaskan waters. Collections will be continued until 1963, at least.

2. Sea lions

Sea lions were first studied in British Columbia during 1913 (Newcombe and Newcombe, 1913) and again during 1915 (Newcombe, Greenwood and Fraser, 1915). Although few stomachs were examined many fishermen and fishing company officials were interviewed. In two areas, the mouth of Rivers Inlet and in Barkley Sound, sea lions, when present in large numbers, evidently affected the fishing industry. Little research was done between 1916 and 1956, when an investigation was initiated by the Fisheries Research Board of Canada to gather information on the general biology of sea lions. Three hundred and seventy-four stomachs have been collected since 1956. Pike (1958), reporting on 81 stomachs collected during the early part of this latter program, tentatively concluded that commercially valuable fishes did not play as important a role in the sea lion diet as was often claimed.

3. Harbour seals

Fisher (1952) was the first to investigate the life history of the harbour seal, its distribution, numbers and food habits, particularly in the Skeena River area. Emphasis was placed on the role of salmon in the diet. Herring, salmon and rockfish contributed 68% by volume to the contents of 27 stomachs. Monetary losses from damaged chinook salmon, the species which suffered most from harbour seal attack, represented approximately seven per cent of the total value of the commercial catch, from a sample of five fishermen. Although Fisher realized his study was not exhaustive, he concluded that harbour seal predation upon Skeena River salmon warranted some control. On his recommendations the Department of Fisheries officials undertook a control program carried out during June of each year when the harbour seals were pupping on the Skeena River. Forty-five stomachs were examined during June of 1948 and 1949 by control officials. Fifty-four additional stomachs have been collected since 1958, when I joined the Marine Mammal Investigation of the Fisheries Research Board.

METHODS AND MATERIALS

A. Specimen collection

1. Fur seal

From 1958 to 1961 Canadian research vessels collected 1,520 fur seal stomachs between 48°00'N latitude to 55°00'N latitude during the months of January to June, inclusive. Only 25 were collected more than 35 miles from the British Columbia coast. Specimens were collected pelagically, while either wintering in British Columbia waters, or on their northward migration to the breeding grounds in the Bering Sea.

Quota commitments centered most hunting effort in areas of seal concentrations. Large numbers of seals were collected between Cape Flattery and the northern tip of Vancouver

Island. A small wintering population of adults in Hecate Strait was also sampled.

Hunting, when weather permitted, was carried out as follows: each morning the vessel left harbour and ran out 25 to 40 miles from shore, collecting all seals possible. During the afternoon the vessel returned to the coast, which was reached by nightfall. In this way the collecting vessel moved up and down the coast, searching for seal concentrations. The vessel occasionally lay one or more nights offshore, particularly if the weather was favourable.

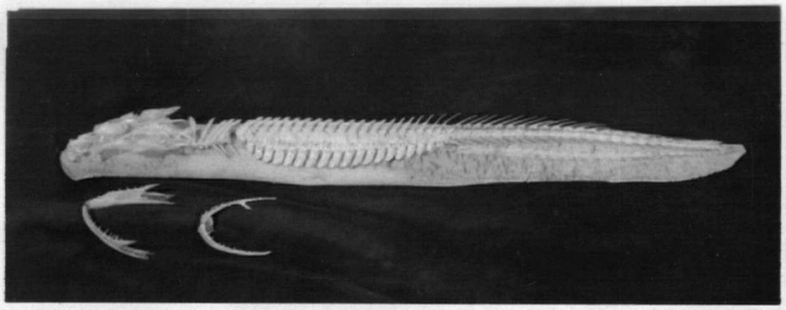
Seals were sighted from the bridge of the vessel (Figure 1) and were killed by means of a shotgun with S.S.G. shot or a 30.06 rifle. Fortunately, dead fur seals do not sink rapidly and only about six per cent were lost due to sinking. Records included time, date and location of capture, sex and breeding condition, and feeding behaviour. Stomachs were removed, injected with 10% formalin, placed in cotton sacks and stored in wooden barrels containing 10% formalin. The presence or absence of food in the stomach was noted in the laboratory and if the stomach was not empty the following data were recorded: weight of contents in grams (Figure 3), volume by displacement (cc), food species and numbers of individuals present.

2. Sea lions

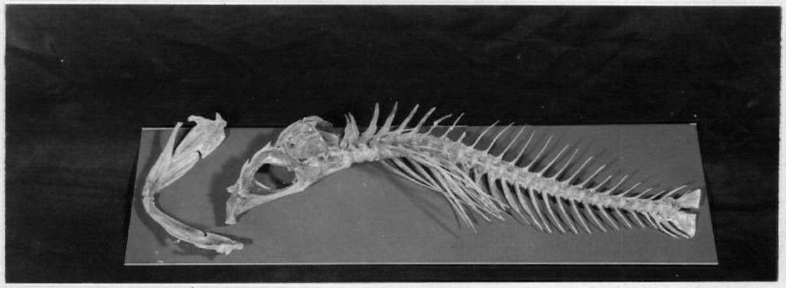
Most specimens were collected by Fisheries Research Board personnel, although Department of Fisheries officials saved or reported on several stomachs. In addition, I accompanied a commercial expedition for five weeks during the spring

Figure 1. M. V. "Pacific Ocean", used extensively for collecting fur seals, harbour seals and sea lions.

Figure 2. Collecting sea lions, Scott Islands, 1959.



Merluccius productus



Sebastodes maliger

Figure 3. Analysis of stomach contents
Top: examples from skeleton collection
Bottom: weighing fur seal stomach contents.

of 1959, collecting sea lions for mink food; 115 stomachs were examined.

Samples were collected mainly on the rookeries or haul-out rocks (Figure 2); collecting at sea was seldom successful as the animals were elusive and sank rapidly when killed. Rifles were used exclusively to collect specimens. Data collected were similar to those collected for fur seals, except that volume by displacement was not recorded for the contents of some stomachs examined in the field.

3. Harbour seals

The pressure of fur seal and sea lion studies has restricted harbour seal research, and few specimens are available. Messrs D. and W. McNaughton of Pender Harbour, working in conjunction with the Department of Fisheries, very kindly saved a substantial sample of 29 stomachs collected in the Queen Charlotte Islands during the fall of 1961.

Harbour seals, which sink almost immediately upon being killed, were collected mainly while swimming in shallow water. Toward the end of the collecting period, however, it was found that a good marksman in a fast boat could kill and collect seals before they sank. Data recorded for harbour seals were similar to those recorded for sea lions.

Table I indicates numbers of specimens collected throughout the calendar year. The fur seals were mainly females, while both sexes are represented approximately equally in the harbour seal and sea lion samples.

Table I. Monthly collection dates for all available harbour seal, fur seal and sea lion stomachs.

Month of collection	No. Specimens Collected		
	Harbour seal	Fur seal	Sea lion
January	1	17	
February	2	68	5
March	3	308	14
April	1	861	4
May	1	741	70
June	47	118	143
July	9		81
August	16		10
September	19		49
October	20		3
November	6		
December	1		14
Totals	126	2,113	393

B. Analysis of stomach contents

An examination of stomach contents is the favoured method of investigating pinniped feeding habits. Scats and spewings have been noted occasionally (Scheffer and Slipp, 1944; Scheffer, 1950; Wilke and Kenyon, 1952; Wilke and Kenyon, 1954), but they are seldom found. Most food items are consumed under water and sight observations are few (Scheffer, 1950). Hynes (1950), outlining the several possible methods of analysing fish stomach contents, has also covered the possible analyses for pinnipeds. The carnivorous feeding habits of most fish and pinnipeds, in an aquatic environment, leads to similar problems in assessing stomach contents. These several methods are discussed below.

1. Degree of fullness

An arbitrary estimate of the fullness of the stomach has been used to demonstrate seasonal variations in food intake.

2. Numbers of individuals

Total numbers of individuals of each food item are tabulated and may be expressed as percentages of all food organisms found in the sample. This is an unsatisfactory technique for a predator whose size of prey ranges from a stickleback to a ten-pound salmon.

3. Dominant items

The number of stomachs in which each food item occurs as the dominant food stuff is expressed as a per cent frequency of occurrence.

4. Points

Food items in each stomach are listed as common, frequent, etc., on the basis of rough counts or judgements made by eye, and each category is then alloted a number of points. All points gained by each food item are then summed and percentage calculations may be made.

5. Volume and weights

This method, and the following one, have been the customary techniques for handling pinniped stomach contents. The weight of each food item in each stomach is calculated in either of two ways: (a) the items in each stomach are separated and weighed; (b) an estimation by eye is made of the percentage contribution of each item to the contents of each stomach; this percentage is then applied to the known weight of the contents of the stomach, to estimate the weight of the individual item.

The weights of each respective food item in the sample are then summed and may be expressed as a percentage of the total contents examined. Volume analyses are carried out in a similar fashion to that described for the weight analysis, except that volume by displacement is measured, rather than weight. Stomach content percentages in both international fur seal programs have been calculated on a per cent by volume basis (Taylor et al., 1955; Anon., 1961).

The weight method of analysis has been modified (Ricker, 1937; Bogorov, 1960) by multiplying the numbers of organisms of each item in the stomach by the known mean live weight of that item. This gives a weight of each kind of food eaten, rather than a weight of each item of food in the stomach at the time the predator was killed.

A third modification of the volume or weight method is to sum the percentages each item contributes to each stomach.

6. Number of occurrences

The number of stomachs in which each food item occurs is tabulated; these occurrences may be summed and expressed as percentages of the total occurrences of all food items.

Two methods, number of occurrences and the volume or weight method, were considered for this study. Ricker's (1937) modifications of the weight analysis give the most accurate analysis if (a) numbers of individuals of each item can be determined, and (b) if prey sizes can be estimated accurately. The numbers of individuals can be counted, but size of prey is extremely difficult to estimate from pinniped stomach contents. Only rarely does one find, as in Figure 5, a stomach in which lengths or weights of the prey can be taken directly. Large fish are swallowed piecemeal, and as pointed out later, heads may be discarded. Estimates of length, therefore, can only be made from the broken remains of vertebral columns. Finally, estimates of squid and octopus weights from beak size is only just receiving attention (Clarke, 1962(a); Clarke, 1962(b)); at present there is no information about beak size and body weight of the squids and octopuses found in pinniped stomachs collected from British Columbia waters. For these reasons I concluded that the analyses must either be based on the actual volume or weights of the stomach contents, or a frequency of occurrence of the individual items.

Hynes (1950) has shown that any of the commonly accepted methods of assessing the composition of an animal's diet will give much the same results, if the data are scaled down to percentages, and if large samples are used. This point, with one exception is illustrated in Figure 4, showing the 1958 to 1961 fur seal sample (volume data from Pike et al., 1958, 1959, 1960, 1961). The one major exception, squid, contributes only 4.7% by volume but 22.3% by occurrence to the sample. Squid remains, usually consisting of beaks and eye lenses, differ markedly from fish remains, which usually include more flesh. Octopus flesh was rarely found in sea lion stomachs. The lack of cephalopod flesh indicates that either squid or octopus were preyed upon earlier in the morning than fish, or their flesh was digested more rapidly than fish flesh. However, the discrepancies between these two calculations are explained, and until evidence to the contrary is produced, I

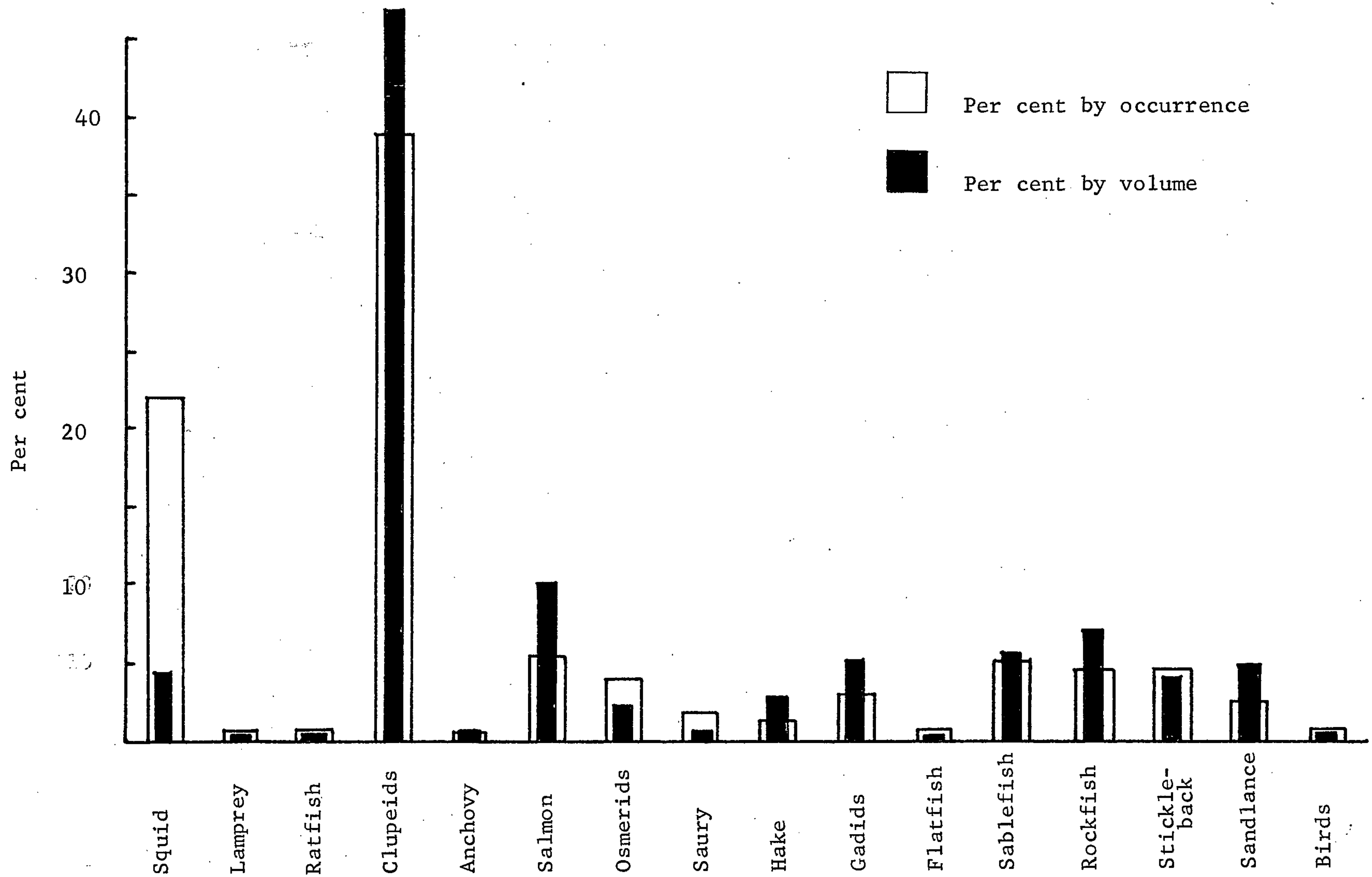


Figure 4. Comparison between a per cent by occurrence analysis and a per cent by volume analysis of contents from 869 fur seal stomachs (1958-1961 data).

Figure 5. Small black cod found in fur seal stomach.

believe the higher value, based on occurrence, is the more meaningful calculation.

A volumetric or weight analysis of a small sample is particularly susceptible to faulty interpretation. As shown later, sea lions and fur seals feed mainly during the early morning. Thus, stomachs collected in the morning are full while those collected towards nightfall are empty. The contents from one stomach collected at daybreak will outweigh the contents from many stomachs collected later in the day, and the item or items in the former stomach will have an exaggerated importance in a percentage by weight analysis.

Percentages based on frequency occurrence calculations avoid such errors. Each item encountered in a stomach is given one point, regardless of the weight of that item. If the predator ate two or more items, but consistently chose more of one item than the others, a frequency of occurrence analysis would exaggerate the importance of that item eaten in lesser amounts. Ricker (1937), examining the food preferences of young sockeye salmon in the laboratory, found that two equally abundant food items were eaten, but one item was consistently taken more often than the other. A frequency of occurrence analysis would exaggerate the importance of that item taken in lesser amounts.

However, there is no evidence for such a consistent selection in favour of one food item by either fur seals, sea lions or harbour seals. Taylor _et al_. (1955) concluded that fur seals were non-selective in their feeding habits, and tended to prey on that item which was easiest to catch at the moment. The following two observations support this conclusion for all three species studied: (a) Each predator usually restricted itself to one prey item per feed (actual figures were: fur seals, 77% of stomachs with food contained only one item; sea lions, 78% of stomachs with food had only one item; harbour seals, 76% of stomachs with food contained only one item). (b) In the total of 33 identified food items only four (lamprey, sea perch, cabezon and skate) had not at one time or another been the sole item in a stomach. Thus, seals and sea lions on the British Columbia coast prey mainly on one item per feed, and have a wide range of possible food items to choose from. Abundance of prey may influence the predator in its choice of food. Pike _et al_. (1961) reported that a mid-water trawl fishing at 28-36 fathoms caught anchovy and eulachon in approximately equal amounts, plus a few herring; the stomach contents of a fur seal collected at the same time in the same position consisted of 50% eulachon and 50% anchovy, the two most abundant species in the area.

To summarize, under the circumstances described above per cent frequency of occurrence will give approximately the same results as per cent by volume (or weight) in a large sample, but a more realistic and unbiased interpretation of a small sample.

Per cent frequency of occurrence calculations have been carried out as follows: the number of times a given item occurred has been expressed as a percentage of the total number of occurrences of identifiable food items in the sample. An example from Table VII (page 51) will clarify this: ninety-two stomachs with food were collected from sea lion breeding colonies during the summer. In this sample, 14 different items were encountered 85 times; rockfish, occurring 11 times (i.e., in 11 stomachs) contributed 12.9% to the total diet in that area.

C. Identification of stomach contents

A fish skeleton collection was begun during the early winter of 1958 and specimens were added when necessary. Frozen or salted specimens were gently boiled, the flesh removed and all bones saved. An attempt was made to keep the skull and vertebral column intact as it was found the vertebrae and vertebral column were the most useful aids in identification of stomach contents (Figure 3). Total vertebral counts, relative positions of first haemal arch and spines, and modifications of parapophyses and zygapophyses were particularly useful in the identification of fish species.

Fish identification was aided by the following publications: Chapman, 1941; Chapman, 1944; Clemens and Wilby, 1961; Clothier, 1950; Gregory, 1933; Hart and McHugh, 1944; Sunde and Lindsey, 1958. Scientific nomenclature and order of arrangement follows Clemens and Wilby (1961).

I never succeeded in satisfactorily identifying all squid and octopus remains which usually consisted of beaks only. Identification of whole squids was facilitated by reference to Berry (1912). One sample was sent to the United States Fish and Wildlife Service in Seattle for identification.

DISTRIBUTION, NUMBERS AND MIGRATORY BEHAVIOUR

A. General habitat description

A description of the several habitats frequented by fur seals, sea lions and harbour seals is included to help understand the differences and similarities in food habits discussed below.

Rugged promontories, peninsulas and islands break up the British Columbia coastal waters into numerous straits, gulfs, bays and inlets of varying shapes and depths, and have resulted in a coastline of an estimated 16,900 miles (Scagel, 1961). In addition, there are many rivers emptying into the sea, creating estuarine conditions. These environments may be roughly divided into four categories, the first two of which have already been described (Cowan and Guiguet, 1956): (1) Pelagic waters biotic area - waters outside any protection from land and open to the full force of all oceanographical and meteorological changes. (2) Coast waters biotic area - bodies of water lying behind, and protected by, islands, points or reefs. (3) Estuaries - river mouths where a mixing of salt and fresh water occurs. (4) Fresh water - coastal rivers, and lakes connected to the marine environment by rivers.

