AN ABSTRACT OF THE THESIS OF

Elizabeth H. Sinclair for the degree of Master of Science in
Oceanography presented on December 16, 1988.
Title: Feeding Habits of Northern Fur Seals (Callorhinus
ursinus) in the Eastern Bering Sea

Abstract approved: Redacted for privacy
William G. Pearcy

This study was conducted to determine the composition and size of prey consumed by northern fur seals (*Callorhinus ursinus*) in the eastern Bering Sea. Eighty three northern fur seals were collected in the summer and fall of 1981, 1982, and 1985 for examination of gastrointestinal contents. A total of 139 midwater and bottom trawls were collected to determine the availability of potential prey. Analysis of trawls confirmed that seals are size-selective midwater feeders during their breeding and haul-out season in the eastern Bering Sea.

Juvenile walleye pollock and gonatid squid, 5-20cm in body length, were the primary prey, but seal prey varied among years and between nearshore and pelagic sample locations. Interannual variation in body sizes of walleye pollock consumed by seals was related to pollock year class strength.

The identification of pollock and gonatid squid as primary fur seal prey in the eastern Bering Sea was consistent with previous reports. However, Pacific herring and capelin, previously considered important fur seal prey were absent in this study.

Feeding Habits of Northern Fur Seals (*Callorhinus ursinus*) in the Eastern Bering Sea

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed December 16, 1988

Commencement June 1989

APPROVED:

Redacted for privacy

Professor of Oceanography in charge of major

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Redacted for privacy

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Date thesis was presented December 16, 1988

Typed by Elizabeth H. Sinclair

This thesis is dedicated to my Mother,
my first and finest teacher

ACKNOWLEDGEMENTS

I extend special thanks to my advisor, Bill Pearcy for his enthusiasm and support in my graduate studies, and for the model he has provided as an educator and a researcher. My committee members Mark Hixon, Tom Loughlin, Bruce Mate, and Phillip Whanger, provided their time, expertise, and constructive criticism. Tom Loughlin has been an active participant in every phase of this study, providing original data, and helping to secure funding and support facilities.

This project was initiated as a joint research effort between the National Marine Mammal Laboratory (NMML), and Resource Ecology and Fisheries Management (REFM), divisions of the National Oceanographic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) Seattle, Washington. Research staff from both divisions and the Resource Assessment and Conservation Engineering (RACE) division, as well as the officers and crew of the NOAA ship <u>Miller</u> <u>Freeman</u>, have been involved in various stages of this research. Robert DeLong and Mike Perez (NMML) developed the 1981 sampling design for seal collections, which served as the foundation for the following two years of collections. Pat Livingston (REFM) was an integral part of the planning and analysis of trawl collections. Special thanks to George Antonelis (NMML) for open discussions regarding the biology and behavior of pinnipeds, and for earlier reviews of this manuscript. Hiro Kajimura (NMML) determined the fur seal ages. Christopher

Bouchet (NMML), Alan Shimada (RACE), and Gary Walters (RACE) provided computer and programming assistance. Sherry Pearson (NMML) made library materials readily available, and the graphics department (NMFS), especially Karen Conlan clarified my illustrations and provided original artwork.

Otolith identifications for 1982 and 1985 were based on the otolith reference collections at the NMML, and Los Angeles County Museum, and confirmed by George Antonelis (NMML). Otolith identifications for the 1981 samples were made by the late John E. Fitch. Kathy Frost and Lloyd Lowry, Alaska Deptartment of Fish and Game, confirmed my otolith identification of gadoid fishes. Identification of fish skeletal remains was made by Jean Dunn (RACE).

Cephalopod identifications were based on the reference collection of the NMML and confirmed by Katharine Jefferts, and William Walker. Cephalopod beak and statolith identifications were confirmed by Clifford Fiscus. Voucher specimens of statoliths, beaks, otoliths, and skeletal material are archived at the NMML.

Finally, thanks to my husband John, for his thoughtful reviews and encouragement.

The National Marine Mammal Laboratory in conjunction with Oregon State University, provided full funding for this study.

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INTRODUCTION

Objectives

The Pribilof Island herd of northern fur seals (Callorhinus ursinus) in the southeastern Bering Sea declined at a rate of 5-8% per year between 1975-1981, resulting in a decrease from 1.2 million animals to the present estimate of 800,000 individuals (York and Kozloff 1987; Fowler 1985). Population levels estimated from pup production during 1981-1987 appear to have stabilized (York and Kozloff 1987). However, based on direct counts of adult and subadult males, population numbers are still decreasing (NMFS unpub. data; Fowler pers. comm.). Causes for the decline have not been determined, but may be related to disease factors; entanglement in pelagic gillnets and net debris (Fowler 1987); or a potential decrease in the size, availability, or quality of prey resulting from the increase in commercial trawl fishing since the mid-1970's (Chapman 1961; York and Hartley 1981; Gentry and Holt 1986).