Table II outlines the distribution of pinnipeds on this coast in relation to the above four environments.

Fur seals are seldom found within 5 miles from the coast; in comparison, sea lions and harbour seals are rarely found farther than 5 miles from shore.

Table II. Coastal habitats and pinniped distribution.

Habitat	Seal or sea lions present		
Pelagic waters biotic area	fur seal[x]		sea lion
Coast waters biotic area	fur seal	harbour seal[x]	sea lion[x]
Estuaries	fur seal	harbour seal[x]	sea lion
Fresh water		harbour seal	

[x] Indicates area of greatest preference

1. Fur seals

The fur seal migration is one of the best documented migrations of marine mammals (Jordan, 1899; Kenyon and Wilke, 1953; Taylor *et al.*, 1955). The mature cows, young males and females, and the four- and five-month-old pups leave the Pribilof Islands in the Bering Sea during late October and November. Many move as far south as southern California in the eastern Pacific, and southern Japan in the western Pacific. In the spring they return to the Pribilofs, arriving in June and July, having covered a distance of up to 6,000 miles each year on their round trip. Males, except for the one- and two-year-olds, and many three- and four-year-olds, remain in the Bering Sea and northern Gulf of Alaska all year.

From published life tables (Abegglen *et al.*, 1960) the Pribilof seal herd consists of approximately 1,250,000 females and 400,000 males one to four years of age. Therefore, approximately 1,650,000 fur seals move south from the Bering Sea each fall, into the North Pacific. Some of these, perhaps a relatively large per cent, winter in waters within 150 miles off either the American or Asian land masses.

Seal concentrations in the eastern Pacific have been studied by the United States and Canadian investigators from southern California to the Bering Sea. Older females move farther south, and few one-, two- and three-year-old males or females travel south of Washington. Relatively high concentrations of younger seals are found in some British Columbia coastal waters. These seals first appear in December and by January may be found in Hecate Strait, Queen Charlotte Sound and the inside channels and inlets of northern British Columbia. The majority remain in these waters until the end of April, and some stragglers may still be found during June and July.

South of British Columbia, particularly off California, there are heavy concentrations of mature females, which first appear in December (Taylor _et_ _al_., 1955; Anon, 1961).

During the spring most seals begin their return to the Pribilof Islands. Many yearlings, however, and some two- and three-year-olds remain at sea the entire year. The northward moving herd of adult cows first appears off southern Vancouver Island during late March; the greatest numbers of these seals are encountered between the middle of April and the middle of May, passing by in a series of waves from five to 35 miles offshore.

Sufficient information is not available to estimate accurately the numbers of seals migrating through or wintering in British Columbia coastal waters.

2. Sea lions

The sea lion migrations are not fully understood at present, although it is known that much of the population undergoes a seasonal movement. In contrast to the fur seals, where the longest migration is undertaken by the females and young males, the sea lion cows with pups apparently remain on the rookeries throughout the entire year; males one year and older move from the exposed rookeries into the inlets or to rocks closer to more sheltered bodies of water. Barren cows and impregnated cows which have lost their pups on the rookeries may also move inshore with the males.

Winter counts indicate that over half the breeding population gradually leaves the rookeries following pupping and breeding. A population of 1,600 animals on the Scott Islands during September, 1960, had dwindled to only 700 (mostly cows and pups) by January, 1961; 200 animals on Cape St. James in April, 1962, had increased to 600 by May 31, 1962.

A census in 1956 indicated 11,000 to 12,000 sea lions ($\pm$ 5%) on the British Columbia coast (Pike and Maxwell, 1957). During 1959 and 1960 the Department of Fisheries reduced these numbers by sending out several hunting parties of their own, and by encouraging killing for mink or pet food. A census taken during the summer of 1961 (unpublished data, Fisheries Research Board of Canada) indicated there were approximately 1,500 pups and 4,500 adults resident in British Columbia waters. During the summer months approximately 70% of this population, or 3,100 adults, concentrate on the two rookeries of Cape St. James and the Scott Islands (Pike and Maxwell, 1957).

3. Harbour seals

This species is regarded as non-migratory in the sense of a seasonal exodus and return of all or a large part of the population into or out of the population area. However, Fisher (1952) noticed a movement into and up the Skeena River following salmon, while bounty hunters have noticed that many seals herd together in small groups during the early summer. Future studies will determine the extent of harbour seal movements, but present information indicates no migration comparable to that of either the fur seal or the sea lion.

A harbour seal census has never been conducted along the British Columbia coast. However, observations made on field trips since 1958 suggest that during the fall and winter, when these animals are widely dispersed, there may be as many as one seal per mile of shoreline, or 17,000 seals. Bounty hunters (D. McNaughton) have estimated there are approximately 20,000 harbour seals on this coast.

To summarize, there are 6,000 (± 5%) sea lions and an estimated 17,000 to 20,000 harbour seals resident in British Columbia's coastal waters. In addition there is an unknown number of fur seals, some of which winter and some of which migrate through these waters. Confidence limits cannot be attached to the estimate of harbour seal numbers as repeated counts are not available.

COMPARATIVE ANATOMY

The comparative anatomy of the digestive tract, including the dentition, was examined to add to our understanding of feeding habits.

A. Dentition

1. Sea lions

The formula for otariid milk dentition (V. B. Scheffer, personal communication) is:

$$di\ \frac{1-2-3}{0-2-3}, \qquad dc\ \frac{1}{1}, \qquad dm\ \frac{0-2-3-4}{0-2-3-4}$$

Permanent dentition is:

$$\frac{1-2-3}{0-2-3}, \qquad \frac{1}{1}, \qquad \frac{1-2-3-4-5}{1-2-3-4-5}$$

By the end of September, at approximately three and a half months after birth, all the permanent dentition is evident except for the two upper and lower canines, which are still represented by deciduous teeth. Figure 6 shows the permanent dentition at this stage as well as the three deciduous post canines still adhering to gum tissue beside the permanent teeth.

The deciduous canines persist until February and March when the young sea lions are eight to nine months old. One male skull, collected March 8, 1961, had two upper canines protruding five mm through the gum, the lower left canine was through two mm, and the lower right was not showing (Figure 7).

Figure 6 illustrates the permanent dentition at 15 months of age. The last post canine is double rooted, while all others are single rooted; crowns are irregularly conical.

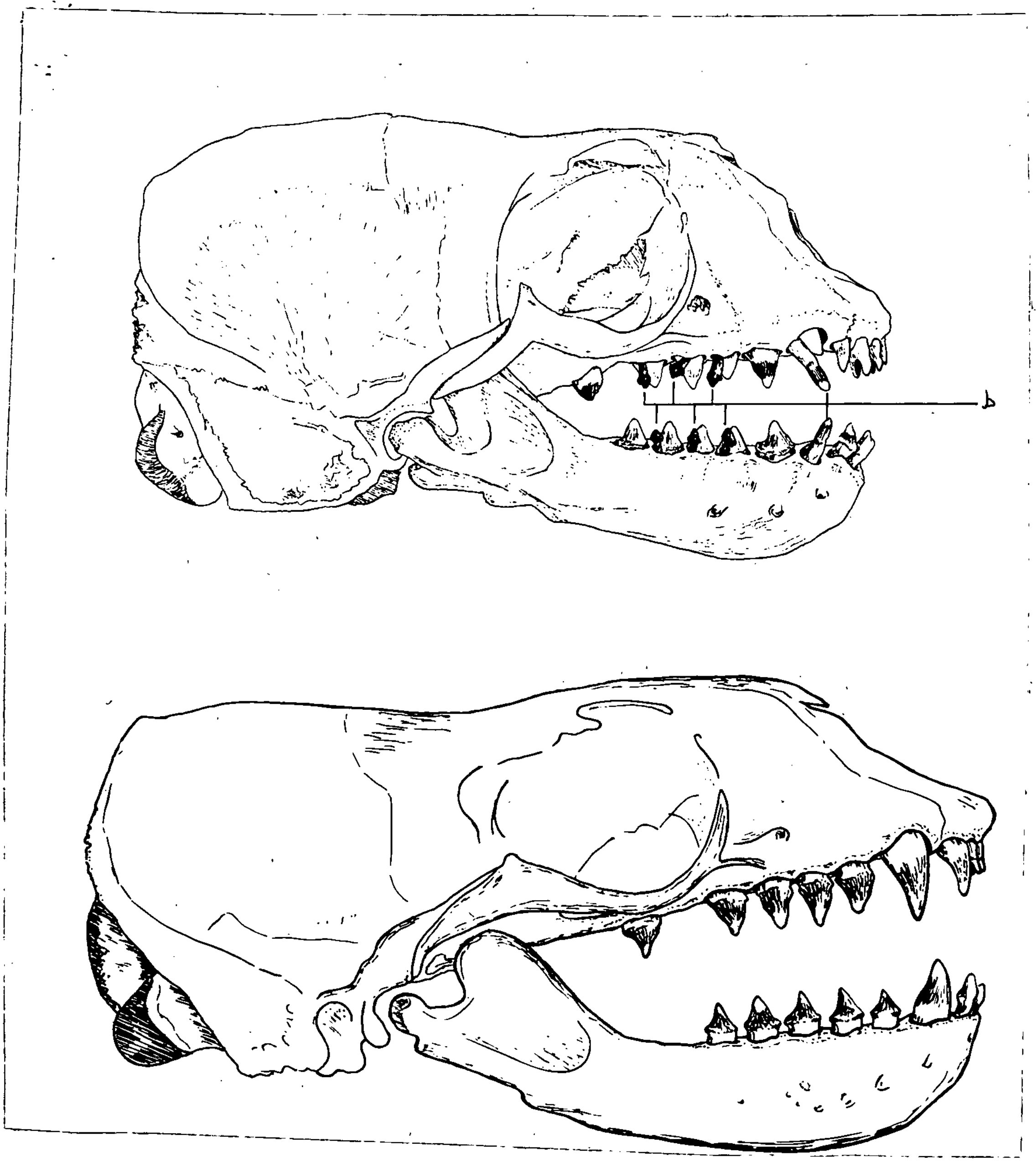


Figure 6. Top: 3-4-month-old male sea lion skull
Bottom: 15-month-old female sea lion skull
(b = deciduous teeth)

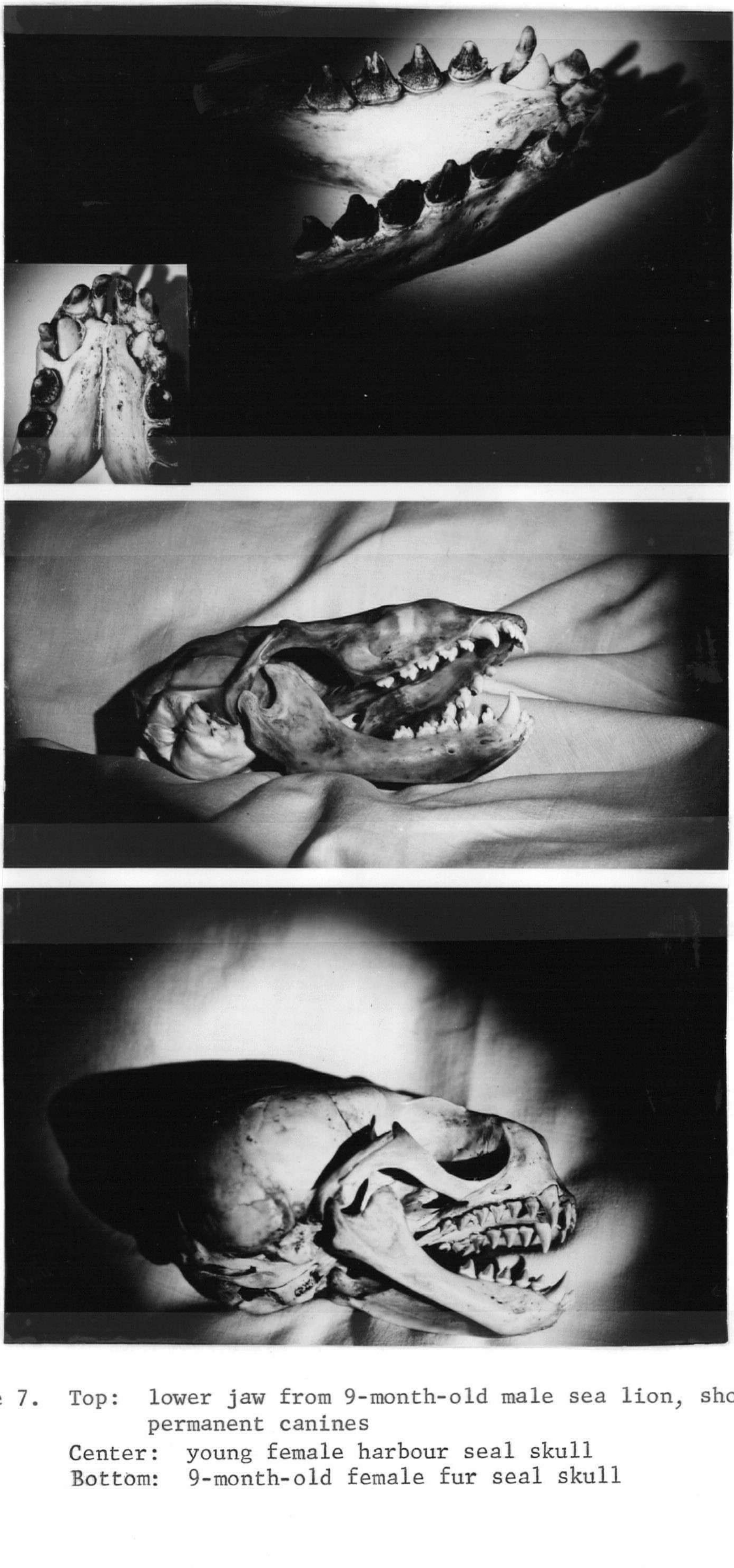


Figure 7. Top: lower jaw from 9-month-old male sea lion, showing permanent canines
Center: young female harbour seal skull
Bottom: 9-month-old female fur seal skull

The lower post canines, particularly the third and fourth, have very slight accessory cusps. Canines of both jaws are large. The two outer upper incisors are canine-like in form and three-quarters as long as the canines.

2. Fur seals

The otariid dental formula (see above) is applicable to fur seals. At birth all the permanent dentition is evident except for the sixth upper post canine (Kuboto and Komuro, 1961). This appears shortly after birth.

Figure 7 illustrates the permanent dentition at eight months of age. These permanent teeth are haplodont, with canines and incisors single rooted, and the post canines incompletely double rooted (Allen, 1880). The canines are large and the outer upper incisor is slightly enlarged.

3. Harbour seals

No foetal or skulls of pups were examined in this study. The dental pattern is as follows (Allen, 1880):

Deciduous teeth - i $\frac{3}{2}$, c $\frac{1}{1}$, pc $\frac{3}{3}$

Permanent teeth - $\frac{1-2-3}{0-2-3}$, $\frac{1}{1}$, $\frac{1-2-3-4-5}{1-2-3-4-5}$

The eruption of the permanent teeth has not been described but Scheffer (1958) states that the milk teeth disappear before or soon after birth. Young harbour seals are weaned at approximately one month of age and probably require a full set of strong teeth for the capture of food.

Figure 7 shows the permanent dentition of a young harbour seal. The post canines are double rooted and multilobed, except for the first post canine which is single rooted. Canines are large and the outer upper incisor is slightly enlarged.

B. Digestive tract

The mouth is simple and rather elongated in each species. The tongue is notched at the tip, perhaps as an aid in sucking from a small teat (Scheffer, 1958). The esophagus leads directly to the simple "J"-shaped stomach, which is aligned with the long axis of the body. An unusually long small intestine and a relatively short large intestine is common to all three pinnipeds. The relative shapes and positions of these organs are the same in each species studied.

Several authors have mentioned the great length of the pinniped intestine. Engle (1926) found the whole intestine of an adult male northern sea lion to be about 38 times the body length. Laws (1953) found that the intestine length in the southern elephant seal (Mirounga leonina) varied from twenty to twenty-five times the body length. Mohr (1952) found that the intestine length was 13 to 22 times the body length of several European pinnipeds.

The ratio of body length to intestine length was examined in each of the three pinnipeds under study (Table III). All lengths were taken to the nearest 10 cm. Harbour seal and fur seal intestine lengths are approximately the same with a ratio of mean body length to mean intestinal length of 1:16 and 1:17, respectively. The range for both groups is 1:13 to 1:21. The sea lion body length-intestine length ratio is nearly twice as great at 1:30, with a range of 1:23 to 1:35.

Table III. Ratio of whole intestine length to body length of fur seals, sea lions and harbour seals. Mean lengths and ratios of means are shown at the bottom of each respective column. Data from animals greater than one year of age.

Fur seals			Sea lions			Harbour seals		
Body length (cm)	Intestine length (cm)	Ratio	Body length (cm)	Intestine length (cm)	Ratio	Body length (cm)	Intestine length (cm)	Ratio
100	2000	1:20.0						
100	1790	1:17.9	150	4500	1:30.0	100	1670	1:16.7
110	1910	1:17.4	160	4760	1:29.7	100	1710	1:17.1
110	1670	1:15.2	160	4430	1:27.6	110	1920	1:17.4
110	1740	1:15.8	180	4170	1:23.2	110	1800	1:16.4
120	2500	1:20.8	180	4960	1:27.5	120	2200	1:18.3
120	2340	1:19.4	180	5000	1:27.8	120	2150	1:17.9
120	1630	1:13.6	190	4840	1:25.5	120	1550	1:12.9
120	1640	1:13.7	190	5450	1:28.6	140	1970	1:14.1
120	2170	1:18.1	210	5900	1:28.1	150	2190	1:14.6
130	1810	1:13.9	220	6260	1:28.5			
130	2080	1:16.0	220	6700	1:30.5			
130	2240	1:17.2	240	8400	1:35.0			
130	2030	1:15.6	250	7080	1:28.3			
140	2230	1:15.9	250	7630	1:30.6			
			260	8320	1:32.0			
			270	8310	1:29.7			
			290	9600	1:33.2			
			300	10130	1:29.7			
119	1985	1:17	216	6469	1:30	119	1907	1:16

There is no satisfactory explanation for the relatively long pinniped intestine or why the northern sea lion has an intestine length nearly twice as great, in relation to its body length, as either the harbour seal or fur seal. The relatively longer sea lion intestine may result from the greater volume of this animal. However, the southern elephant seal with a maximum weight of two and one-half tons has a relatively shorter tract than the northern sea lion, with a maximum weight of one ton.

Laws (1953) suggested the long pinniped intestine may be an adaptation to diet; in particular a mechanism to aid in the breakdown of the chitinous beaks of molluscs. However, the diet of the three pinnipeds studied here is quite similar (Figure 13), yet marked differences are evident in the body length - intestinal length ratio. Further studies to investigate differences at the cellular level of the intestine may clarify this problem.

From this brief examination two anatomical differences have emerged: the sea lions' complete permanent dentition is not evident until the animal is eight to nine months of age, and the body length-intestine length ratio is approximately 1:30. In comparison fur seals and harbour seals, not as closely related taxonomically as fur seals and sea lions, show similarities in these two respects: body length-intestine length ratio is approximately 1:16 in both cases, and all permanent teeth appear before the pups of both species are three months old.

Sea lions show the only adjustment in feeding behaviour which may be related to the eruption of permanent dentition: sea lion pups suckle for several months (at least 15 months in some cases) while the fur seal and harbour seal pups are weaned within one to three months after birth.

FEEDING HABITS

A. Comparative feeding behaviour

1. Capture of prey

(a) Fur seals. Most fur seal food consists of small schooling fishes or squids which are eaten beneath the surface. Except for very small items, such as lanternfish, the prey is usually swallowed head first (Figure 5). Seals have been observed eating salmon and rockfish at the surface on four occasions, and a fish believed to be a cod once. Larger fish such as salmon, cod and rockfish are brought to the surface, reduced to pieces by violent shaking, and swallowed piecemeal.

Fur seals waste little of their prey when feeding. Fish flesh unaccompanied by bones has been observed only twice during the examination of 2,000 stomachs. However, heads of rockfish may sometimes be discarded; 18 out of 28 rockfish (65%) which had not been affected by digestion, lacked heads.

Euphausiids are frequently encountered in fur seal stomachs containing herring or rockfish remains. Data comparing frequency of occurrence of euphausiids and the stage of digestion of fish remains in the seal stomach indicate that these invertebrates are found only when the fish stomach is exposed by digestion. Such euphausiids had been eaten by fish which in turn were preyed upon by seals.

Table IV lists the maximum numbers of certain food items found in the stomachs of fur seals.

(b) Sea lions. Small fish such as herring are eaten under water. Larger prey are brought to the surface and reduced to small pieces by violent shaking. On eight occasions sea lions have been observed eating lingcod, rockfish, salmon and halibut, at the surface. Sleptsov (1950) records an observation of a sea lion surfacing with an octopus in its jaws.

Table IV lists the maximum numbers of certain food items encountered in sea lion stomachs.

(c) Harbour seals. An adult seal was observed eating a large sculpin or rockfish at the surface on one occasion, while Fisher (1952) observed harbour seals feeding on salmon in the Skeena River. Small schooling fish, such as herring and eulachon are probably eaten below the surface, while larger prey are consumed at the surface.

Table IV lists the maximum numbers of fish encountered in harbour seal stomachs.

Table IV. Maximum numbers of certain food items found in individual stomachs of fur seals, sea lions and harbour seals.

Food item	Maximum numbers of items found in individual stomachs		
	Fur seals	Sea lions	Harbour seals
Squid	244		
Dogfish		7	
Herring	34		18
Salmon	15	7	2
Eulachon		154	148
Hake		18	
Whiting		19	
Sablefish			11
Rockfish	7	15	22

2. <u>Feeding in relation to hours after sunrise</u>

Both fur seals and sea lions have less food in their stomachs as the day progresses (Figures 8 and 10). Figure 8 illustrates two samples of fur seal stomachs, one from the Gulf of Alaska and one from British Columbia, relating mean stomach content (volume) and hours after sunrise. The Alaska sample shows clearly that feeding begins late in the evening and reaches a peak some time during the hours of darkness. All stomachs contained food early in the morning but by 11 hours after sunrise all stomachs were empty. The British Columbia sample illustrates the same type of feeding behaviour. Figure 9 shows the corresponding increase in per cent of empty stomachs as the day progresses for the British Columbia sample. Sea lion stomach contents show a similar decrease from a mean of 1,732 cc at 1.5 hours after sunrise to only 2 cc at 15.5 hours after sunrise (Figure 10). Figure 11 shows the corresponding increase in per cent empty stomachs.

In comparison with fur seals and sea lions the harbour seal sample of 50 stomachs indicates daylight feeding (Figure 12).

Samples have not been collected during the hours of darkness. This includes a period of four hours for fur seals, eight hours for sea lions and 12 hours for harbour seals. No conclusions can be reached regarding feeding habits of harbour seals during the hours of darkness; feeding may or may not occur.

However, fur seals and sea lions feed mainly during the hours of darkness and the early morning. Stomachs collected during the morning contain food and mean volumes are high.

These contents are digested throughout the day and by early evening stomachs are empty.

B. Daily food consumption

In order to find out the effect of pinniped predation upon commercially valuable fish stocks, an estimation of daily food requirements must be made. Table V indicates that pinniped food requirements range from two to eleven per cent of body weight, with an average daily food intake of six per cent of the animals' body weight. Refinement of these data to allow for growth, pregnancy, lactation or hard work (for long migrations) is impossible; detailed studies of the nutritional requirements of pinnipeds have not been undertaken.

C. Comparison of food items eaten

Food items identified in the stomachs of each of the three pinniped species under investigation have been summarized in Figure 13, regardless of date or location of collection. Items which occurred only once in the sample are not included. This figure has been arranged in such a manner as to point out similarities and differences which exist between each of the predators studied: food items common to all three are shown first and items common to two or only one follow.

The factors which prevent extensive intermingling of the northern fur seal, sea lion and the harbour seal do not restrict movements of their prey. Ten of the 21 food items in Figure 13, squid, clupeids, salmon, rockfish, cod, hake, flatfish, greenling, lamprey and smelts are common to all three pinnipeds; combined they contribute over 50% to the diet

Table V. Daily food consumption of pinnipeds as reported in the literature, plus the maximum weights of stomach contents from individual animals collected in the field.

Species of seal	Authority	Body weight (lb)	Food intake (lb/day)	Daily food intake as a percentage of body weight
Northern fur seal	Scheffer (1958)	66	4	7
	Anon. (1962)	65	4	6
	Sergeant (1962)			5
	Observed maximum	106	11	10
Northern sea lion	Scheffer (1958)	600	14	2
	Observed maximum	490	19	4
		1500	35	2
Harbour seal	Havinga (1933)	66	3	5
	Scheffer (1958)	70	4	6
	Observed maximum	62	7	11
Gray seal	Myers (1955)	150	10	7
			Mean	6

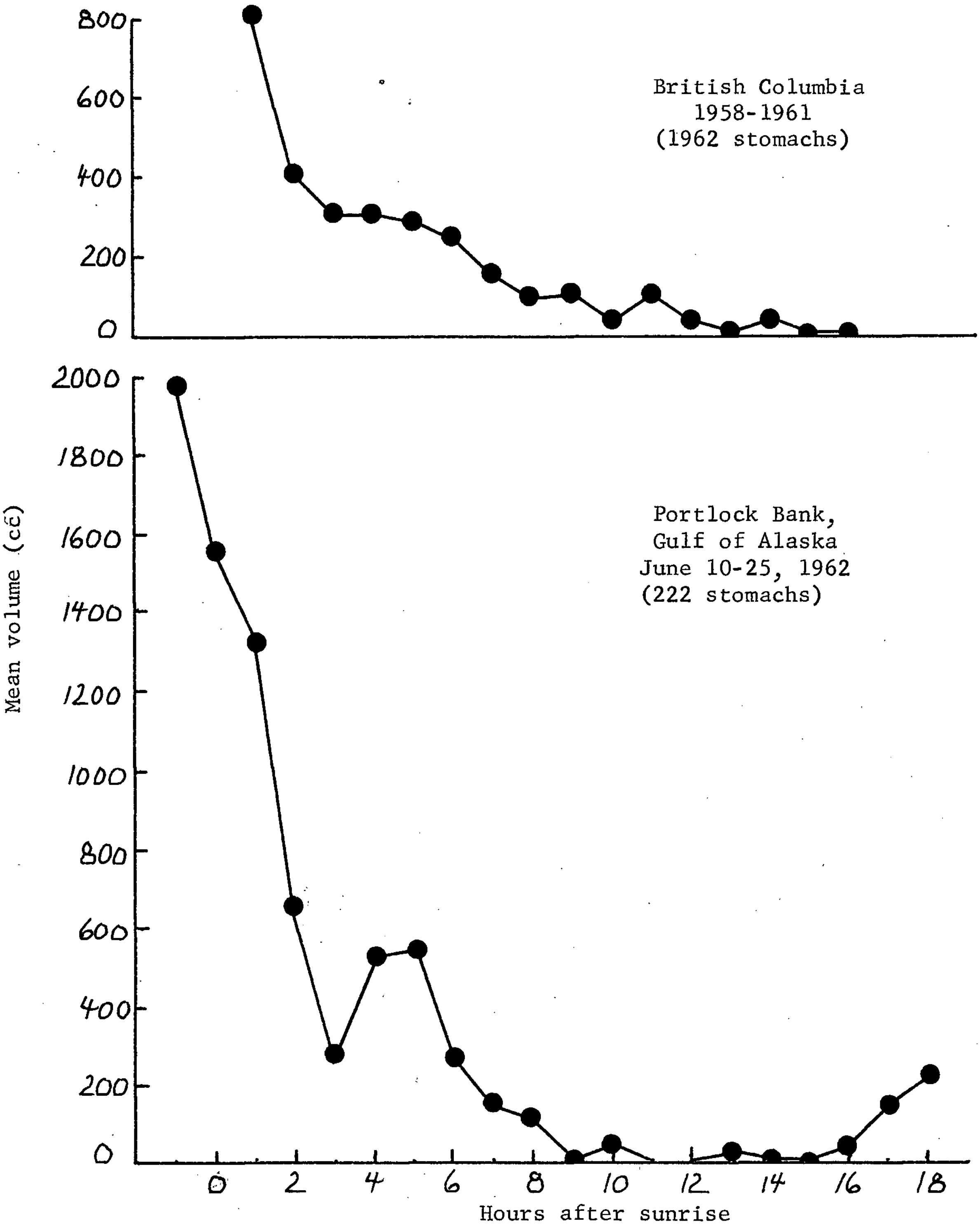


Figure 8. Fur seal stomach volumes and hours after sunrise.

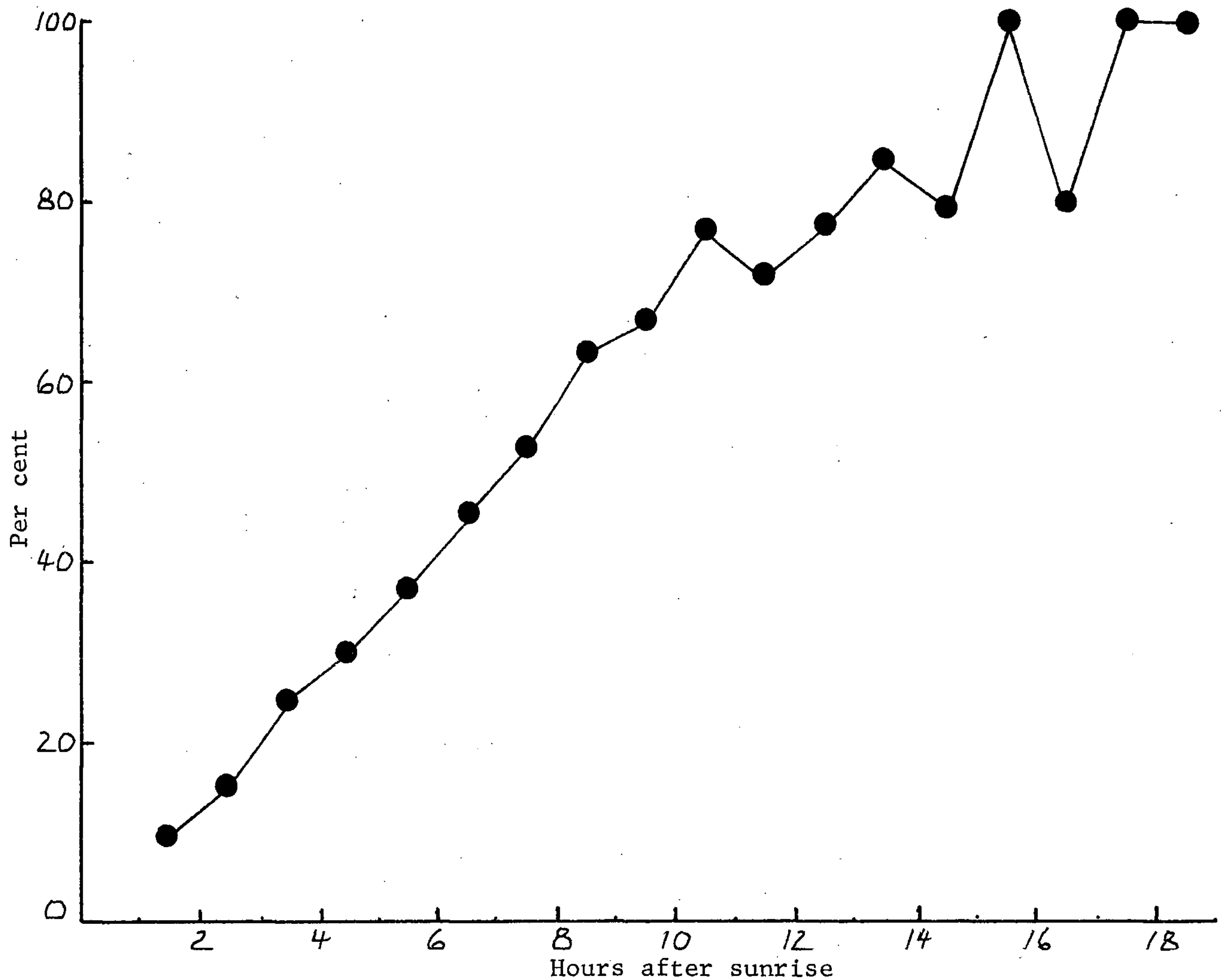


Figure 9. Per cent empty stomachs and hours after sunrise (fur seals).

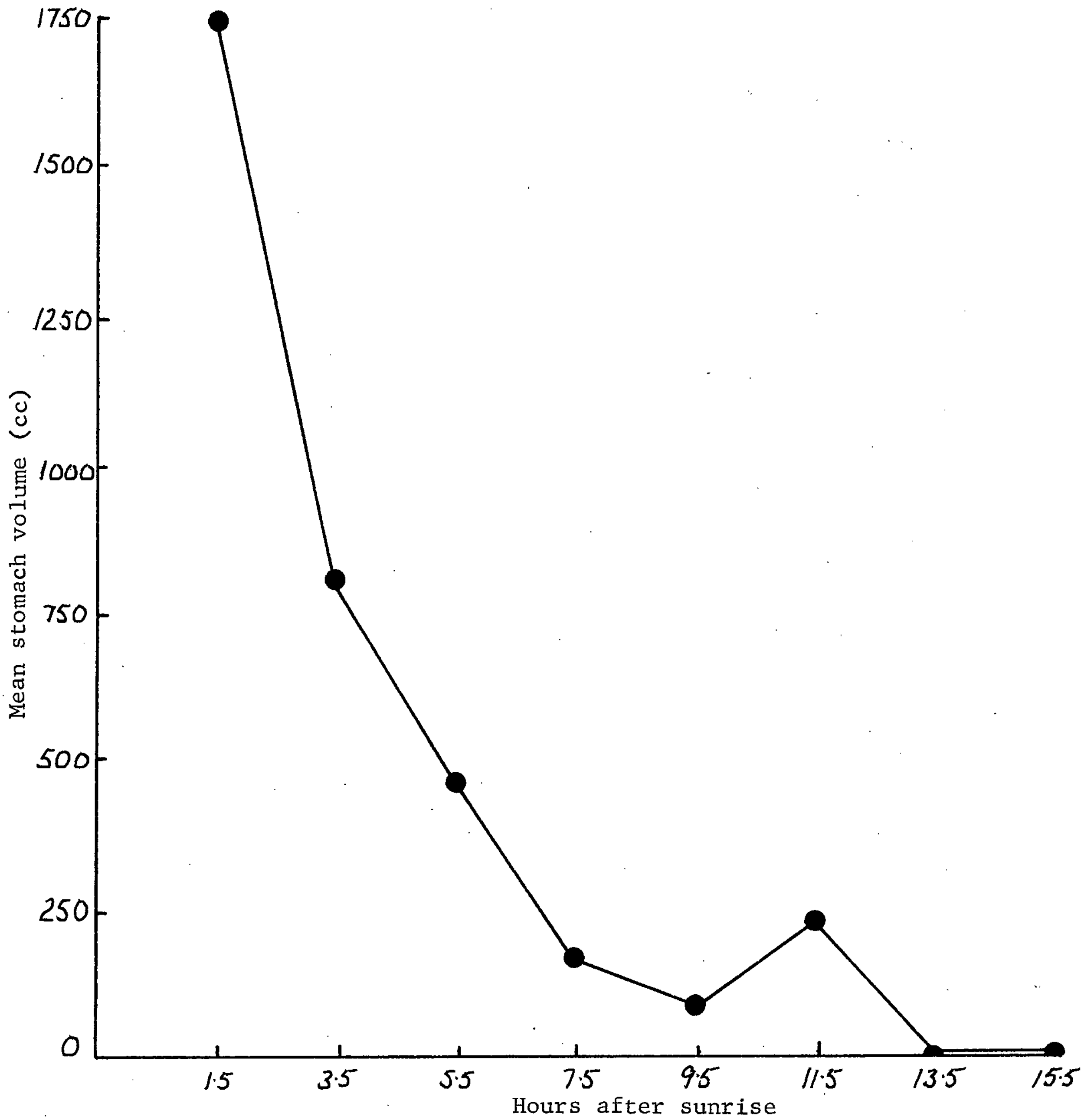


Figure 10. Mean stomach volume of 269 sea lions and hours after sunrise.

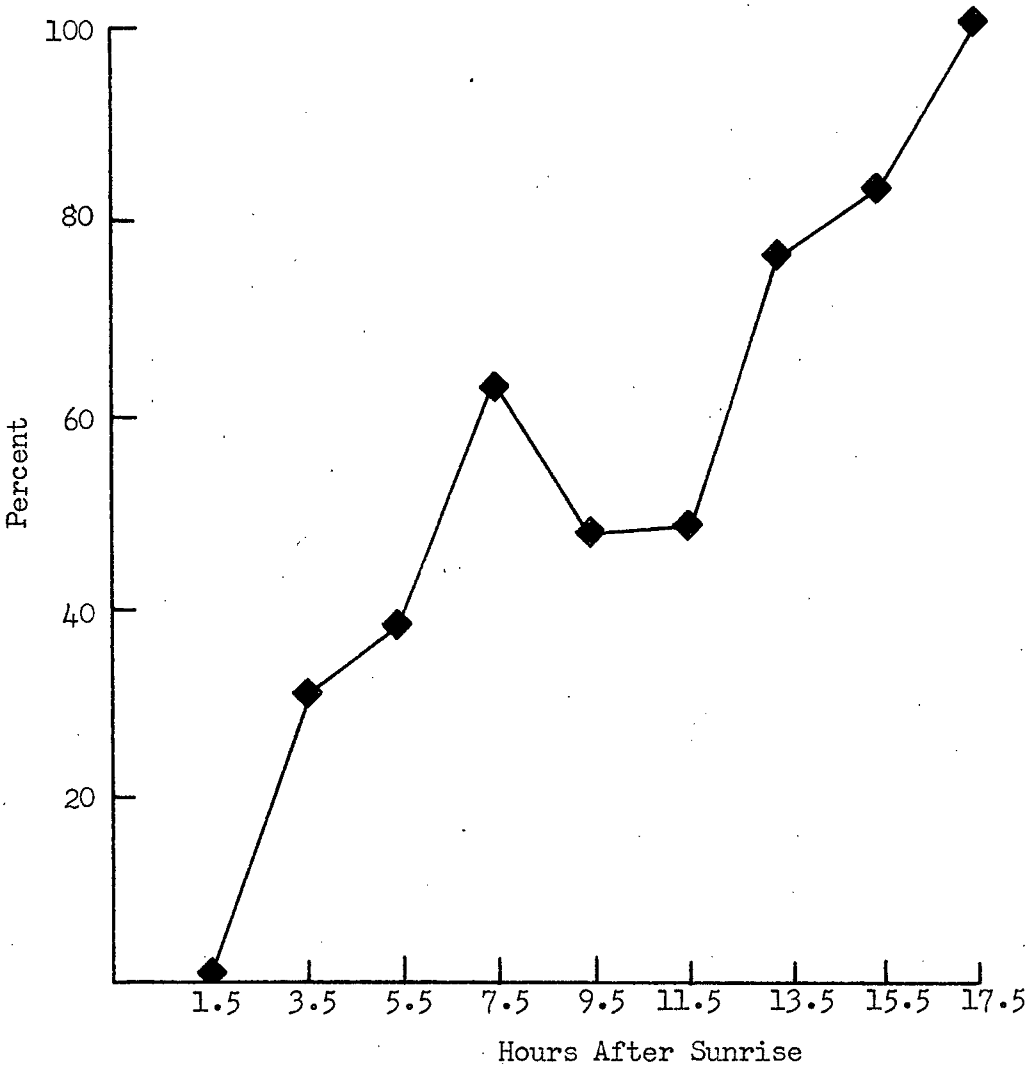


Figure 11: Percent empty stomachs and hours after sunrise - sea lions, 269 stomachs, 130 empty.