The objectives of this study were to determine the feeding habits and size of prey eaten by northern fur seals in the eastern Bering Sea through analysis of gastrointestinal contents. Fur seal prey selectivity was examined by comparing the composition and body size of fishes and cephalopods consumed by seals with those caught in midwater and bottom trawls in the vicinity of fur seal collections or observations. Although previous studies have been conducted on the feeding habits of northern fur seals, no work has been done since the increase in commercial fishing or since the decline in the Pribilof Island herd. Neither prey body lengths nor selectivity of prey have been previously examined in detail.

Background

Callorhinus ursinus is a monotypic genus of the Otariidae, or eared seals (Fiscus 1978; Lander and Kajimura 1982). The population is distributed in subarctic and temperate waters from 30-32°N in the eastern and western Pacific north to 58°N, across the Bering sea and west into the Okhotsk Sea (Figure 1).

During the non-breeding season, November through May, northern fur seals are pelagic and loosely grouped or solitary (Fiscus 1978). Females and immature males of the Pribilof Island herd usually occupy waters along the continental slope and shelf of the eastern North Pacific Ocean, and may travel as far south as California (Kenyon and Wilke 1953; Wilke and Kenyon 1954; Fiscus 1978; Kajimura 1984). Large numbers of females and immature males are found off the coasts of Washington and Oregon during the non-breeding season (Fiscus 1978; Antonelis and Perez 1984). Although the migratory route and winter distribution of adult males is unknown, they have been seen along the ice edge and it is assumed that they winter in pelagic waters of