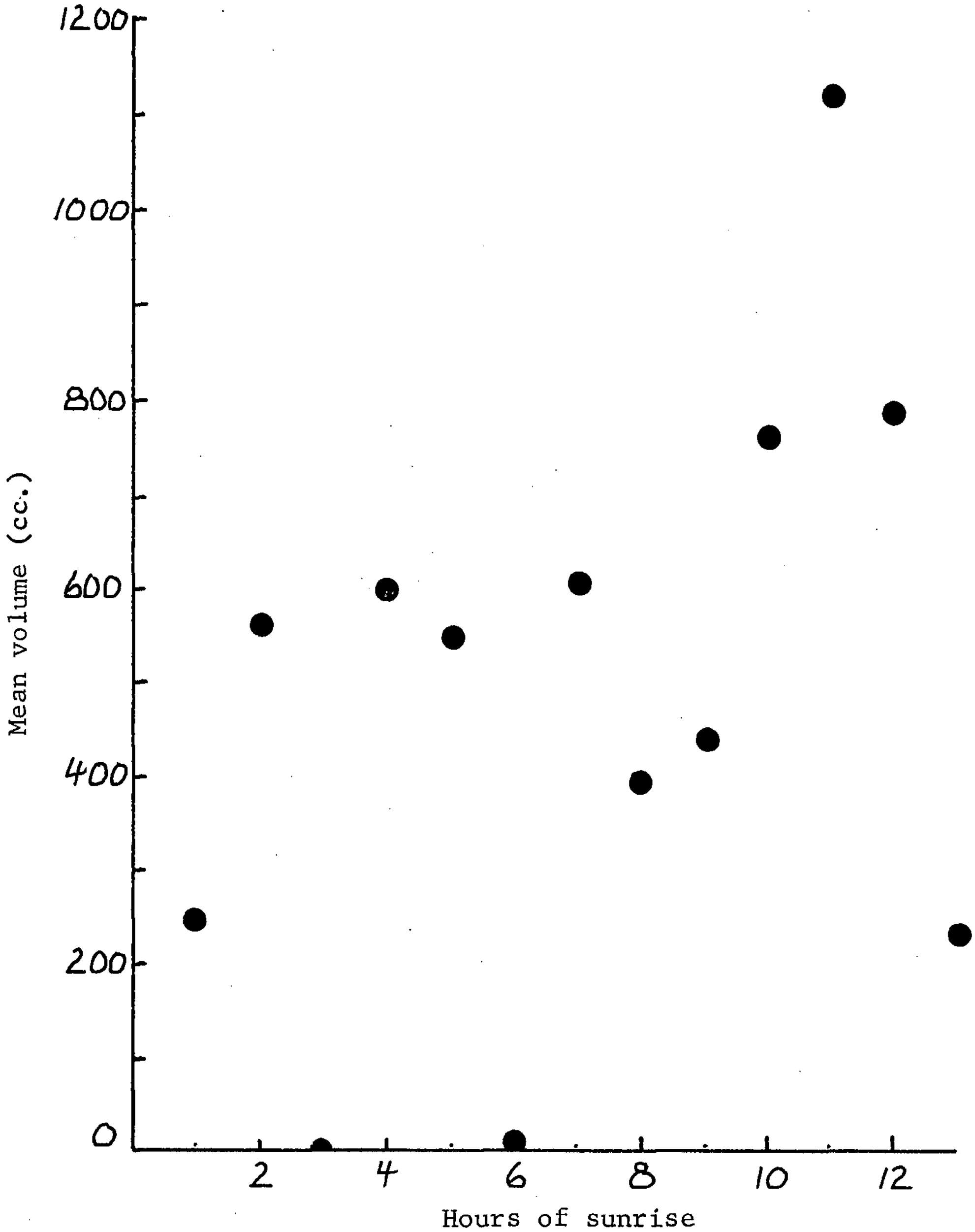


Figure 12. Mean stomach volumes and hours after sunrise in a sample of 50 harbour seals.

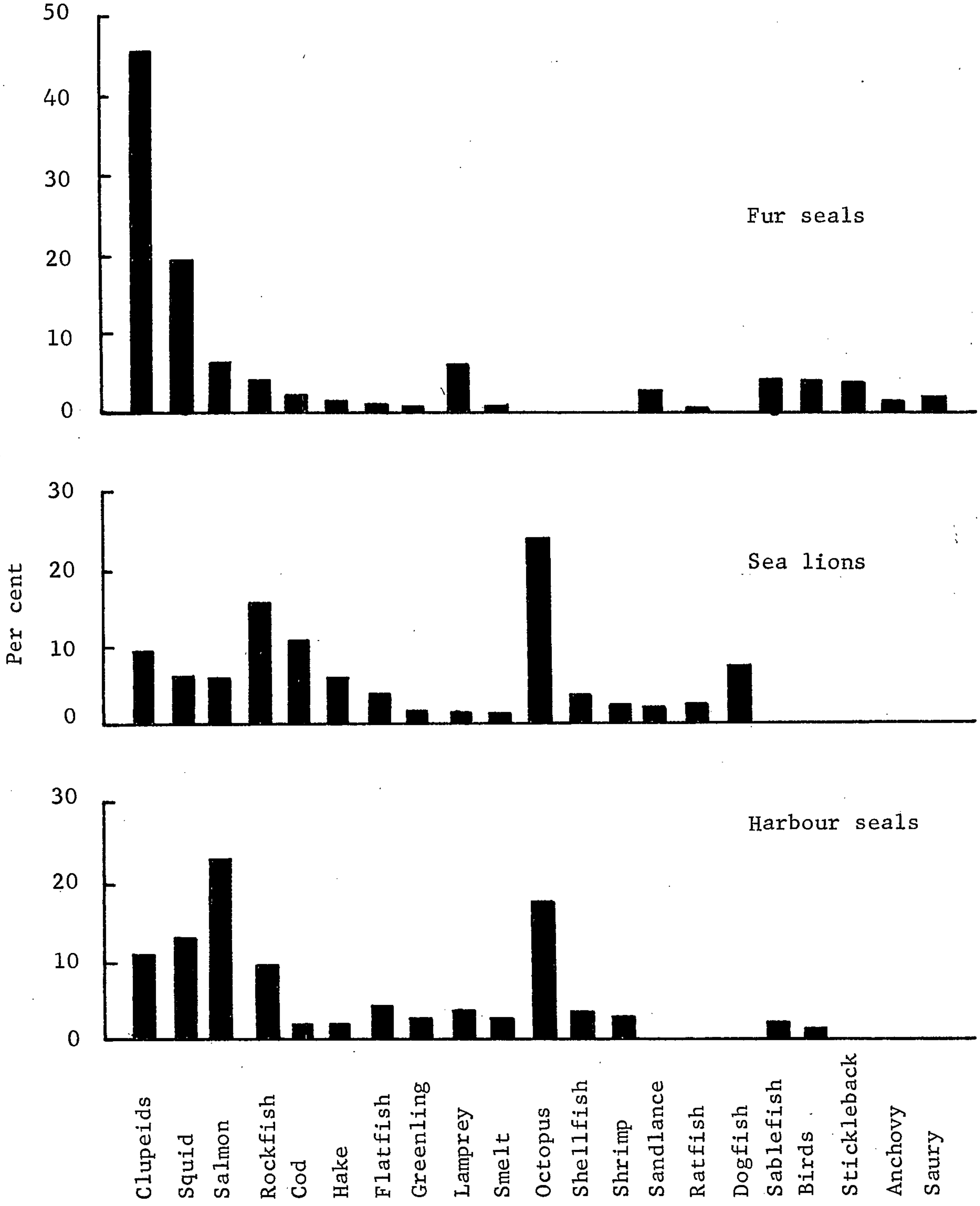


Figure 13. Stomach contents of fur seals, sea lions, harbour seals, collected along the coast of British Columbia.

of each predator. The differences which do exist, however, may be explained largely by differences in distribution of each group of predator. Most fur seals are offshore (Table II) and their diet consists largely of small fish and squid schooling at the surface. Sea lions and harbour seals are inshore (Table II); bottom fish and octopus are more important in their diet. The high percentage of salmon in the harbour seal sample is due to 29 stomachs collected in the vicinity of salmon spawning creeks during September and October, 1961; this is not representative of the actual role of salmon in the yearly diet of these seals.

D. Unusual stomach contents

Small pebbles, sand, bits of wood or bark, kelp and small clam shells have occasionally been found in stomachs of each of the three groups studied. It is believed these are ingested accidently. However, smooth stones of varying shapes from one-half inch to three inches across, are found so frequently in sea lion stomachs that some functional explanation is indicated. One to ten stones weighing up to four pounds were found in one-third of all sea lion stomachs examined.

Several suggestions have been presented in an attempt to explain the presence of stones in pinniped stomachs: (a) stones are taken accidentally when sea lions prey on octopuses which have stones grasped in their tentacles (Sleptsov, 1950); (b) they add bulk to the stomach during periods of fasting (Howell, 1930, and Laws, 1956); (c) they aid in diving (Murray and Renard in Emery, 1941, and Hamilton, 1933); (d) they macerate stomach parasites (Hamilton, 1933); (e) they aid in the physical breakdown of food in the stomach (Mathews, 1929).

Two observations do not support the theory that stones are ingested accidentally with octopus remains: (a) stones were found in the stomach of a six-month-old nursing sea lion; apparently even young animals are capable of picking up and swallowing such objects; (b) stones are not found in the stomachs of harbour seals which frequently prey upon octopus. Although Laws (1956) presented convincing evidence to support his theory that stones add bulk to the stomach of a fasting elephant seal, his theory does not apply to the stones found in northern sea lion stomachs. These are found throughout the year and in the stomachs of lactating cows, when nutritional requirements are high.

Mathews' (1929) theory that stones aid in the breakdown of food is supported by evidence from the northern sea lion. The sea lion teeth, particularly the post canines, are designed for grasping and tearing rather than grinding (Figure 6); thus, food is swallowed in pieces. As much of the sea lion food consists of large, heavily-boned species the grinding activity of stones in the stomach would be of great assistance in the physical maceration of flesh, bones and octopus beaks. Observations of captive animals have shown that such stones are easily regurgitated, and this occurs after the digestion of food (Emery, 1941). Stones similar to those found in sea lion stomachs are also found on sea lion haul-out rocks.

The majority of the fur seals' food, and probably that of the harbour seal, is smaller fish or squid; an additional grinding mechanism in the stomach is not needed.

E. Comparative seasonal feeding habits

Differences in feeding habits of these three pinnipeds are evident, relating to time of year and also to area. Accordingly, the samples have been grouped as to season and area of collection.

The feeding habits of fur seals during January, February, March, April and May are described in detail (Table VI); whenever possible comparisons have been made with the feeding habits of sea lions and harbour seals (Table VII).

Following the northward migration of fur seals, sea lions and harbour seals remain. The samples from these two species have been divided into "summer breeding" and "summer non-breeding" categories for sea lions, and a "summer" sample for harbour seals. Samples from September 15 to December 30 have also been combined.

The British Columbia coast has been divided into four main areas (Figure 14) as an aid to describing feeding habits. This figure also shows the major sea lion and harbour seal localities mentioned in the text. Area I extends from 48°00'N to 51°00'N or the north end of Vancouver Island; area II includes waters off the west coast of the Queen Charlotte Islands; area III includes Hecate Strait, Queen Charlotte Strait and Dixon Entrance; while area IV includes all protected channels and inlets of the British Columbia coast.

References to numbers of stomachs in the following account refer to numbers of stomachs with food only.

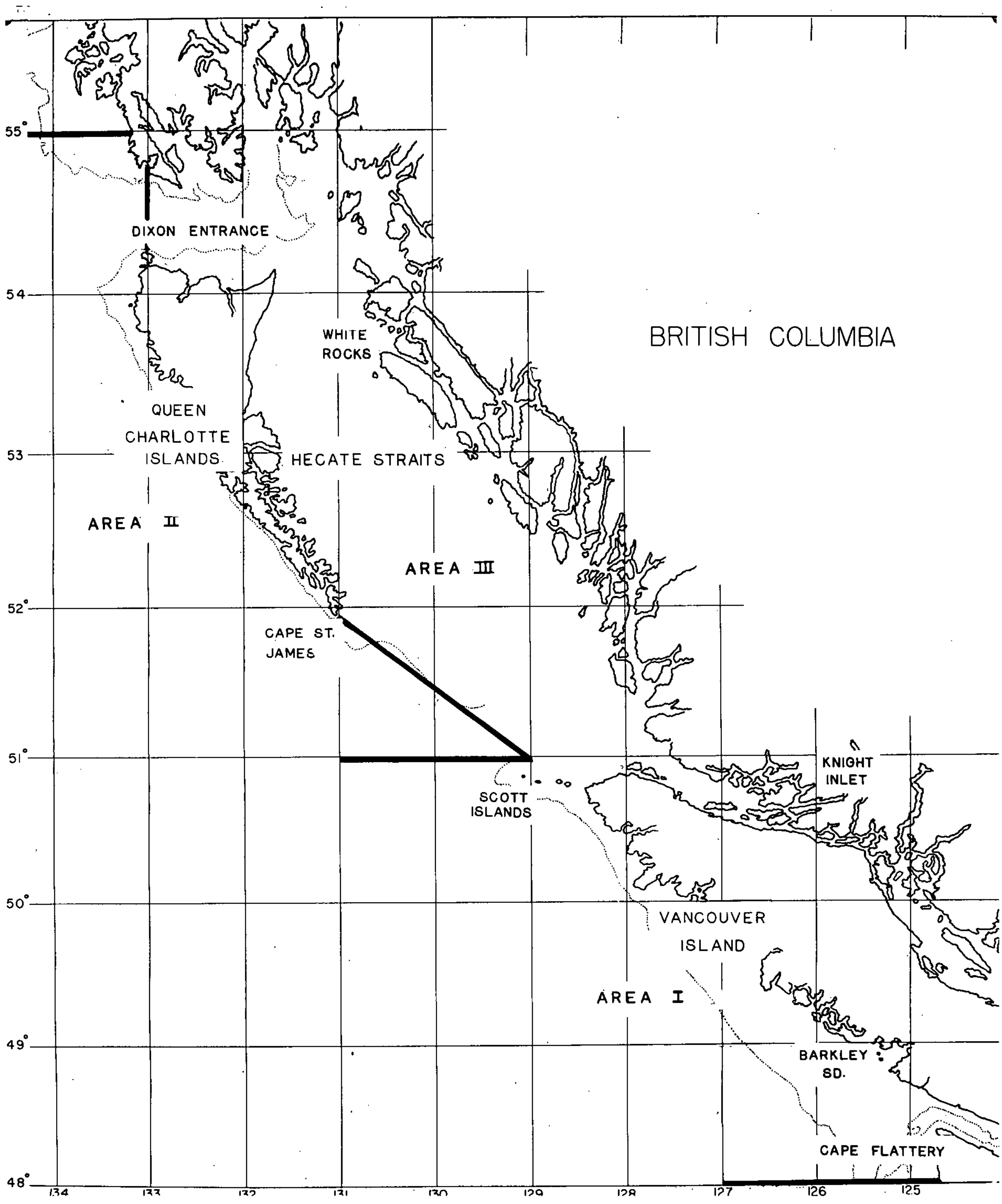


Figure 14. Collecting areas on the British Columbia coast (Area IV includes all protected inlets and channels).

TABLE VI: Fur seal stomach contents by month and area. Source of data as in Table I.

MONTH	JAN.	FEBRUARY			MARCH						APRIL				MAY			JUNE					TOTALS
AREA	IV	I	III	IV	I		III		IV		I		III	IV	I		IV	I		II	III	IV	
Stomachs with food.	8	1	22	15	69		20		46		334		9	6	324		2	43		9	3	1	912
Stomachs empty.	9		19	11	118		16		39		495		16	1	413		1	53		7	1	1	1,200[1]
TOTALS	17	1	41	26	187		36		85		829		25	7	737		3	96		16	4	2	2,112
SPECIES	F[2]	F	F	F	F	%[3]	F	%	F	%	F	%	F	F	F	%	F	F	%	F	F	F	F
Loligo op.				1	3	3.4	2	6.2			2	0.5			5	1.5							13
G. magister									28	58.3													28
Unid. Squid	6		4	3	19	21.9	4	12.5	11	22.9	44	10.9	2	5	44	13.1		6	11.1	9	1		158
Lamprey					3	3.4					1	0.2			1	0.2				1			6
Ratfish				3											1	0.2				1		1	6
Herring			7	1	24	27.6	8	25.0			180	44.8	6		188	56.0	1	28	51.9				443
Shad					2	2.3					19	4.7			3	0.9							24
Clupeids				1											4	1.2							5
Anchovy					3	3.4					4	1.0						2	3.7				9
Salmon					6	6.9	1	3.1			14	3.5			34	10.1		4	7.4				59
Eulachon					2	2.3			4	8.3	30	7.5		2	5	1.5		5	9.3				48
Capelin											1	0.2											1
Smelt				2							6	1.5	1		1	0.2							10
Saury					1	1.2					6	1.5			7	2.1				1			15
Hake				1	1	1.2			2	4.2					4	1.2	1	3	5.6				12
Whiting	1		2				7	21.9	1	2.1	1	0.2			3	0.9				1			16
Cods					2	2.3	1	3.1			1	0.2						1	1.8		1		6
King-of-the-salmon															1	0.2							
Flatfish							1	3.1			2	0.5	2		4	1.2							9
Greenling											1	0.2			3	0.9		3	5.6				7
Pomfret															1	0.2							
Squaretail															1	0.2							
Sablefish	2			3	4	4.6	7	21.9			18	4.5			12	3.6							46
Rockfish					6	6.9					28	7.0			7	2.1							41
Stickleback					11	12.6			1	2.1	25	6.2			2	0.6							39
Sandlance											18	4.5			7	2.1		1	1.8				26
Birds			1	1			1	3.1	1	2.1	2	0.5			1	0.2		1	1.8	1			9
Misc.[4]	1		1	1			2		1		9				8								
Unid. Fish[4]	2	1	9	4	22		3		4		60		4		93		1			4	2		
TOTALS	9		14	16	87	100.0	32	99.9	48	100.0	403	100.1	11	7	339	100.1	2	54	100.0	14	2	1	1,036

1 - one empty stomach collected in area 4 during May not included
2 - frequency of occurrence
3 - per cent frequency of occurrence
4 - not used in calculations

TABLE VII: Harbour seal and sea lion stomach contents, by month and area. Source of data as in Table I.

	SEA LIONS										HARBOUR SEAL								
	WINTER				SUMMER				FALL		WINTER					SUMMER		FALL	
MONTH	Dec.	Feb.	Mar.	Apr.	May 15-Sept. 15		May 15-Sept. 15		Sept. 16-Dec. 15		Jan.	Feb.	Mar.	Apr.	May	May 15-Sept. 15		Sept. 16-Dec. 15	
AREA	IV	IV	IV	IV	Breeding Colonies		Non-Breeding Colonies		Entire Coast		IV	IV	IV	IV	IV	IV		IV	
Stomachs with food.	14	3	9	2	92		35		35		1	1	2	1	0	26		38	
Stomachs empty.	0	2	5	2	155		22		17		0	1	1	0	1	48		6	
TOTALS	14	5	14	4	247		57		52		1	2	3	1	1	74		44	
SPECIES	F[1]	F	F	F	F	%[2]	F	%	F	%	F	F	F	F	F	F	%	F	%
Shrimp					2	2.4			1	2.4						2			
Clamshell	2				3	3.5	1	2.4	1	2.4						2	6.5	1	2.2
Octopus	1		1	1	36	42.4	5	12.2	1	2.4						8	25.8	7	15.2
Squid	1				5	5.9	2	4.9	3	7.1						1	3.2	8	17.4
Lamprey					1	1.2										2	6.5		
Skate				1															
Ratfish					2	2.4	2	4.9	1	2.4									
Dogfish	1	1	1		5	5.9	2	4.9	3	7.1									
Herring	12	1	3		1	1.2			1	2.4				1		3	9.7	5	10.8
Salmon					6	7.1			4	9.5						5	16.1	14	30.4
Eulachon				1									2						
Smelt											1							1	2.2
Hake					3	3.5			8	19.0		1							
Graycod							1	2.4	1	2.4									
Whiting		1	2		3	3.5	9	21.9	3	7.1								1	2.2
Halibut							1	2.4											
Flatfish							4	9.8	3	7.1								4	8.7
Seaperch																		1	2.2
Mackereljack									1	2.4									
Sablefish																1	3.2	1	2.2
Lingcod			1				1	2.4								1	3.2		
Greenling																		1	2.2
Rockfish			2	1	11	12.9	9	21.9	7	16.7						7	22.6	1	2.2
Cabezon																		1	2.2
Sandlance					1	1.2	2	4.9											
Sea bird																1	3.2		
Milk			1		6	7.1	2	4.9	4	9.5									
Kelp[3]							1		1										
Unidentified[3]			2		25		3		4			1				19		6	
TOTALS	17	3	11	4	85	100.0	41	99.9	42	99.9	1	2	2	1	0	33	100.0	46	100.1

1 - frequency of occurrence   2 - per cent frequency of occurrence   3 - not used in calculations

1. Winter-spring

(a) January. Fur seals first appear in January and are to be found in Hecate Strait, Queen Charlotte Sound and some of the northern inlets. These are mostly young males and females, but some adult cows are also seen at this time.

Eight fur seal stomachs were collected during January in Knight Inlet and Queen Charlotte Strait. Squid and small sablefish were the most important food species identified.

Male sea lions, plus a few non-lactating cows and immature females are to be found on haul-out rocks adjacent to the coast, or in more protected waters following herring; most cows with pups are on the rookeries. There are no sea lion stomachs available for this month.

Harbour seals may be found anywhere along the coast. One harbour seal, collected in Knight Inlet during January, had been feeding on eulachon.

(b) February. Distribution of all species is quite similar to that of January, although more young fur seals are evident in all northern areas and some adult and young fur seals may also be found off the west coast of Vancouver Island.

Stomach contents from 22 fur seals collected in Hecate Strait indicate that herring was the primary item in the diet while whiting and squid were of secondary importance. Fur seals from inside waters were feeding mainly on small sablefish, ratfish and squid which formed over half the diet.

Three sea lions, collected from Barkley Sound and Saanich Inlet at this time of year had been feeding on whiting, herring and dogfish.

One harbour seal collected in Barkley Sound during February had been feeding on hake.

(c) March. By late March the young fur seals begin to leave the protected waters of British Columbia's coast, while there is an increase in the number of adult fur seals appearing off Vancouver Island.

One hundred and thirty-five fur seal stomachs were collected during March in areas I, II and IV. Twenty stomachs from Hecate Strait indicated that herring was the most preferred fish, while squid, whiting and small sablefish were also important. A sample of 69 stomachs from area I indicated that herring and squid were the two most important items contributing 50% to the diet. Fur seals from inside waters, predominately yearlings collected in Knight Inlet, were preying heavily upon the squid, *Gonatus magister.*

Quantitative data on the movement of sea lions in Barkley Sound indicate that sea lions reach their maximum numbers in March, presumably following the herring. Sea lions move into Knight Inlet during March and April.

Nine sea lion stomachs were collected in Knight Inlet and Queen Charlotte Strait during March. Whiting, herring and rockfish occurred seven times in a total of eleven identifiable foods.

The harbour seals collected in Knight Inlet during March had been feeding on eulachon.

(d) April. During April the main northward-migrating fur seal herd has reached southern British Columbia waters, while most of the young fur seals have moved out of the sheltered inside waters.

Three hundred and forty-nine fur seal stomachs were collected in areas I, III and IV. Herring predominated in the nine stomachs collected in Hecate Strait. A large sample of 334 stomachs from southern Vancouver Island indicated that herring was again the most important food species, but squid, shad, stickleback, eulachon and rockfish were also taken frequently. Squid predominated in stomachs of six young animals collected from area IV.

Sea lions which, prior to April, had scattered throughout many of the inlets and inside passages probably begin their migration back to the rookeries by the end of April. Two sea lion stomachs were collected during April in Barkley Sound and Knight Inlet; the former had been feeding on rockfish, octopus and skate, while the latter had been feeding on eulachon.

Harbour seals are distributed over the entire coast, with no evidence of herding. One harbour seal collected off Maude Island, Strait of Georgia, in April, had been feeding on herring.

(c) May. During the early part of May, virtually all fur seals have left Hecate Strait and area IV waters, while fur seals of all ages are abundant off Vancouver Island. By the end of May the adults have passed into Alaskan waters.

Three hundred and twenty-six fur seal stomachs from areas I, III and IV contained food during May. A large sample of 324 stomachs collected in area I indicated that herring again comprised over half the food. Salmon assumed its greatest importance during May in the fur seal diet in this area when it contributed 10.1% to the total intake of food.

The three species, king-of-the-salmon, pomfret and squaretail, were encountered in one stomach collected 200 miles southwest of Estevan Point, Vancouver Island.

All sea lion and harbour seal specimens were collected later than May 15 and have therefore been placed in the appropriate "summer" category below.

2. Summer

(a) Fur seals. During June there are still a few late migrants, mostly young animals off British Columbia. Forty-seven seals from the west coast of Vancouver Island had been feeding on herring, hake, cod and squid. Only nine fur seal stomachs have been collected from waters west of the Queen Charlotte Islands. These seals, collected during June between 100-150 miles offshore, were feeding mainly on an unidentified squid (nine out of a total of fourteen occurrences), while saury, ratfish, whiting and lamprey remains were also identified. One of these nine stomachs, collected at 54°21'N-136°24'W, contained lamprey, whiting and ratfish which is typical of an inshore stomach. A mistake may have been made in positioning this seal; if this was the case squid has an even greater importance in this sample than is shown in Table VI.

(b) Sea lions. By late May and early June 70% of the sea lion population have congregated on the rookeries of Cape St. James and the Scott Islands, fur pupping and breeding. Octopus, forming nearly half of the contents examined, is by far the most important food, although rockfish, dogfish and salmon were also preyed upon quite heavily. Six yearling stomachs contained milk.

The sample from non-breeding, or haul-out, rocks indicates that octopus is of less importance while whiting and rockfish are the two major food items.

(c) Harbour seals. By June, according to D. McNaughton (personal communication), many harbour seals have congregated into small herds in isolated areas along the coastline where pupping occurs. Many of these herds apparently remain together until the end of the summer. However, in some areas, e.g., the Skeena River, seal herds break up following the pupping period and the animals move either down or up river by the end of June (Fisher, 1952).

Twenty-six stomachs are available for the summer months, collected mostly from the Fraser and Skeena Rivers. In this sample octopus, rockfish, salmon and herring are the most important food items.

3. Fall

There are no fur seal stomachs available for the four months from September to December. This species is rarely found in British Columbia waters until January (Manzer and Cowan, 1956).

(a) Sea lions. During the early fall many sea lions begin to leave the breeding rocks and scatter along the coastline. Males, and females without pups, probably move south from the Scott Islands towards Vancouver Island or towards the mainland inlets. Sea lions on Cape St. James probably move northwards up both the east and west coasts of the Queen Charlotte Islands, or across Hecate Strait to the mainland. The sample of 35 stomachs from Scott Islands, Cape St. James, inside waters of Moresby Island, Skedans and Isnor Rocks, indicates that at this time of year rockfish and hake are the most important food species. Salmon is the third most prevalent food and is taken largely by sea lions which have moved into the inlets and creek mouths where salmon are readily available. Five mackereljack, totalling 18 pounds, were identified in one stomach collected from the Scott Islands during September, 1961. This species is fairly common during the summer months in waters off the British Columbia coast (Clemens and Wilby, 1961). Milk was identified from four 14-15-month-old animals collected during the fall.

(b) Harbour seals. During the early fall the small herds of harbour seals apparently break up and all members disperse. It is believed these movements are relatively limited although they have not been studied closely.

The 44 stomachs available for this period are predominately from the Queen Charlotte Islands, collected when salmon were moving into the streams to spawn; collections were also made on the Scott Islands and in the Gulf of Georgia. Salmon was the most important food item (mostly chum and pink salmon) contributing 30.4% to the diet (Table VII). Octopus and squid were frequently eaten.

The seasonal food habits of these three pinnipeds may be summarized as follows:

i) Fur seals: Herring is the most important food during all months off Vancouver Island and in Hecate Strait, while squid are also taken frequently. Salmon assumes importance only during May off Vancouver Island. Seals in inside waters feed mainly on squid, ratfish and sablefish.

ii) Sea lions: Rockfish are one of the main food items for all sea lions at all times of the year. In addition to rockfish, herring are important during the winter; octopus, dogfish and salmon are taken frequently by breeding animals, while non-breeding animals feed heavily on whiting during the summer. Rockfish, salmon, whiting and hake are important food items during the fall.

iii) Harbour seals: During the winter eulachon is an important food, particularly in the inlets. Summer sampling, mostly on the Skeena and Fraser Rivers, indicated that octopus, rockfish and salmon were the important food items. During the fall, salmon constitutes nearly one-third of the food eaten.

F. Predator-prey size relationships

Prey size may have an important bearing upon the fish species preferred by each respective predator and two aspects of this problem have been investigated: (a) different feeding habits between sea lions and fur seals produced by inter-specific size differences; (b) an increase in prey size with the increasing age (and size) of fur seals.

1. Inter-specific differences

Table VIII compares the importance of large and small food items in the diet of fur seals and sea lions. The mean fur seal weight was only 29.1 kg with a range of 5.9-63.5 kg, while the mean female sea lion weight was 177 kg with a range of 58-265 kg. Although no mature bull sea lion weights were taken, some bulls weigh 900 kg (Cowan and Guiguet, 1956). Professional butchers have estimated that large bulls taken for mink food weigh 680 kg (1500 lb).

This table illustrates the importance of small schooling fishes in the fur seals' diet: 63% compared to 11% in the sea lions' diet. In comparison, the large species of salmon, rockfish, dogfish, cod, hake, halibut and lingcod comprise 43% of the sea lions' food but only 12% of the fur seals' food.

As 75% of the harbour seal stomachs were collected in the vicinity of salmon streams and rivers they cannot be analysed in the above manner.

2. Intra-specific differences (fur seals)

Table IX and Figure 15 summarize the available data on feeding behaviour of fur seals, according to age. Unidentified contents and species which occurred only rarely have not been included.

With increasing age, and thus size of predator, fish of larger size (salmon, cod, hake, rockfish and shad) become increasingly important: a rise occurs from three per cent frequency of occurrence in the one year age group to 38% and 37% respectively, in the nine to ten and 10+ age groups. Shad eaten by fur seals are larger than other clupeid species and have therefore been grouped with the larger food items. With increasing age of fur seals, foods other than those larger species mentioned above are of decreasing importance in the diet.

These comparisons show that predator size has a direct bearing upon prey size. Large fur seals prey on larger food items than small fur seals; sea lions prey on larger food items

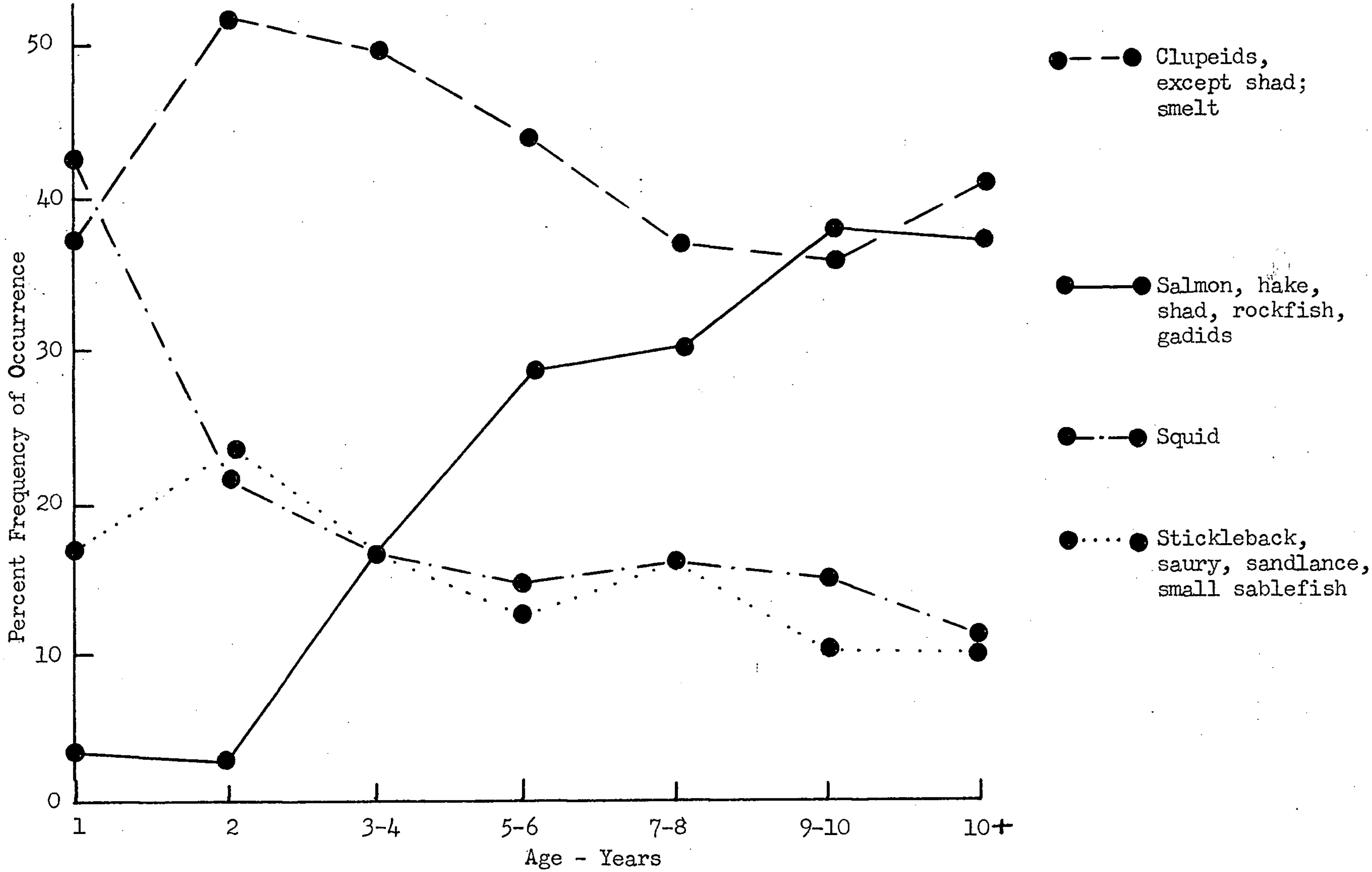


Figure 15: Analysis of 699 fur seal stomachs containing food, showing selective food preferences according to age.

Table VIII. Comparison of large and small food items eaten by fur seals and sea lions. Frequency expressed as a percentage of total occurrences of all food items from Table VI.

Prey (large)	Predators	
	Sea lions F*	Fur seals F
Salmon	10	59
Rockfish	30	41
Cod	20	22
Dogfish	13	
Hake	11	12
Halibut	1	
Lingcod	2	
Mackereljack	1	
Sub total	88	134
Total occurrences (all species)	203	1036
Per cent	43.4	11.9
Prey (small)		
Clupeids	18	481
Smelt	1	59
Sablefish (small)		46
Stickleback		39
Sandlance	3	26
Sub total	22	651
Total occurrences (all species)	203	1036
Per cent	10.8	62.8

*Frequency of occurrence

Table IX. Analysis of 699 fur seal stomachs containing food showing selective feeding behaviour according to age. (Data from present investigation only.)

Food items		Age (years)							
		1	2	3-4	5-6	7-8	9-10	10+	Totals
Clupeids[1] and smelt	F[2]	77	38	45	59	35	18	49	301
	%[3]	37.0	52.0	50.0	44.3	37.6	36.0	41.5	
Salmon, cod, rockfish, hake and shad	F	7	2	15	25	28	19	44	140
	%	3.4	2.7	16.7	28.4	30.1	38.0	37.3	
Squid	F	89	16	15	13	15	8	13	169
	%	42.8	21.9	16.7	14.8	16.1	16.0	11.0	
Sablefish, saury, stickleback and sandlance	F	35	17	15	11	15	5	12	110
	%	16.8	23.3	16.7	12.5	16.1	10.0	10.2	
Totals	F	208	73	90	88	93	50	118	720
	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
Total food		196	77	98	79	90	48	111	699
Total empty		261	115	140	80	75	41	65	777

[1]Clupeids do not include shad.

[2]Frequency of occurrence.

[3]Per cent frequency of occurrence.

than the smaller fur seals.

G. Feeding habits and reproduction

Pinniped food habits during the pupping and breeding season were examined primarily to determine the period of reduced food intake.