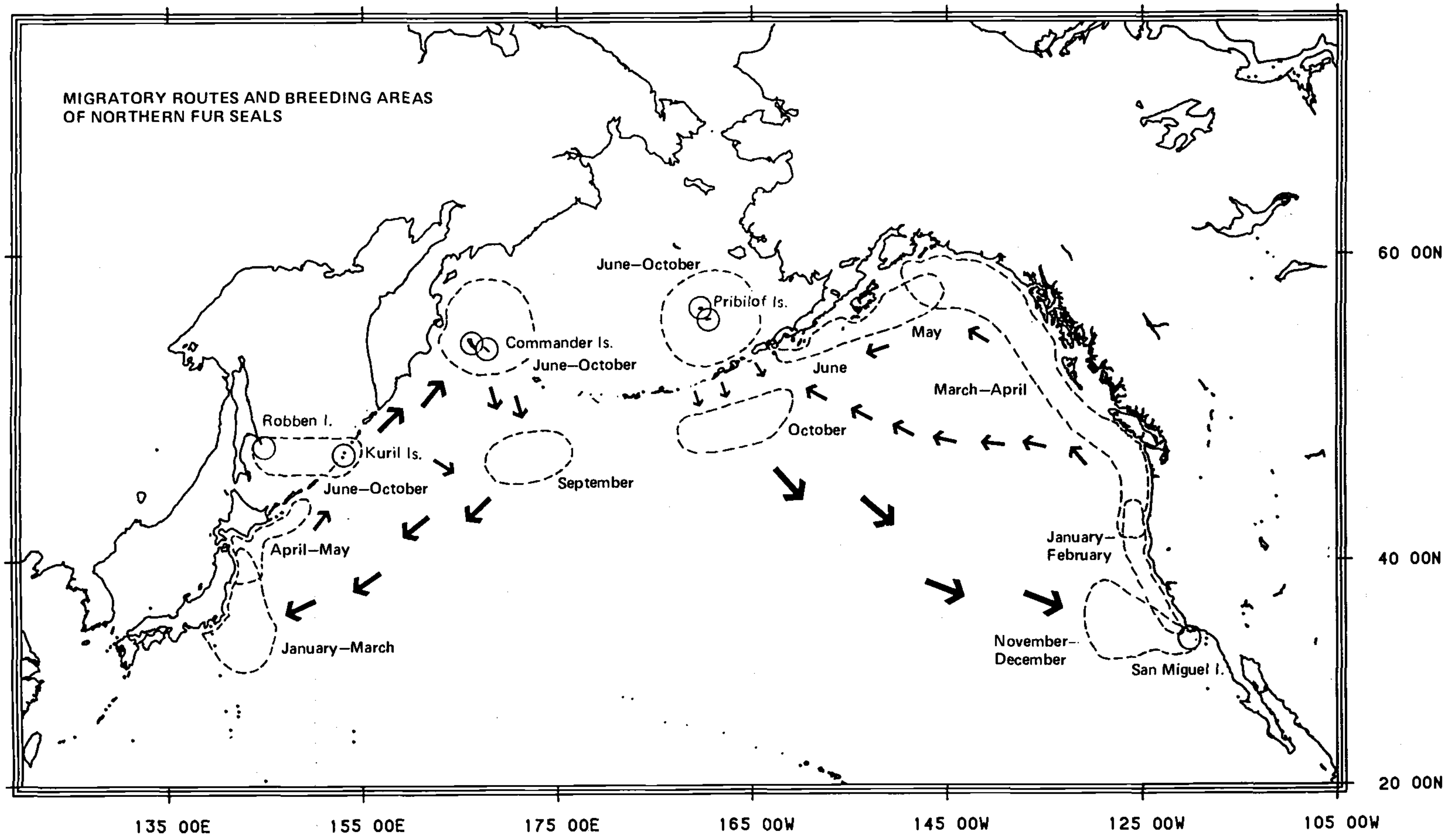

Figure 1 - Locations of the major rookery areas and migratory patterns of adult female and immature *Callorhinus ursinus* (*from*: Gentry and Holt 1986. Dotted circles represent general areas of movement). Adult males spend May-September on the rookery sites and probably winter in the Bering Sea.

the Gulf of Alaska and Bering Sea (Fiscus 1978).

During the breeding season most fur seals haul-out in large polygynous groups. Breeding and pupping take place on five major rookery areas located in the Bering Sea and North Pacific (Figure 1). Ninety percent of the breeding population breeds on the Commander and Pribilof Islands in the Bering Sea (Gentry and Holt 1986). The remainder of the breeding population haul-out on Robben Island in the Okhotsk Sea, the Kuril Islands in the western Pacific, and San Miguel Island off southern California, as well as a small colony on Bogoslof Island in the southern Bering Sea. Although northern fur seals generally return to the rookery of their birth during the breeding season, intermixing among Bering Sea breeding herds has been well documented by recoveries of tagged animals (Lander and Kajimura 1982). The highest exchange (12-21%) occurs between rookeries on the Commander Islands and Pribilof Islands (Lander and Kajimura 1982). Primary exchange occurs among individuals in pre-reproductive stages of growth (Fiscus 1978; Griben 1979).

Adult males (≥5 yrs) arrive at the Pribilof Island rookeries in May, at which time they attempt to establish and defend territory. At the height of the breeding season, successful males may maintain up to 50 females within their territory. The territorial bulls fast, or feed only intermittently during this time. Pregnant females arrive in mid-June through July. They give birth within 2 days and breed within one week. Post-partum females leave the rookery to feed within 7-9 days after their arrival. Adult females (≥4 yrs) do not feed on a daily basis but make periodic feeding trips to sea. The duration of foraging trips becomes longer as the season progresses, averaging 5.9 days with return visits to land of up to 2.5 days (Gentry et al. 1986; Loughlin et al. 1987). Feeding excursions continue until pups are weaned in October and November. One and two year old juveniles of both sexes are pelagic until August or September (Fiscus 1978) at which time they haul-out and moult (Fiscus 1978). Immature males (3-5 yrs) and females (3 yrs) haul-out in June or July for variable periods of time. Most of the population leave the rookeries by late November.

The Pribilof Island herd of northern fur seals was discovered in 1786 and nearly decimated under hunting pressure for their pelts by 1834. With only periodic protection, the herd declined to 200,000 animals by 1910 (Roppel and Davey 1965). An international agreement for fur seal management was established in 1911 between Canada, the United States, Russia, and Japan, and by 1957 the population of the Pribilof Island herd numbered 1.5 million. Pelagic sealing by the United States and Canada for research and management of the fur seal population took place between 1958-1974, and it is from these collections that most previous analyses of food habits were derived.

Fur seal population estimates for the Pribilof Islands and the Robben Island groups declined during 1975-1981 (Lander and Kajimura 1982; Fowler in press), while an increase in population occurred in the San Miguel and Kuril Island breeding groups (Lander and Kajimura 1982). Increases at San Miguel and the Kuril Islands have not been as large as the decline on the Pribilof Islands and Robben Islands, thus emigration of animals to other rookeries does not fully account for the Pribilof and Robben Island decline. The Commander Island population appears to be stable.

The Study Area

The Bering Sea is nearly equally divided between continental shelf (<200m) and abyssal plain (>3500m) (Kinder 1981). Kinder and Schumacher (1981) describe four hydrographic regions in the eastern Bering Sea that are characterized by depth, temperature, salinity, and degree of vertical stratification, tidal motion, and wind. These are termed the coastal shelf, middle shelf, outer shelf, and oceanic domains (Figure 2). Each domain is separated by a frontal boundary along the 50m, 100m, and 200m isobaths respectively. The vertical composition of the coastal domain is homogenous, but in the middle shelf region, a two layered vertical structure dominates in summer and autumn with winter mixing by storms. The outer shelf contains well