1. Fur seals

Available data indicate that food intake by the males is reduced. Abegglon *et al* (1958) report that "only 27 stomachs contained food among the thousands of empty ones in the St. Paul Island fur seal harvest". Bartholomew and Hoel (1953) concluded that harem masters did not feed for the two months of June and July while they maintained their territories. Studies carried out during the present fur seal research program have indicated, however, that this type of behaviour does not always occur (Anon, 1961). Russian investigators have shown that harem bulls on the Commander and Robben Islands remain on their territories for less than one month at any one time, and that vacancies on the rookeries are filled by reserve bulls.

The cows come ashore, and within three days give birth to their pups (Bartholomew and Hoel, 1953). Within four to seven days after parturition copulation takes place; the cow then goes to sea either on the same day or the day following that on which copulation occurred, leaving her pup on the rookery. Her first stay away from the rookery lasts approximately six days. She returns for one to two days and then re-enters the sea for an average of eight days; each successive trip to sea becomes longer. The pups first venture into the water in August (Baker, 1957) and from August to October or November, when abandoned by the cows, they gradually learn to feed for themselves. Fur seal pups have tripled their birth weight by October.

The lack of food in waters adjacent to the rookeries may provide an explanation for the lengthy trips of post-partum females. Dragging operations (Wilke and Kenyon, 1954) and pelagic stomach samples indicate that only a limited food supply is available within a radius of 30 miles of the Pribilof Islands. Eighty-five per cent of the stomachs collected within this 30-mile radius are empty (Niggol, _et al_., 1960). These authors suggest that the 1.5 to 2 million seals in this area during the six months from June to November have reduced the available food, particularly bottom fish. Salmon migrate past the Pribilof Islands but are seldom taken by fur seals (Wilke and Kenyon, 1954).

Chapman (1961) has suggested that the lack of food in this area may explain the heavy mortality of fur seal pups.

2. Sea lions

Pupping begins during the last week in May and is finished by the end of June (Pike and Maxwell, 1958; personal observations made during 1959).

The relationship between the pupping and breeding season and feeding habits of male and female sea lions is shown in a series of samples collected from May to September. Table X compares the percentage of empty stomachs to those with food in these samples. Normally, approximately sixty

Table X. Changing ratio of stomachs with food to empty stomachs throughout the pupping and breeding season in 228 male and female sea lion stomachs. Pups not included. (Data from present investigation only.)

		Male		Female	
		Food	Empty	Food	Empty
May 22-29 Rookeries	F[1] %[2]	14 (58.3)	10 (41.7)	13 (41.9)	18 (58.1)
June 5-18 Rookeries	F %	16 (76.1)	5 (23.9)	15 (27.2)	40 (72.8)
July 3-22 Rookeries	F %	2	7	12 (57.1)	9 (42.9)
September 21-30 Rookeries	F %	2	0	16 (64.0)	9 (36.0)
Non-breeding May 21 - August 17	F %	15 (60.0)	10 (40.0)	11 (73.3)	4 (26.7)

[1] Frequency of occurrence

[2] Per cent frequency of occurrence

per cent of sea lion stomachs collected during the daylight hours contain food.

During the last week in May males have taken up territories but are feeding regularly as 58% of stomachs contain food. The females, which have just started to pup, show the first signs of a decrease in food intake, with only 42% of stomachs containing food.

The next period of observation, June 5-18, is during the peak of the pupping period and presumably there is little breeding activity on the part of the males. This sample of 21 males indicates an increase in feeding. Female food intake is at a minimum, with only 27% of female stomachs containing food. The probable explanation for the high percentage of empty female stomachs at this time is that cows are remaining with their newborn pups.

The first three weeks in July indicate a complete reversal of the June situation. Feeding is at a minimum in the male population, but is nearly normal for the females. Although the male sample is small I believe the high frequency of empty stomachs (seven out of nine examined) accurately reflects the fact that many males are busy maintaining territories and breeding. The cows have finished pupping, lactation is well in progress and normal feeding has been re-established (57% of stomachs with food). Although no detailed study of sea lion breeding behaviour comparable to Bartholomew and Hoel's (1953) fur seal study is available, it is probable that sea lion cows in contrast to the fur seal cows, do not leave their pups for extended periods of time. Food is abundant in the immediate vicinity of the sea lion rookeries (see below) and the cows' feeding trips are probably only of a few hours' duration.

The last sample, collected during late September is predominately a female sample. By this time nearly all the bulls and many cows without pups have departed for more protected waters, leaving the lactating cows and pups on the rookeries. Feeding by the adult cows is probably at a maximum, with 65% of stomachs containing food. Pups have more than doubled their birth weight and make heavy nutritional demands on the cows.

It is not known when lactation ceases. However, observations of females suckling animals 12 and 15 months old indicate that up to 25% of the yearlings are not completely weaned. In some instances a yearling sea lion will be nursing, and supplementing this milk diet with fish, e.g., on July 6, 1959, a yearling sea lion was collected with milk and a ratfish in its stomach.

Increased numbers of sea lions on rookeries during the summer months could seriously reduce stocks of fish adjacent to such rocks. Exploratory fishing (page 85) has shown, however, abundant food supplies adjacent to Cape St. James and the Scott Island rookeries.

3. Harbour seals

During the actual pupping period food intake is at a minimum. Only five stomachs contained food in 45 collected on the Skeena River during the peak of the pupping period. How long this period of fast continues is not definitely known, but in the case of the Skeena River population probably only until the adults move down river to the Gibson Island area. From Fisher's (1952) data it is evident that by August harbour seal pups, born in June, are feeding on their own. These observations are strengthened by those of McNaughton (personal communication) who has observed that the first pups are born during the last week of May and pupping reaches a peak about the middle of June. This is comparable to the sea lion pupping behaviour. However, Mr. McNaughton noted that in contrast to sea lion pups, the harbour seal pups are quite capable of looking after themselves within one month of birth, and at this early age are abandoned by the cows.

4. Fasting

The phenomena of fasting among pinnipeds has been referred to by several authors. Some adult male northern fur seals will fast for two months while maintaining their harems (Bartholomew and Hoel, 1953); the southern elephant seal fasts for over two months in the wild and 100 days in captivity (Laws, 1956); a monk seal underwent a four-month fast in captivity (Scheffer, 1958). Howell (1930) refers to the "many weeks" of fast that a male sea lion undergoes when guarding his harem, while Pike (1958), when discussing the food habits of the northern sea lion, observes that "...during a large part of the year most of the population is fasting".

Seasonal fasting by sea lions and harbour seals has been examined. Female sea lions do not eat while pupping, a period of a few days only. Harem bulls may not feed for at least part of July, while maintaining harems. However, a prolonged fast does not occur in the sea lion population; the possibility of such an occurrence cannot be suggested to minimize the effect of sea lion predation upon commercially valuable fishes.

The limited harbour seal data indicate that post-partum cows in the Skeena River area undergo a fast for at least part of June.

Summarizing the available information regarding pinniped food habits and reproduction the following was found:

(a) Fur seals: Present evidence regarding male feeding behaviour on rookeries is contradictory. Bartholomew and Hoel (1953) state that harem bulls fast for two months; Russian investigators have found this does not always occur and a frequent exchange of bulls in the harem may take place. Stomachs from most young males collected commercially are empty. Females fast for about ten days during the pupping period and then start feeding, but may be forced to make extensive forages to sea for food.

(b) Sea lions: A fast occurs for a few days during June (exact number of days not known) while the cows pup. Upon the termination of this fast food intake is increased to sustain the rapidly growing pup. Harem masters probably fast during part of July when they are maintaining their harems.

(c) Harbour seals: Harbour seals on the Skeena River undergo a post-partum fast during June, although the exact length of this fast is not known.

H. Interspecific competition

The term competition as used here refers to an interspecific interaction which adversely affects the growth and survival of individuals of one species by another dominant or more successful species (Odum, 1960).

Fur seals, sea lions and harbour seals have been found together only in Knight Inlet and Barkley Sound. Sea lions and harbour seals may be seen together occasionally along the coast.

During February and March of most years, yearling fur seals congregate towards the head of Knight Inlet, which is four miles wide. During March, 1961, there were approximately 100 fur seals in mid-channel at a distance greater than one mile from either shore and two miles from the estuary of the Kleen River at the head of the inlet. When this area was sampled only four fur seals had ventured inshore in the direction of the estuary. These four had been feeding exclusively on eulachon. Sixty seals collected in the middle of the inlet had been feeding on squid.

During this same period approximately 30 sea lions in groups of four to ten were ranging up and down the shore, moving occasionally into the middle of the inlet or the estuary of the river. One sea lion collected had been feeding on dog-fish and whiting.[x]

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[x] One sea lion stomach collected and examined by Department of Fisheries officials during April, 1960, in Knight Inlet, contained eulachon.

Twenty-five harbour seals were found at this time in the estuary of the Kleena Kleen River; some solitary individuals were found along the shore of the inlet, maintaining a stationary position, close to the beach. Two hair seals from the river estuary had been feeding on eulachon.

Therefore, harbour seals plus the few fur seals which had moved into the Kleena Kleen estuary were feeding on eulachon. The majority of the fur seals were feeding on squid, while the one sea lion collected had been feeding on dogfish and whiting.

During February, 1958, the three pinnipeds were found together in Barkley Sound; distribution there was similar to that observed in Knight Inlet. The fur seals were greater than one mile from shore; sea lions and harbour seals were both close to shore although the sea lions were usually actively swimming, in contrast to the more sedentary harbour seals. At this time there were approximately 25 fur seals, 300 sea lions, and an unknown number of harbour seals in the area. Stomach contents indicated that fur seals (four stomachs with food) were feeding on herring, ratfish, hake and smelts, while sea lions (two stomachs) were feeding on herring and whiting; one harbour seal collected was feeding on hake. Although both fur seals and sea lions were feeding on herring, the small numbers of fur seals in the area, and the large volume of herring available in Barkley Sound at that time of year, indicated that any active competition between these two species was unlikely, particularly when their relative distributions were considered.

Sea lions are rarely found offshore in the vicinity of fur seals, and when located are difficult to kill. However, on May 21, 1961, a young sea lion was collected 10 miles outside Tofino in 30 fathoms of water. This animal, killed in waters where fur seals were feeding predominately on herring (75% by volume during May, 1961) had been feeding on lingcod and on unidentified flatfish. Fur seal stomachs occasionally contain flatfish, but lingcod have never been identified in stomachs collected in British Columbia waters.

On Triangle Island a small population of 25 harbour seals live near 500-600 sea lions. The sea lions haul out on small rocks situated a few yards to one mile off Triangle Island, while harbour seals haul out on the beaches of the main island spend considerable time in protected pools behind the outer reefs (Figure 16). Occasionally harbour seals have been seen outside the surf, near a sea lion rock or a group of swimming sea lions, but no animosity has been observed between the two species. Two harbour seals collected had fed on lingcod and small sablefish, neither of which have been identified in an examination of 35 sea lion stomachs with food from Triangle Island.

Thus, inter-specific competition appears to be negligible in British Columbia waters even though it is known that in several instances the same species of fish may be preyed upon by each of the three pinnipeds. In the relatively few areas where the three predators (or only two of them) occur together, intermingling is rare. When stomach contents indicate that the same food species is being preyed upon by two,

Figure 16. Triangle Island
Top: harbour seal habitat behind breakers. Sea lion rock in far right background
Bottom: sea lion rock with Triangle Island in background

or the three, predators in the same area and at the same time, the numbers of predators are so few, and the prey species is so abundant that competition is unlikely.

Where larger populations are concerned, however, competition may exist. Intermingling of adult fur seals, sea lions and harbour seals was observed during June, 1962, on the Portlock Bank, Gulf of Alaska, 30 to 40 miles from shore. Whether or not active competition for food occurred was not determined as only fur seals were collected. These latter were feeding exclusively on sandlance. Sea lions were observed at the surface eating rockfish twice and salmon once.

EFFECT OF SEAL AND SEA LION PREDATION UPON BRITISH COLUMBIA'S COMMERCIAL FISHERY

Two problems must be faced when considering pinniped predation upon the commercial fishery: (a) the effect of seal and sea lion predation upon fish stocks; (b) the effect of this predation upon the commercial fisherman and his gear. This study has attempted to find the answer to (a). The answer to (b) requires further investigation in the form of questionnaires and interviews with fishermen. The Department of Fisheries is at present undertaking such a program.

The amount of salmon and herring eaten by sea lions and harbour seals has been estimated in Appendix 1. There are insufficient data to estimate the amounts of herring and salmon eaten by fur seals.

A. Fur seals

Species of greater or lesser economic importance make up a large part of the fur seal diet in British Columbia waters. Over the past four years they have totalled 65% of the contents examined, and include herring, salmon, hake, cod, sablefish, rockfish and flatfish. However, only predation upon herring, salmon and some of the species exploited by the trawl fishery can be regarded as potentially serious, as it is these groups of fish which at present are being heavily exploited by man. No concern is expressed regarding predation upon other commercially valuable fishes as they are either fished spasmodically or taken in very small quantities by fur seals.

1. Herring

Herring are the most favoured fish species taken by fur seals in British Columbia waters, and contribute 43% to the total diet (Figure 13).

The northward migration of fur seals off the west coast of Vancouver Island coincides with the offshore movement of herring out of Barkley and Clayoquot Sounds after spawning, which reaches a peak during mid-March. An index of the size of the adult herring population is computed on the basis of "miles of spawn" deposited. The amount of spawn deposited is estimated each year by the Department of Fisheries and consists of measuring the length and width of each spawn deposition. In addition, intensity of deposition is expressed as one of five broad categories based on the numbers of eggs per linear inch of narrow bladed vegetation, or per square inch of broad-leafed vegetation. The spawn index, expressed as "miles of spawn", is then calculated by summing the lengths of all spawnings, after adjustments have been made for differences in intensity and width (Outram, 1961).

Indices of abundance for 1958, 1959, 1960 and 1961 have been compared with the per cent frequency occurrence of herring found in stomachs collected in waters between Barkley and Clayoquot Sounds (Figure 17). The trend of a sharp decrease in the size of the herring spawning population as exhibited by the "miles of spawn" index from 1958 to 1959, followed by a levelling off from 1959 to 1960, and an increase in 1961 appears to be fairly well duplicated by the presence of herring in seal stomachs. Thus, the magnitude of fur seal predation upon herring is apparently related to the abundance of spawning herring.

2. Salmon

Salmon have occurred only 59 times (5.8% frequency of occurrence) in a total of 2113 stomachs examined. Fur seals do not appear to show a preference for salmon and they may, in fact, prefer smaller fish such as herring, when the two types of prey are available. The only indication of salmon availability is the presence of the trolling fleet off southern Vancouver Island: seals collected in the vicinity of trollers presumably have had an opportunity to prey upon salmon. During 1960, in nine stomachs containing food collected in the vicinity of the trolling fleet on La Perouse Bank, none contained salmon. Herring was the predominate food species. In 1959, six stomachs containing herring were collected in an area where salmon were reported as plentiful by trollers. During the 1961 pelagic collecting program there was an apparent

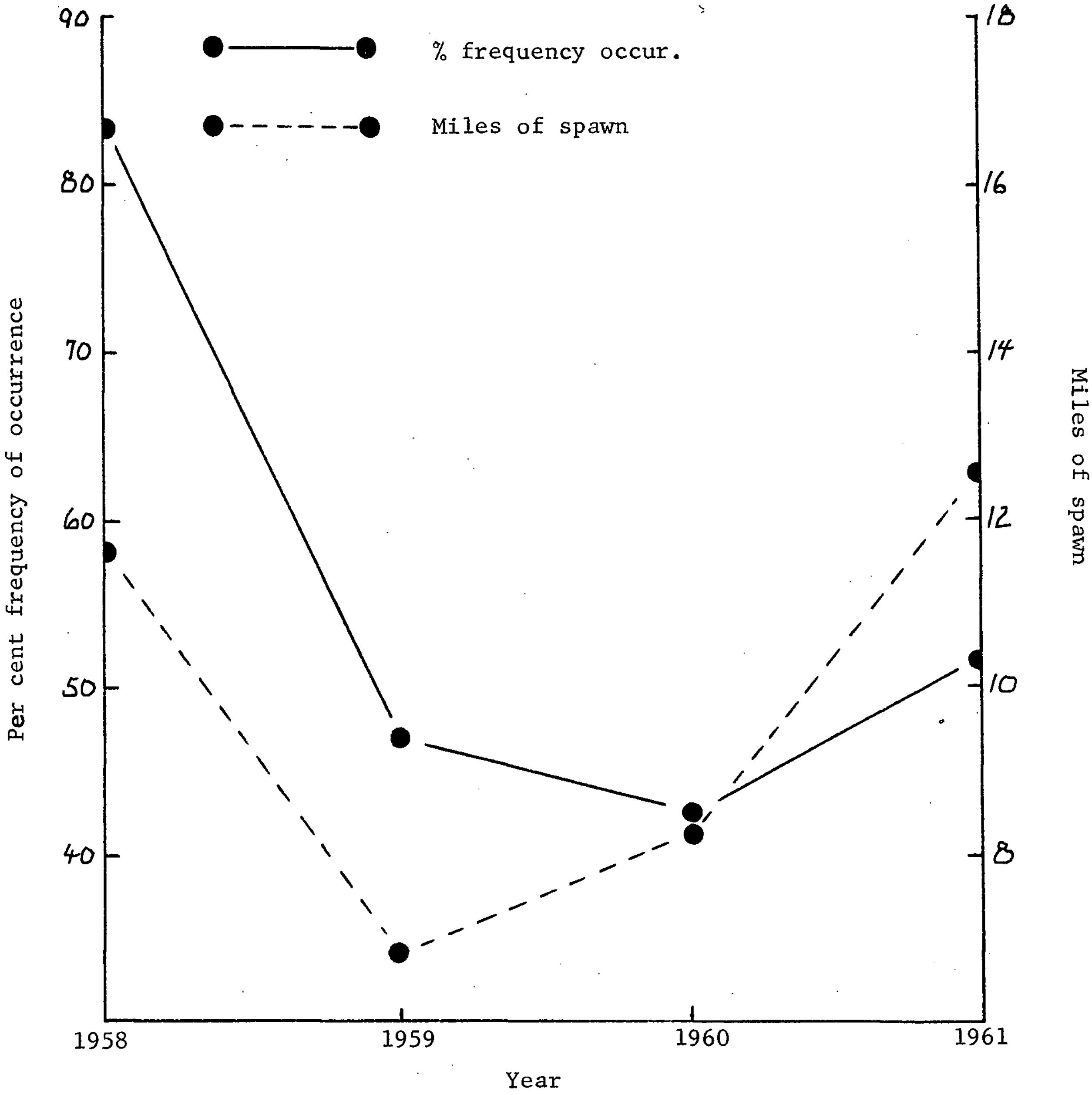

Figure 17. Per cent frequency of occurrence of herring in fur seal stomachs off southern Vancouver Island and miles of herring spawn in Barkley and Clayoquot Sounds (139 stomachs).

increase of small coho off Barkley and Clayoquot Sounds, as reported by commercial trollers. However, seal stomachs were empty when collected in the vicinity of trollers. Despite these negative results the occurrence of salmon in stomachs increased during 1961 (over 1960), which probably reflected an increased abundance of small salmon.

There is no correlation between frequency of occurrence of salmon in seal stomachs and the commercial catch of spring and coho salmon in the areas under study.

3. Trawl fishery

The migratory path of many fur seals passes across most of the trawl fishing banks, and several fish species identified in seal stomachs are also exploited by this fishery.

During February and March, from 1959 to 1962 inclusive, fur seals were hunted in the vicinity of the White Rock trawling ground in northern Hecate Strait. A total of 38 stomachs with food were collected during these four years. Catch statistics for the two months under consideration, totalled for three years, have been compared with seal stomach contents (Figure 18). These commercial data include not only food fish, but also fish species caught for mink or pet food and are therefore representative of bottom fish available on the grounds.

There is little relationship between the two sets of statistics illustrated in Figure 18. Commercial grey cod are large mature fish caught between 45 and 63 fathoms, which may be too deep for fur seals (Kenyon, 1951). Whiting, although apparently not too abundant, are second in importance to herring in the fur seal diet. There are virtually no sablefish of

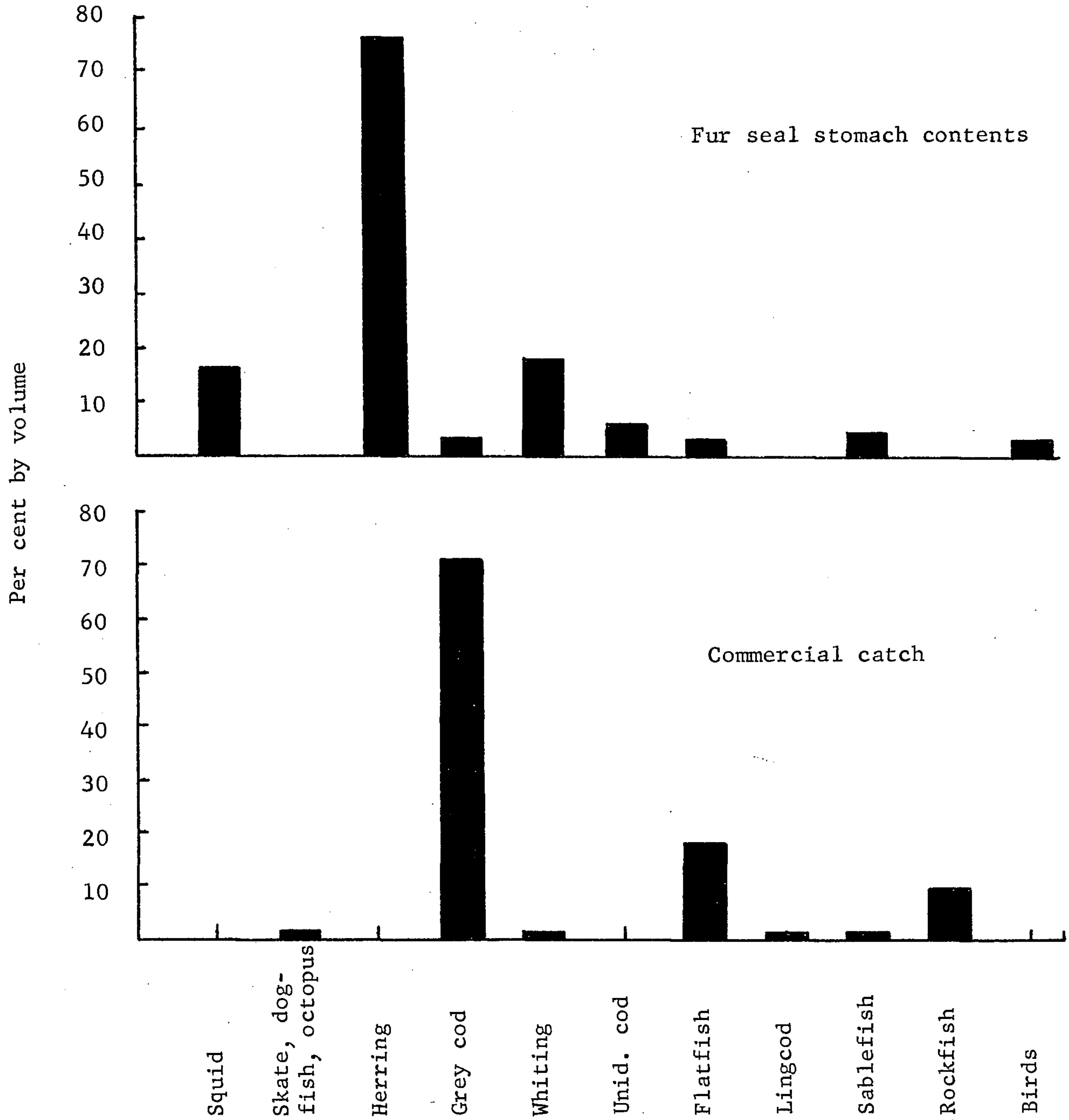

Figure 18. Trawl fishery catch statistics for 1959-1961 (White Rocks fishing grounds), and fur seal stomach contents collected from this vicinity.

commercial size in this area, but small sablefish do show in some of the trawl catches; these smaller fish are taken by seals.

Studies conducted by the Fisheries Research Board of Canada have shown that sablefish, whiting and herring frequently school together. When looking for fish other than herring caught in herring purse seines, the only two species in large numbers, other than herring, were small sablefish (9"-14") and small whiting (11"-14"). Exploratory fishing with mid-water trawls in Saanich Inlet indicated that herring and small whiting (12") were well off the bottom (Barraclough and Herlinveaux, 1961). Therefore, small whiting and sablefish rise off the bottom and in some cases mingle with the herring schools; commercially valuable grey cod and flatfish remain on the bottom, and are seldom preyed upon by fur seals.

B. Sea lions

Commercially valuable fish contributed 52.5% to the total sea lion sample. These include herring, salmon, hake, grey cod, whiting, flatfish, halibut, sablefish, lingcod and rockfish. Several of these fisheries are not fully utilized by man and only the herring, salmon and halibut fishery will be discussed in detail.

1. Herring

Compared to fur seals, sea lions do not rely so much upon herring as a food; approximately 10% of the sea lions' diet is herring compared to 43% for fur seals. Nevertheless, in certain localities sea lions prey extensively upon herring during the winter months, and are observed by fishermen swimming close to, or in, their herring seines, feeding on herring.

As mentioned earlier, herring migrate into Barkley Sound during the winter months to spawn. Each winter, sea lions are also found in these waters, remaining until April. A total of 30 stomachs have been examined from the Barkley Sound area since 1914. Herring, which occurred 16 times in a total of 29 identifiable food items, was the most important food item (Table XI). However, the relatively high number of octopus and rockfish remains indicate that herring were not the exclusive diet of sea lions, even in areas of herring abundance.

Table XI. Contents of 23 sea lion stomachs from Barkley Sound: 14 collected in December, 1915 (Newcombe et al., 1918); nine collected during the present investigation.

Species	Frequency	% Frequency
Herring	16	55.2
Rockfish	3	10.3
Octopus	3	10.3
Skate	1	3.5
Lingcod	1	3.5
Flatfish	2	6.8
Whiting	1	3.5
Squid	1	3.5
Dogfish	1	3.5
Total	29	

2. Salmon

The overall percentage contribution of salmon to both the fur seal and sea lion diet is quite similar: 5.6% for sea lion and 5.8% for fur seals. However, predation by fur seals begins when salmon are still offshore, during March, April and May in waters examined. Sea lion predation begins in June, and during July and August apparently increases (Table XII). Following the summer breeding activity most male sea lions and females without pups leave the rookeries and move to haul-out rocks closer to the mainland, or into the inlets. During this time there is a further predation upon salmon.

The Scott Island rookery, situated at the north end of Vancouver Island, is advantageously located for sea lion predation upon the large salmon runs moving toward the spawning rivers on the mainland. During the years under study this population has varied from 1,700 to 1,100 adults per breeding season. From a total of 63 occurrences of identifiable food remains only four (six per cent) were salmon (Table XII). However, this figure may be misleadingly low. There was virtually no predation upon salmon in this area during May, June and September, but salmon occurred in three of the four stomachs collected during July and August. Commercial catches of sockeye, coho and pink salmon in fisheries area 12, which includes the Scott Islands, reach a peak during July and August. Therefore, the main salmon runs pass these rookeries during the months when there are very few data on sea lion feeding habits.

Although no direct evidence is available regarding the effect of sea lions on these salmon runs, Figure 19 compares the total salmon catch in area 12 with the reduction of the Scott Island sea lion population since 1956. The reduction in sea lions has not resulted in a corresponding increase in the commercial salmon catch.

Table XII. Contents from 52 sea lion stomachs from the Scott Islands and adjacent waters. (Data from present investigation only.)

Month	Stomach contents (frequency of occurrence)											
	Salmon	Octopus	Rockfish	Dogfish	Hake	Whiting	Squid	Mackereljack	Herring	Ratfish	Flatfish	TOTALS
May		10	4	5		2	1					22
June	1	16										17
July	2		1									3
August	1											1
September			6		7	2	1	1	1	1	1	20

Salmon predation by the Cape St. James sea lions during the summer months of June, July and August may not be as serious as around the Scott Islands. During July, the only month when salmon were encountered in stomachs from Cape St. James, these species were found once in a total of ten identifiable food occurrences.

Following the gradual breakup of the breeding population, which begins during August and early September, some sea lions follow and prey upon salmon in the coastal inlets. Stomachs from three female sea lions, collected at the mouth of Klinkwoi Bay in the Queen Charlotte Islands, October, 1960,

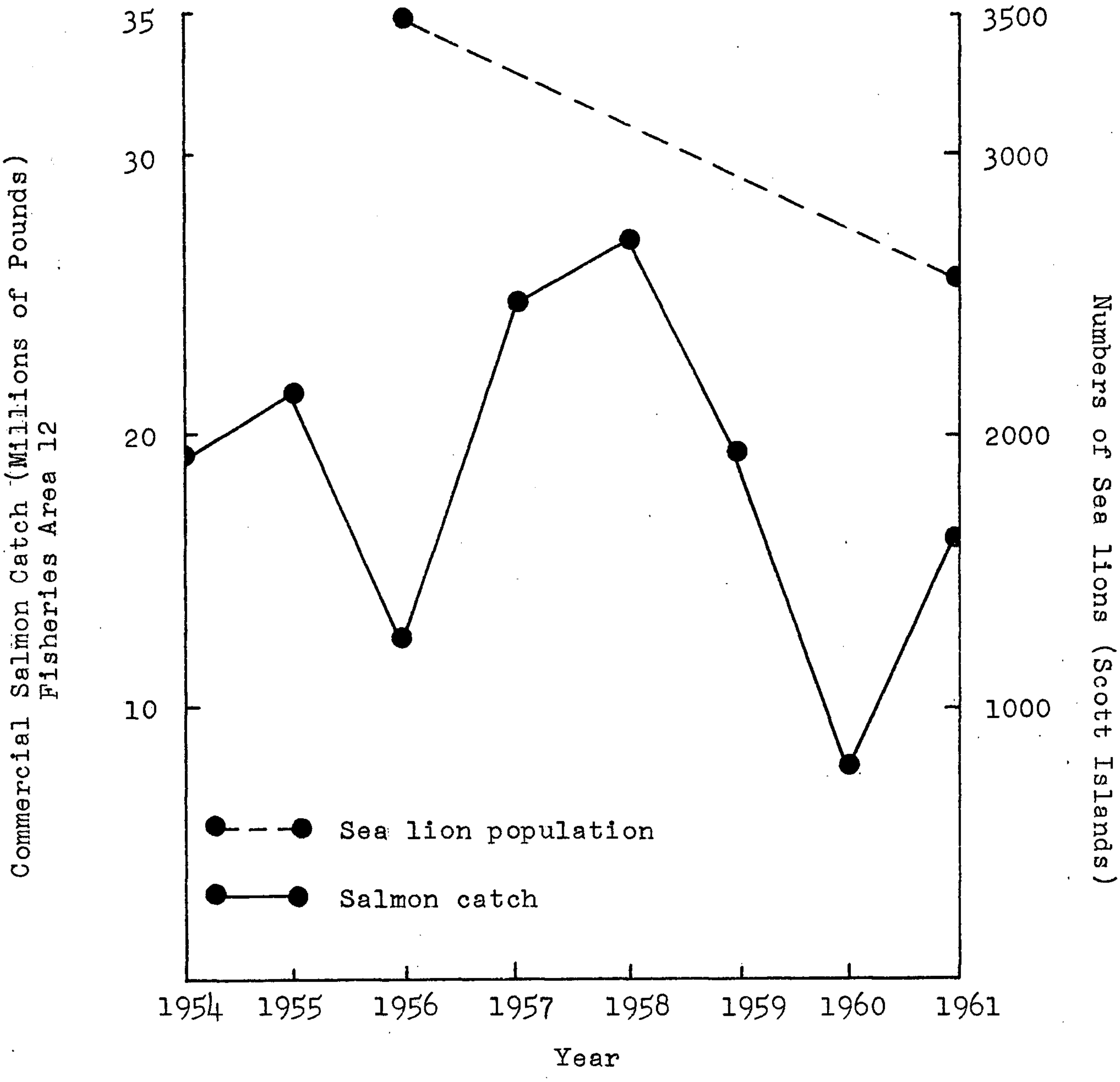

Figure 19: Salmon catches (all species) and the decreasing sea lion population in fisheries area 12, from 1954 to 1961.

contained remains of pink and chum salmon. These three were pregnant and had therefore moved from a breeding rookery (probably Cape St. James) some time during the late summer.

3. Halibut

Although sea lions eat halibut, there is little documental evidence to help assess the extent of this damage. Halibut were identified once from a stomach collected on the west coast of the Queen Charlotte Islands; a sea lion was observed eating a halibut at the surface in northern Hecate Strait on March 6, 1959. From the scarcity of halibut in stomach contents, it may be guessed that sea lion predation is not serious enough to reduce existing stocks of this species.

4. Availability of fish around sea lion rocks

The numbers of fish in the immediate vicinity of sea lion haul-out and breeding rocks was investigated. Fishing was done with stainless steel jigs. Results from exploratory fishing cruises were also examined.

A large trawling ground, 60 square miles in extent, has recently been found within 15 miles of the Scott Islands' rookeries (Hitz et al., 1961). Catches of rock sole, in 50 fathoms of water, averaged 750 lbs per hour. In deeper tows (70-120 fathoms) rock fish dominated the catches. Sea lions can dive to depths of 100 fathoms, and frequently dive to 60 and 80 fathoms (Kenyon, 1951).

The Cape St. James area was also examined for evidence of serious sea lion depredations upon commercially valuable fishes. Available evidence indicated this to be slight. Waters adjacent to these rookeries are fished for halibut and have been for many years. The now deserted Indian village of Skunggwai, on Anthony Island, 15 miles north of these rookeries, received its name from the large numbers of fish, particularly rockfish, found in the vicinity (Duff and Kew, 1957). This was before any control measures were exerted upon the sea lion population.

The following three observations indicate the availability of fish, mostly rockfish and lingcod, around sea lion rocks:

(a) April 7, 1958. Six lingcod and two rockfish (Sebastodes sp.) were caught in 25 minutes at Folger Island, Barkley Sound, where 200 adult sea lions were wintering.

(b) March 8, 1961. Three small lingcod, two red snappers (Sebastodes ruberrimus) and two orange spotted rockfish (Sebastodes maliger) were caught within half an hour's fishing at Bright Island, Queen Charlotte Strait, where 50 sea lions, mostly large males, were hauling out.

(c) September 26, 1960. Three lingcod jigged in 10 minutes and 14 large red snappers (Sebastodes ruberrimus) caught in one hour at Sartine Island where 300 adults with 250 nursing pups were located.

Sea lions have little or no effect in seriously reducing the numbers of fish in the vicinity of their rookeries and haul-out rocks. A general observation, which has been strengthened over the past four years of collecting, is that lingcod and rockfish are abundant near sea lion rocks.

C. Harbour seals

Fish of commercial value comprise 54% of the harbour seal diet. These include herring, salmon, eulachon, hake, whiting, flatfish, sablefish and lingcod. Concern is directed mainly towards the possible effect of harbour seal predation upon herring and salmon.

1. Herring

This species is important to harbour seals, although the present study may not show its true importance. The sample indicates only a 12% contribution to the total diet (Figure 13), but herring have been found in stomachs collected during April, July, September and November - essentially throughout the entire year. There are few, if any, complaints from the fishing industry regarding harbour seal predation upon herring.

2. Salmon

Harbour seal predation upon salmon may be extensive at certain times of the year. Salmon contributed approximately 30% to the contents of a sample collected for the most part near salmon spawning streams during the fall; sampling indicates that salmon are also eaten during the summer months, particularly June.

However, seals prey on other food even when salmon are abundant. Fisher (1952) discussed the relative importance of salmon in the harbour seal diet on the Skeena River during the summer months. He noted that, although salmon were very numerous, other fish species were preyed upon, particularly as the seals moved towards the sea after pupping. Since Fisher's study, 45 more stomachs have been collected from this area and examined by Department of Fisheries officials during June, 1948, and June, 1959. Forty of these were empty indicating that little feeding occurs on the Skeena River during part of June at least. Of the four stomachs with food, salmon occurred twice, a lamprey once and feathers once.

Fisher also noted that in a sample of three stomachs collected at the mouth of the Fraser River during salmon migrations, two stomachs contained herring and one contained salmon.

During the present investigation a harbour seal collected in Luxanna Bay, Queen Charlotte Islands, was feeding on herring while pink salmon were moving into a creek at the head of the bay. At the same time three seals were killed in Howe Bay, approximately 10 miles away, where there was no salmon spawning creek. These stomachs contained rockfish, octopus and greenling. Thus, there was no obvious movement of seals following the salmon (or herring) which were present in Luxanna Bay. This type of behaviour was also evident in Barkley Sound in 1958. One harbour seal collected had eaten hake, although spawning herring were in the area.

These observations on food other than salmon or herring in harbour seal stomachs have been recorded not to minimize the possible seriousness of seal predation, but to illustrate the necessity for accurate figures on numbers of seals preying on salmon. Harbour seals are scattered over the coast during the summer and fall and it is not adequate to say that as there is a total population of X seals, all are feeding on salmon. It appears that only those in the vicinity of salmon creeks can be regarded as potential predators.

CONCLUSIONS

A. Effect of fur seals, sea lions and harbour seals upon commercially valuable fish

Fur seals, sea lions and harbour seals eat fish of commercial importance, especially herring and salmon. Herring is the most important food for the migrating fur seal herd moving up the British Columbia coast, and for the wintering animals; it is preyed upon from January to June. Harbour seals also feed on herring and will take this fish whenever it is available. In contrast, sea lions feed upon herring mainly during the winter months. The total tonnage of herring eaten by sea lions and harbour seals has been estimated at 7,250 (2,400-13,250) tons, or 4% (1.0-6.2%) of the average annual commercial catch of 200,000 tons (Appendix 1)

Herring are subjected to intense predation throughout their entire life cycle by many fish, birds and mammals. Total mortality of mature and maturing fish is up to 80%, of which an average of 50-60% results from natural mortality in ages five to twelve years (F. H. C. Taylor, personal communication). Pinniped predation, accounting for an estimated 5% of the average annual catch, is not a serious factor in herring mortality.

Salmon also are taken by these three predators. Migrating fur seals occasionally take salmon, usually small fish, off the west coast of Vancouver Island, as salmon are moving towards coastal waters. Fur seal predation upon salmon cannot be evaluated until the numbers of seals preying upon these species can be estimated. Harbour seals prey upon salmon, particularly during the fall when the salmon are moving into the rivers. However, harbour seals do not always make a special effort to congregate in areas of salmon abundance, and when salmon are available do not restrict their diet exclusively to salmon. Salmon form up to 30% of the diet of seals collected in the mouths of salmon streams.