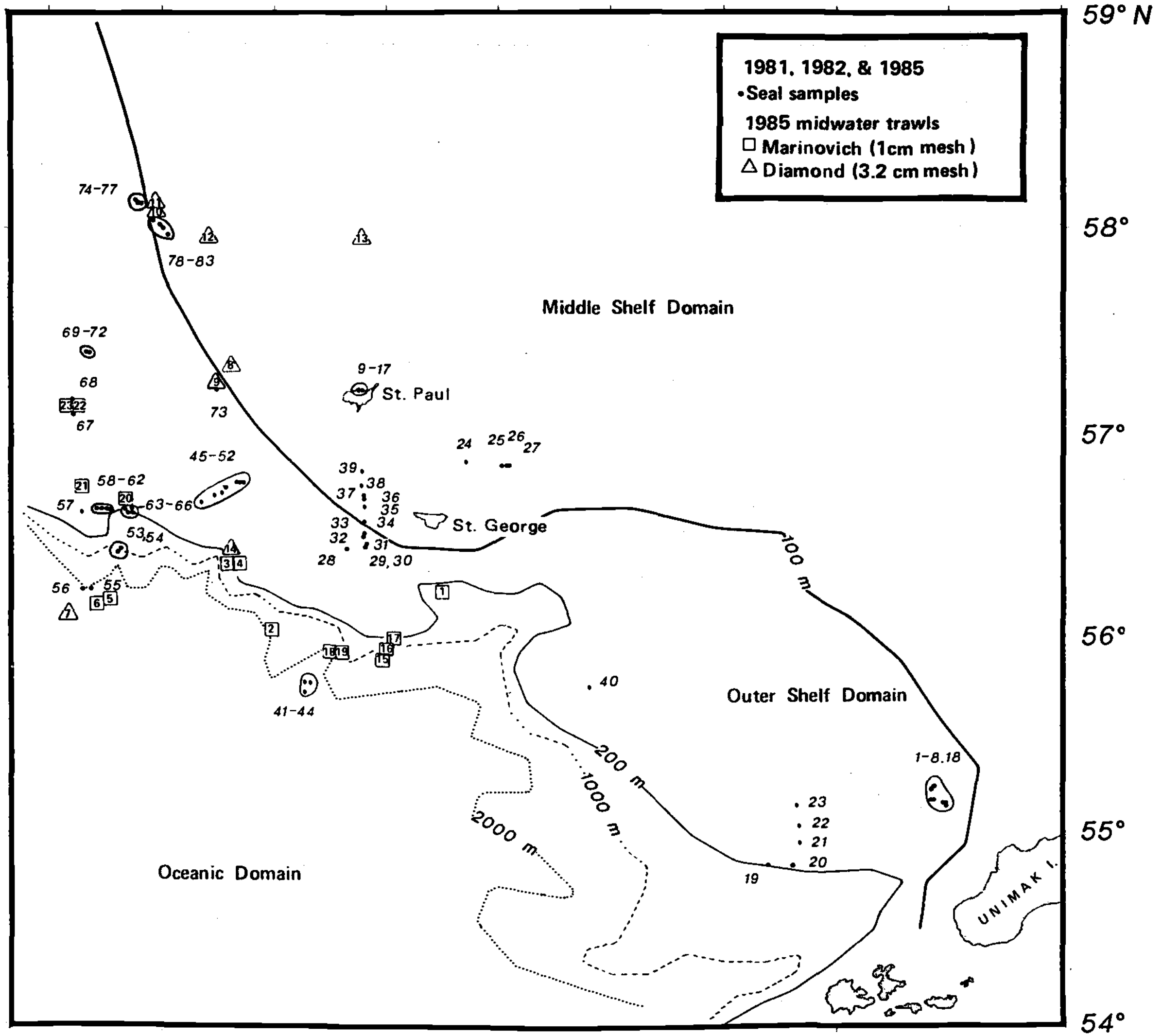

Figure 2 - The study area with midwater trawl and fur seal collection positions. The frontal boundaries between the two shelf domains and the oceanic domain coincide with the 100m, and 200m isobaths described by Kinder and Schumacher (1981). Numbers designate individual seals examined (1 to 17, 1981; 18 to 40, 1982; and 41 to 83, 1985); and midwater trawl collections (1 to 23 in 1985). (See Appendices I and II).

mixed, separated, upper and lower layers year-round. Oceanic water higher in temperature and salinity than shelf water lies over the shelf break and slope.

Currents of the southeastern Bering Sea shelf generally flow parallel to isobathic boundaries. Mean current speeds increase east to west along the shelf but are sluggish overall. The shelf domains, particularly midshelf and coastal, are most strongly influenced by buoyancy input and tidal mixing, and advection is most intense in the outer shelf domain. The Pribilof Islands are within the midshelf region near the 100m isobath. Seals were collected within 185km to the east, west, south, and northwest of the Pribilof Islands over the continental shelf, continental slope, and oceanic domain of the Bering Sea (Figure 2).

Previous Studies

Previous analyses of stomach contents of northern fur seals in the eastern Bering Sea and North Pacific Ocean were based almost entirely on specimens collected by the United States and Canada during the sixteen years (1958-1974) of pelagic sealing. Over 18,000 animals were collected and approximately 1,800 of those were collected from the eastern Bering Sea in 1960, 1962-1964, 1968, 1973, and 1974. Annual results of food habits analyses were summarized in North Pacific Fur Seal Commission Reports (1962-1980) and have since been reviewed by Kajimura (1985), Perez and Bigg (1986), and Perez and Mooney (1986).

Scheffer (1950a) reviewed all fur seal stomach content information collected between 1892-1950 in the Bering Sea. With the exception of some pelagic collections made in 1892, most pre-1950 collections were made on the Pribilof Islands. The remains of walleye pollock (Theragra chalcogramma), gonatid squid, and bathylagid smelt (Leuroglossus schmidti) were the most frequently occurring prey. Wilke and Kenyon (1952) described remains of walleye pollock from fur seal spewings of whole fish and from otoliths collected on the Pribilof Islands. In 204 stomachs collected pelagically from Unimak Pass to St. Paul Island, capelin (Mallotus villosus) was the dominant prey by volume, pollock was the next highest in volume, but squid (Gonatidae) had the highest frequency of occurrence (Wilke and Kenyon 1957).

In recent reviews of the pelagic data (1958-1974), pollock was the predominant prey of fur seals in the eastern Bering Sea (Kajimura 1985; Perez and Bigg 1986). Kajimura (1984) included Pacific herring (Clupea pallasi), capelin, atka mackerel (Pleurogrammus monopterygius), and gonatid squids (Gonatus spp., Berryteuthis magister and Gonatopsis borealis) as principal prey in the eastern Bering Sea. The relative importance of any one prey type varied by sample area and year of collection. For instance, Kajimura (1984) cited atka mackerel and capelin as primary prey in the Bering Sea, but the two species were found in high volume only during 1960-1964 in seal samples collected near the

Aleutian Islands. Fiscus et al. (1964) reported 56.8% capelin by volume in 1962 collections from Unimak Pass, while in other years, herring and squid were more important in this area (Lucas 1899; May 1937).

Feeding habits of fur seals differ between neritic and oceanic regions in the Bering Sea. Wilke and Kenyon (1957) reported capelin predominant as prey in Unimak Pass and near the Aleutian Islands while squid and pollock were more important offshore. In their overview of the pelagic collections (1958-1974) Perez and Bigg (1986) also concluded that capelin was a major food item in the southern portion of the eastern Bering Sea near Unimak Pass, with squids the primary oceanic prey, however, they considered walleye pollock the most prevalent seal prey around the Pribilof Islands and inshore waters in the Bering Sea. Pollock was well represented as prey in offshore regions of the eastern Bering Sea, however *Gonatopsis borealis* was equally important and *Berryteuthis magister* was identified as the predominant offshore prey. Kajimura (1985) also reported pollock most prevalent in seals collected over the continental shelf and shelf edge while squid was important off the shelf. Bathylagids were first described as prey by Lucas (1899) in northern fur seals collected over deep water in the eastern Bering Sea, and have since been reported in association with gonatid squid (Perez and Bigg 1986). Kajimura (1984) concluded that bathylagids were important prey in some but not all years in the eastern Bering Sea.

The most abundant prey by volume, frequency, and biomass in stomach contents of seals collected from California to southeast Alaska in the eastern North Pacific were northern anchovy (Engraulis mordax) and Pacific herring (Clemens and Wilby 1933; Clemens et al. 1936; Schultz and Rafn 1936; May 1937; Taylor et al. 1952; Wilke and Kenyon 1952; Spalding 1964; Antonelis and Perez 1984; Kajimura 1985; Perez and Bigg 1986). Rockfish (Sebastes spp.) and salmon (Oncorhynchus spp.) were also important in collections off Washington State (Kajimura 1984; Perez and Bigg 1986), and atka mackerel was consistently present in stomach contents from seals collected in and north of the Gulf of Alaska.

Despite variation in seal diet between the southern and northern extremes of the migratory range, prey identified from seals collected in any one oceanographic subregion is consistent between early studies. With the exception of Loligo opalescens which was an important prey inshore, squids were the main food offshore throughout the western North American range of fur seals (Stroud et al. 1981; Kajimura 1985; Perez and Bigg 1986). Although fishes are commonly referred to as inshore prey, close examination shows their importance as prey offshore as well. Pacific hake (Merluccius productus), and market squid (Loligo opalescens) were of secondary importance relative to northern anchovy in coastal waters of the California Current region, and onychoteuthid squids and saury (Cololabis saira) were important offshore (Antonelis and Perez 1984; Kajimura 1984; Perez and Bigg 1986). Herring, salmon, and onychoteuthid squids were primary prey in offshore waters of British Columbia, and Loligo opalescens was important in coastal inlets (Kajimura 1984; Perez and Bigg 1986). Herring, Pacific sand lance (Ammodytes hexapterus), capelin (Mallotus villosus), and walleye pollock were primary prey in the Gulf of Alaska, with rockfishes, salmonids, and gonatid squids (Gonatus spp. and Berryteuthis magister) being important offshore (Kajimura 1984; Perez and Bigg 1986).