Sea lions prey upon salmon during the summer months as the salmon migrate past the rookeries. In addition, sea lions probably follow the salmon into bays and river mouths, and prey upon them there.

The total amount of salmon eaten by sea lions and harbour seals is estimated to be 4.0 (1.2-7.1) million pounds annually, which is approximately 2.5% (0.8-4.7%) of the average 148 million pound annual commercial catch (Appendix 1).

Salmon mortality rates are high both in fresh water and the ocean. Neave (1953) estimated freshwater survival of pink and chum salmon to vary between one per cent and twenty-four per cent; ocean survival was assumed to average approximately five per cent for each species. Ricker (1962) estimated average total losses of ocean sockeye to vary from 95% to 64%. Fishing mortality of returning adult salmon ranges from 50% to 80%, depending upon the species (Shepard and Stevenson, 1956). The present study indicates that sea lions and harbour seals take an amount equal to 2.5% of the fishing mortality.

What role predators play in the reduction of these populations is not fully understood. Elson (1962) has shown that bird predation upon young salmon during their freshwater existence can seriously reduce the number of smolts entering the sea. No study has yet been made to determine the effect of predators upon salmon during their ocean existence.

Parker (1962) has estimated, on a theoretical basis, that although a coastal natural mortality factor could be calculated for adult migrant salmon, such mortality was slight and was of negligible influence on the total mortality. This study supports these theoretical conclusions.

I wish to emphasize that knowledge concerning the effect of pinnipeds, particularly fur seals, upon salmon is far from complete. Although the coastal zone has been studied, it is difficult to estimate numbers of migrating fur seals in this area. In addition, virtually nothing is known about the feeding habits of adult fur seals which must winter and migrate over much of the mid-North Pacific Ocean. These seals are usually scattered and difficult to hunt; as a result very few have been collected farther than 200 miles from shore during the present pelagic fur seal program.

During June, 1962, however, a Canadian vessel collected thirty-seven seals in the middle of the Gulf of Alaska. Salmon occurred in ten of the 26 stomachs with food. No conclusions can be drawn from such a small sample although the desirability of further collections offshore is indicated.

To summarize briefly: each year sea lions and harbour seals consume an estimated amount of salmon equivalent to 2.5% of the annual commercial salmon catch and an estimated amount of herring equivalent to 4% of the annual commercial herring catch. Predation at this level is not believed to be a serious factor in either salmon or herring mortality. More collecting should be done offshore to determine the effect of fur seals upon ocean salmon. Halibut stocks on the British Columbia coast appear to be unaffected by pinniped predation.

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APPENDIX 1: A quantitative estimate of the effect of sea lions and harbour seals on the British Columbia salmon and herring fisheries.

Effective estimates of the amount of salmon and herring eaten by pinnipeds must be based on the following information: (a) daily food intake of each predator; (b) numbers of predators and how long they prey on each respective food item; (c) per cent contribution of each prey to the total food intake. In order to complete the calculations below, the following procedure has been followed:

(a) Daily food intake. This ranges from 2% to 11% of the body weight, with a mean of 6% (Table V). All calculations are based on 6% of the body weight with the possible range included in brackets.

(b) Numbers of predators and duration of predation. The highest estimate of a population size has been used. Predation time is based on how long the predator population was in the vicinity of its prey.

(c) Per cent contribution of each item. This has been calculated on a per cent frequency of occurrence basis, and has been taken from Table VI and VII and Figure 13.

The calculations have been carried out by multiplying the daily food intake (estimated from mean body weight) by the number of predators, by the number of days of feeding, by the per cent contribution of the particular food item.

The following calculations are based on data which are often incomplete; further studies may alter these estimates.

A. Sea lions

The mean female sea lion weight is 177 kg, or 450 lb; a representative sample of males has not been weighed. However, as large adult males frequently weigh 1,500 lb, the mean female weight has been doubled to arrive at a mean body weight of 900 lb for the total population.

1. Herring

The population of 4,500 animals (excluding pups) will require an estimated 87.5 (29.2-160.4) million lb annually. Herring, forming 10% of this (Figure 13) will contribute 4,650 (1,550-8,500) tons.

2. Salmon

Salmon contribute 8% to the food intake of 3,100 sea lions on the rookeries from May 15 to September 15 (Table VII). During these four months an estimated 20.4 (6.8-37.4) million lb of food are required; salmon would contribute 1.6 (0.5-3.0) million lb. During the early fall approximately one-half, or 1,500 sea lions leave the rookeries and move inshore to join the non-breeding element of the population. Therefore, salmon forms 10% of the diet of approximately 3,000 sea lions during October and November when the late salmon runs are still available to sea lions. During these two months 3,000 sea lions require 9.7 (3.2-17.8) million lb of food and salmon would constitute 1.0 (0.3-1.8) million lb.

Combining these two estimates of summer and fall consumption of salmon by sea lions gives a figure of 2.6 (0.8-4.8) million lb.

B. Harbour seals

The mean body weight of 23 harbour seals was 100 lb.

1. Herring

The estimated 20,000 harbour seals annually require 43.2 (14.4-79.2) million lb of food. Herring forming 12% of this would contribute 2,600 (850-4,750) tons annually.

2. Salmon

The numbers of harbour seals preying on salmon may be estimated by calculating the average number of seals per salmon spawning stream and multiplying this by the total numbers of such rivers and streams on the coast.

There are approximately 900 salmon spawning creeks entering salt water or lakes accessible to seals, excluding the Skeena River system (Department of Fisheries files). An average of five to ten harbour seals per creek is estimated from my own observations, plus those of fisheries officers and others working on salmon streams. If ten seals per creek is taken as a maximum, 9,000 seals may be regarded as potential predators upon salmon in the 900 streams mentioned above. Fisher (1952) estimated there were 400 seals in the lower Skeena River, plus "several hundred" upriver. For the purpose of these calculations a total population of 1,000 seals in the Skeena River system has been estimated. An average predation period of 70 days was calculated from the seasonal duration of salmon runs in 37 streams chosen at random (Department of Fisheries files). Runs of salmon of all species lasted an average of 70 days in each stream.

Therefore, 10,000 seals would require 4.2 (1.4-7.7) million lb of food for 70 days. Salmon forming 30% of this would constitute 1.3 (0.4-2.3) million lb.

When these estimates are combined sea lions and harbour seals eat an estimated 7,250 (2,400-13,250) tons of herring and 4.0 (1.2-7.1) million lb of salmon annually. The average annual herring catch is 200,000 tons (Outram, 1961), and pinniped predation, therefore, may account for an amount equivalent to 4% (1.0-6.2%) of the annual catch. The average annual salmon catch is 148 million lb and pinniped predation may account for an amount equivalent to 2.5% (0.8-4.7%) of the annual commercial catch.

Appendix Table I. Scientific and common names of food items mentioned in text.

Invertebrates	
P. Mollusca	
C. Pelecypoda	shellfish
Yoldia myalis	clam
Mytilus sp.	mussel
Mytilus californianus	mussel
C. Cephalopoda	
S. Order Octopoda	octopus
Polypus hongkongensis	
Tremoctopus sp.	
S. Order Decapoda	squid
Loligo opalescens	
Gonatus magister	
G. fabricii	
Gonatus sp.	
Gonatopsis sp.	
G. borealis	
Onychoteuthis sp.	
O. banksii	
Ommastrephes sloani	
Watasenia acintillans	
Dosidicus gigas	
Moroteuthis lonnbergii	
Stenoteuthis bartrami	
Chiroteuthis veranyi	
Abraliopsis sp.	
P. Arthropoda	
C. Crustacea	crayfish, lobster, shrimp, crab
O. Decapoda	
Upogebia pugettensis	
Callianassa californiense	
Cancer oregonensis	
C. magister	
C. gracilis	

Hemigrapsus oregonensis
Pagurus sp.
Petrotisthes cinctipes
P. eriomerus
Pinnixia schmitti
Caridae
Crago franciscorum
C. stylirostris
Pandalus platyceros

Vertebrates

C. Chondrichthyes

Family Petromyzontidae	
Entosphenus tridentatus	Pacific lamprey
Family Squalidae	
Squalus suckleyi	dogfish
Family Rajidae	skate
Raja sp.	
R. binoculata	big skate
Family Chimaeridae	
Hydrolagus colliei	ratfish
Family Pterothrissidae	
Pterothrissus gissu	gisu

C. Osteichthyes

Family Clupeidae	herrings (clupeids)
Clupea pallasii	Pacific herring
C. Harengus	Atlantic herring
Alosa sapidissima	shad
Sardinops melanosticta	sardine
Family Engraulidae	anchovy
Engraulis mordax	Northern anchovy
E. japonica	
Family Salmonidae	salmon
Oncorhynchus gorbuscha	pink salmon
O. *Kisutch*	coho salmon
O. *keta*	chum salmon

O. nerka	sockeye salmon
O. tshawytscha	spring salmon
Salmo gairdneri	steelhead
Salvelinus sp.	trout
Family Osmeridae	smelts
Hypomesus pretiosus	surf smelt
Mallotus villosus	capelin
Ihaleichthys pacificus	eulachon
= Osmerus mordax	American smelt
Family Argentinidae	
Bathylagus sp.	black smelt
Family Melanostomiatidae	
Tactostoma macropus	arrow fish
Family Myctophidae	lantern fish
Electrona sp.	
Tarletonbeania sp.	
T. crenularis	blue lantern fish
Lampanyctus sp.	
L. nannochir laticauda	
Myctophum californiense	
Notoscopelus elongatus	
Family Scopelarchidae	
Scopelosaurus	
Scopelarchus linguidens	pearleye
Family Paralepidae	
Magnisudis barysoma	barracudinas
Family Anotopteridae	
Anotopterus pharao	daggertooth
Family Ophichthidae	snake eels
Family Scomberesocidae	
Cololabis saira	Pacific saury
Family Atherinidae	
Atherinipsis californiensis	jack smelt

Family Exocoetidae	
Cypselurus pedurо	
Family Merlucciidae	
Merluccius productus	Pacific hake
Family Gadidae	cods
Theragra chalcogrammus	whiting (walleye pollock)
Pollachius virens	pollock
Gadus macrocephalus	Pacific cod
G. morrhua	Atlantic cod
G. ogae	Greenland cod
Melanogrammus aeglefinus	haddock
Lotella sp.	
Microgadus proximus	Pacific tomcod
Family Trachypteridae	
Trachypterus rexsalmonorum	King-of-the-salmon
Family Pleuronectidae	flatfish, flounder
Atheresthes stomias	arrowtooth flounder
Hippoglossus stenolepis	Pacific halibut
Hippoglossoides elassodon	flathead sole
H. platessoides	plaice
Glyptocephalus cynoglossus	witch flounder
Lyopsetta exilis	slender sole
L. putnam	smooth flounder
Lepidopsetta bilineata	rock sole
Parophrys vetulus	lemon sole
Platichthys stellatus	starry flounder
Pseudopleuronectes americanus	winter flounder
Citharichthys sp.	flounder (sand dab)
Family Embiotocidae	sea perches
Damalichthys vacca	silver perch
Cymatogaster aggregatus	shiner, sea perch
Family Trichodontidae	
Trichodon trichodon	Pacific sandfish
Family Bramidae	
Brama raii	pomfret
Family Scorpidae	
Medialuna californiensis	halfmoon

Family Carangidae	
= *Trachurus symmetricus*	mackeral jack
Family Scombridae	mackerals
Scomber japonicus	mackeral (Pacific mackeral)
Promethichthys prometheus	snake mackeral (black tuna)
Trachurus japonicus	horse mackeral
Family Tetragonuridae	
Tetragonurus cuvieri	squaretail
Family Sphyraenidae	
Sphyraena sp.	barracuda
Family Anoplopomatidae	
Anoplopoma fimbria	sablefish
Family Hexagrammidae	
Hexagrammos sp.	greenling
Pleurogrammus monopteryguis	Atka mackeral
P. azonus	
Ophiodon elongatus	lingcod
Family Scorpaenidae	rockfish
Sebastodes sp.	
S. flavidus	yellow rockfish
S. paucispinis	Bocaccio
S. alutus	ocean perch
S. entomelas	widow perch
S. jordani	shortbelly rockfish
S. ruberrimus	red snapper
Sebastes marinus	redfish
Family Cottidae	sculpins
Scorpaenichthys marmoratus	midshipman
Family Cyclopteridae	lumpsuckers
Family Gasterosteoidea	
Gasterosteus aculeatus	threespine stickleback
Family Syngnathidae	
Syngnathus californiensis	kelp pipefish

Family Bathymasteridae	
Bathymaster signatus	searcher
Family Anarrhichadidae	wolffishes
Family Stichaeidae	blennies
Family Labridae	
Tautogolabus adspersus	cunner
Family Zoarcidae	eelpouts
Family Ammodytes	
Ammodytes hexapterus	sandlance (launce)
Family Batrachoididae	
Porichthys notatus	midshipman (singing fish)
Class Aves	
Aethia *cristatella*	
Oceanodroma homochroa	ashy petrel
Fulmarus glacialis	fulmar
Xema sabini	sabine gill
Ptychoramphus aleuticus	Cassin's auklet
Brachyramphus marmoratus	marbled murrelet
Synthliboramphus antiquus	ancient murrelet

Appendix Table II. Pinniped stomach contents from collections made in North American waters and the Western Pacific.

Species of seal	Authority	Month of collection and location	*Number in sample	Identified food items (terminology of each author has been maintained)
Northern fur seal	Taylor *et al.* (1955)	Western Pacific (February-June)	1,138	Squid, herring, anchovy, salmon, lantern fish, saury, "hake", mackerel, snake mackerel, rock-fish, eel, birds.
Northern fur seal	Anon. (1962)	Western Pacific (February-October)	3,769	Squid, gisu, sardine, anchovy, salmon, trout, pearleye, lantern fish, saury, *Sphyraena* sp., walleye pollock, *Lotella* sp., horse mackerel, Pacific mackerel, black tuna, Atka mackerel, *Pleurogrammus azonus*, Cyclopteridae, *Cypselurus piduro*, sandlance.
Northern fur seal	Alexander (1892) *in* Taylor *et al.* (1955)	Gulf of Alaska	104	Squid, salmon, rockfish.
Northern fur seal	Lucas (1899)	Gulf of Alaska and Bering Sea (April-September)	409	Squid, octopus, lamprey, salmon, black smelt, cod, whiting, rock-fish, cottid, wolf fish.
Northern fur seal	Schultz and Rafn (1936)	Washington (spring)	41	Shrimp, squid, lamprey, herring.
Northern fur seal	May (1937)	Washington (spring)	54	Squid, herring.
Northern fur seal	Bonham (1941) *in* Taylor *et al.* (1955)	Washington (April)	5	Squid, shad.
Northern fur seal	Wilke and Kenyon (1954)	West Crawfish Inlet (December-March)	148	Squid, herring, whiting.

Species of seal	Authority	Month of collection and location	*Number in sample	Identified food items (terminology of each author has been maintained)
Northern fur seal	Taylor *et al.* (1955)	California, Oregon and Washington (February-April)	125	Squid, lamprey, shad, Pacific herring, anchovy, salmon, surf smelt, jack smelt, eulachon, saury, hake, sand dab, sablefish, rockfish, sandlance, birds.
Northern fur seal	Taylor *et al.* (1955)	Alaska (June-July)	116	Squid, capelin, hake, sandlance.
Northern fur seal	Anon. (1962)	California (December-April)	1,781	Squid, octopus, dogfish, shad, herring, anchovy, salmon, surf smelt, eulachon, arrow fish, lantern fish, barracudines, saury, hake, king-of-the-salmon, flatfish, pomfret, halfmoon, jack mackerel, Pacific mackerel, black cod, rockfish, kelp pipefish, midshipman, birds.
Northern fur seal	Anon. (1962)	Oregon (January-June)	93	Squid, lamprey, shad, herring, salmon, eulachon, *Scopelosaurus*, lantern fish, saury, hake, king-of-the-salmon, flatfish, jack mackerel, blackcod, rockfish.
Northern fur seal	Anon. (1962)	Washington (January-April)	480	Squid, lamprey, shad, herring, anchovy, salmon, surfsmelt, c capelin, eulachon, Osmeridae, lantern fish, saury,hake, whiting flatfish, sablefish, rockfish, stickleback, sandlance.

Species of seal	Authority	Month of collection and location	*Number in sample	Identified food items (terminology of each author has been maintained)
Northern fur seal	Anon. (1962)	Alaska (February-June)	1,258	Squid, lamprey, herring, salmon, capelin, eulachon, Osmeridae, lantern fish, daggertooth, grey cod, tomcod, whiting, flatfish, Pacific sand fish, Atka mackerel, sablefish, Hexagrammidae, rockfish, sculpins, Cyclopteridae, searcher, sandlance, birds.
Northern sea lion	Smith (1904)	California (July-August)	13	Crab, octopus, squid, skate, shark, clupeids, perch, caranagoid fish, rockfish, hogfish.
Northern sea lion	Starks (1918)	California	8	Squid, sardine, salmon, rockfish.
Northern sea lion	Imler and Sarber (1947)	Alaska (May-August)	15	Octopus, skate, salmon, tomcod, whiting, starry flounder, arrow-toothed halibut, halibut.
Northern sea lion	Kenyon and Wilke (1952)	Alaska	3	Cephalopod beak, cod, pollock, flounder, halibut, starry flounder, sculpin, sandlance.
Northern sea lion	Thorsteinson and Lensink (1962)	Alaska (summer)	56	Crab, clam, mussel, snail, squid, octopus, flatfish, halibut, greenling, rockfish, cottids, sandlance, lumpfish.
Northern	Mathison *et al.* (1962)	Alaska (summer)	114	Coelentenates, segmented worms, sand dollar, common bivalves, shrimp, crabs, isopods, unclassified crustaceans, lamprey, salmon, smelt, greenling, rockfish, sculpin, sandlance.

Species of seal	Authority	Month of collection and location	*Number in sample	Identified food items (terminology of each author has been maintained)
California sea lion	Smith (1904)	California (July-August)	13	Squid, ratfish, rockfish.
California sea lion	Starks (1918)	California (July-August)	13	Squid, fish.
Harbour seal	Fisher (1950)	Atlantic coast of Canada		Squid, small fish (including sardines)
Harbour seal	Fisher and Mackenzie (1955)	Maritime Provinces (January-December)	201	Shrimp, squid, herring, shad, smelt, hake, cod, haddock, winter flounder, smooth flounder, unidentified flatfish, rosefish, Gaspereau.
Harbour seal	Templeman *et al.* (1957)	Newfoundland and Labrador	96	Shellfish, clam, mussel, crab, lobster, shrimp, herring, salmon, trout, capelin, smelt, cod, Greenland cod, pollock, flounder, sculpin, launce, cunner, eel, eel-pout.
Harbour seal	Scheffer (1928); Scheffer and Sperry (1931)	Washington coast (U.S.A.) (January-December)	95	Crabs, shrimps, crayfish, squid, octopus, lamprey, skate, ratfish, herring, salmon, hake, cod, tomcod, whiting, flounders, shiner, silver perch, lingcod, rockfish, sculpins, blenny, sand-lance, midshipman.
Harbour seal	Imler and Sarber (1947)	Alaska (May-August)	166	Shrimp, octopus, skate, herring, salmonids, eulachon, cods, flounder, rockfish, sculpin, blenny.

*Stomachs with food only