Body size measurements of fur seal prey have rarely been reported in the literature, even though common reference is made to seal consumption of "small" schooling fishes and squids. Historical accounts describe both the "large" and "small" size of prey in seal spewings and stomachs (Lucas 1899; Wilke and Kenyon 1952). In the only reference to prey body lengths from the 16 years of pelagic collections, McAlister and Perez (1976) report a pollock length range of 5-40cm in 1973, and 10-35cm in 1974 ($\bar{x}$=19.3cm for 1974) eastern Bering Sea collections. Previous descriptions of the body lengths and analyses of biomass of fur seal prey (Antonelis and Perez 1984; Perez and Mooney 1986) were restricted by methods of collection and preservation of stomach samples prior to the late 1970's. Total body lengths were obtained only from whole prey recovered from gut contents with no description of specimen condition. Due to rapid digestion, intact prey are uncommon in marine mammal stomachs. Hard parts such as fish otoliths and squid beaks are less readily digested than flesh and can be a primary means of identifying prey species in the absence of whole remains (Fitch and Brownell 1968; Clarke 1986). However, stomach samples from the pelagic collections (1958-1974) were preserved in unbuffered 10% formalin, which causes dissolution of otoliths. Thus, earlier summaries may have underestimated the numbers and diversity of fishes consumed, especially for small species or fishes that are easily digested.

Earlier summaries based on the pelagic collection may have also been biased by the patchiness of collections. Kajimura (1984) cautions that pelagic collections between 1958-1963 were often made over short time periods from known areas of high seal abundance in order to rapidly fill the large quota requirements of each nation. Because northern fur seal prey varies by oceanographic area, intensive collections in any one region potentially biased results.

Beyond the biases specific to the pelagic data set, interpretation of marine mammal food habits based on stomach and intestinal contents are potentially biased by a number of other factors that influence estimates of prey volume, weight, number, rank and frequency of occurrence (Perrin et al. 1973; Jobling and Breiby 1986; Harvey 1987). As a result, prey composition or prey sizes may be present in proportions dissimilar to initial consumption. The potential biases are:

1. Differential Digestion - Differential wear between prey hard parts may bias length frequencies based on the direct relationship between otolith length and fish body length. Digestion of fleshy remains is generally rapid relative to prey hard parts which may be retained in gut reticulae of marine mammal stomachs. Captive studies on Callorhinus ursinus have demonstrated complete digestion of all whole fleshy remains within 12 hours (Miller 1978; Bigg 1981; Bigg and Fawcett 1985). Digestion of the flesh of soft-bodied animals such as squid was generally complete within 4 hours (Bigg and Fawcett 1985).

2. Retention - Prey hard parts, such as fish otoliths and cephalopod beaks may preferentially accumulate in gastrointestinal tracts and otoliths of large prey may be retained longer than those of small prey. Examples of retention have been cited by Kritzler (1952), Condit and Le Boeuf (1984), Bigg and Fawcett (1985), and Hacker (1986), demonstrating that prey remains may represent meals from days or weeks prior to the time of sample collection.

3. Secondary Introduction - The prey of the study animal ingests smaller animals, and the remains of the "prey of the

prey" are released in gastrointestinal (GI) tracts. Secondary introduction is a recognized source of potential bias in marine mammal food habit studies (Fitch and Brownell 1968; Walker 1981; Mead et al. 1982) but has only been speculated upon in studies of free ranging animals.

4. Selective Consumption - Seals may eat only portions of the prey, sometimes disposing of hard parts useful in prey identification. Pinnipeds probably eat small prey underwater, but they have been observed eating large fish above water, sometimes discarding the skull and consequently the otoliths (Spalding 1964; Pitcher 1980; Kajimura 1984).

5. Regurgitation - This may result in the loss of prey hard parts that have accumulated in gut reticulae. Miller (1978) describes regurgitation of squid beaks in captive animals. Spewing of fish and squid is also common in rookery environments (Scheffer 1950; Wilke and Kenyon 1952).

6. Sample Location - In the case of northern fur seals, sampling bias may occur depending on the time away and distance offshore from the rookery. The gastrointestinal tracts of individuals feeding in the surf zone or near the breeding rookeries would have a much different prey composition than animals collected offshore.

MATERIALS AND METHODS

Seal Collection and Prey Analysis

A total of 83 northern fur seals were collected at sea in 1981, 1982, and 1985. Position, collection time, water depth, sex, and age of each animal are summarized by year (Appendix I). Due to the proximity of collections to the Pribilof Islands, it was assumed that seals collected were members of the Pribilof Island herd.

Seventeen seals were collected during October 17-28 in 1981, 23 from September 24 through October 6 in 1982, and 43 from August 6-16 in 1985, mostly over depths less than 200m within the outer shelf domain. Collection areas were chosen to match the eastern Bering Sea pelagic sealing locations (1960, 1962-1964, 1968, 1973, 1974) as closely as possible. Sampling positions varied in distance from the Pribilof Islands between years (Figure 2). In 1981, samples were collected over the continental shelf directly off St. Paul, and 56km northwest of Unimak Island over the outer continental shelf. In 1982, collections were primarily over the outer continental shelf within 111km northwest of Unimak Island and within 56km northeast and west of the Pribilofs on the mid and outer continental shelf. Collections in 1985 were all on the continental midshelf, continental slope, and over the oceanic domain within 185km west, northwest, and southwest of St. Paul Island.

Seals were returned to the ship for examination within

1.5 hours of collection. Their esophagous was checked for food as an indication of regurgitation, and gastrointestinal tracts were removed and frozen to prevent continued digestion. Stomachs were thawed and drained of excess liquid in the lab ashore. Intestines were thawed and split lengthwise. In 1981 and 1982, weight and displacement volume of total contents were measured from the entire gastrointestinal tract. In 1985, weight and displacement volume of intestinal and stomach contents were measured and analyzed separately, then combined for direct comparison with 1981 and 1982 samples. The GI tract was labeled as "empty" when no remains of prey were found, and as "trace" when contents were <10ml. Contents were rinsed gently through a series of graded sieves (0.71, 1.00 or 1.40, and 4.75mm in 1981 and 1982; 0.50, 1.00, 1.40, and 4.75mm in 1985), and sorted by major prey group. Fish hard parts were stored dry. Cephalopod hard parts were preserved in 70% isopropyl alcohol.

Prey were identified from whole body remains, skeletal material, otoliths of fishes, and rostra (beaks) and statoliths of cephalopods. Techniques and references for identification of prey remains based on otoliths include Fitch and Brownell (1968), Morrow (1979), Frost and Lowry (1981), and otolith reference collections. References for beak and statolith identification included Clarke (1962), Young (1972), Roper and Young (1975), Clarke et. al.

(1980), Clarke (1986), and beak and statolith reference collections.

Fur seal ages were derived from direct readings of canine tooth thick sections following Scheffer (1950b). Males, females, and lactating females of all ages were treated as one group in this analysis due to the small sample size.

Small pieces of fish bone were categorized as single unidentified fish. The highest number of either upper or lower cephalopod beaks and left or right otoliths was recorded as the maximum number of each species present. If over half of an otolith or beak was present it was included in the prey count. If deterioration prevented determination of left from right otoliths, the total otolith count was divided by two. The number of each prey taxon was recorded for each gastrointestinal tract. The percent by number (%N) and percent frequency of occurrence[1] of each prey taxon were determined for all gastrointestinal samples within each sampling location and year and for the three years combined. Although stomach volumes and weights were recorded (Appendix I), only prey number and frequency of occurrence are examined and discussed. The numbers and body lengths of prey were emphasized in this study, as opposed to estimates of biomass, because few whole prey were found and analysis

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[1] the percent frequency of occurrence represents the percentage of animals in the sample population containing a particular prey taxon.

was largely dependent on remains of prey hard parts.

Body lengths were determined for gonatid squids and walleye pollock, the primary prey represented in the three sample years. Dorsal mantle lengths (DML) of squids and fork lengths (FL) of pollock were measured directly on whole prey present in the stomachs, and estimated by measurement of prey hard parts. The lower rostral length (LRL) of gonatid squid beaks and the total length of walleye pollock otoliths were measured to the nearest .05mm with vernier calipers. The body lengths of gonatid squid from the gastrointestinal contents were estimated by comparison of the 389 LRL measurements, to the ratios of LRL/DML of 51 gonatids caught in trawls (Figure 3). Pollock body lengths were estimated by a regression of pollock otolith length on the fork length of intact specimens given by Frost and Lowry (1981). For otoliths measuring:

>10.0mm, then (FL) $Y = 3.175X - 9.770$ ($R = 0.968$)
≤ 10.0mm, then (FL) $Y = 2.246X - 0.510$ ($R = 0.981$)

A total of 2390 positively identified and 268 tentatively identified pollock otoliths were measured. Ages were estimated from these lengths based on length-age keys developed by Smith (1981) and Walline (1983) for pollock from the Bering Sea. Pollock greater than or equal to 20cm or 2 years, the length and age at which approximately 1% of the population are sexually mature (Smith 1981; Walline 1983), are classified as "adults" in this study. Pollock less than 20cm FL are called "juveniles".

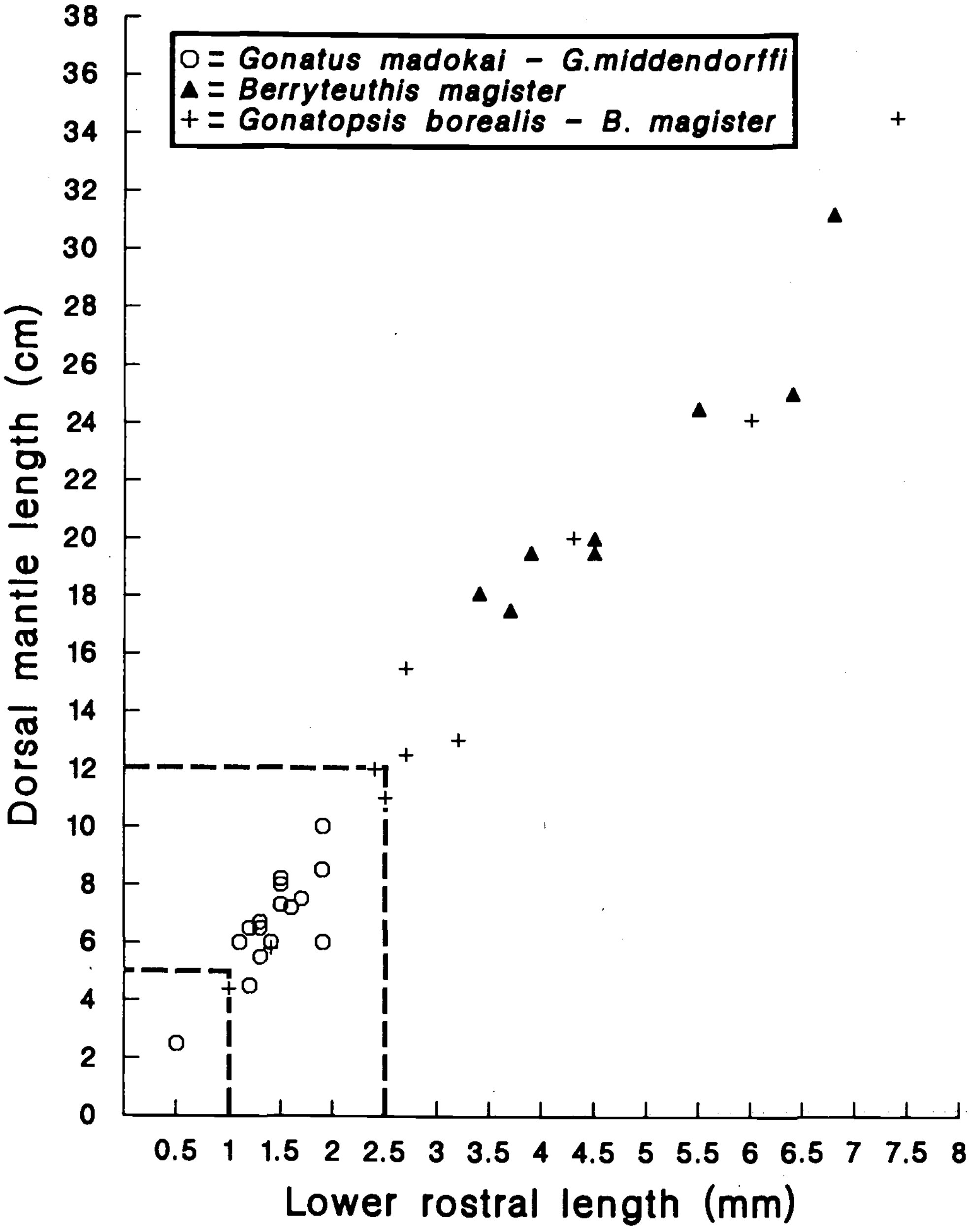

Figure 3 - Lower rostral length (LRL)/dorsal mantle length (DML) relationship of gonatid squid caught in 1985 trawls. This relationship was used to estimate DML of squid from rostra found in fur seal gastrointestinal contents. The area within the dashed lines represents 79% of the estimated values obtained.

Because otoliths dissolve or erode to varying degrees depending on their size and duration in fur seal stomachs, an attempt was made to evaluate the bias introduced by eroded otoliths in estimating fork length. Pollock otoliths were divided into four categories (excellent, good, fair, and poor) based on amount of wear. "Poor" otoliths, broken or worn beyond the point where key features were readily identifiable, were counted but not measured. "Fair" otoliths appeared either completely smooth or sometimes chalky but were still identifiable to species. "Good" otoliths, though worn, retained detail at the edges and sulcus. Those in "excellent" condition looked as if they were recently removed from a fish. After quality categorization, the maximum lengths of otoliths (except "poor") were measured for estimation of body length by regression, and length frequencies of each category were determined. It was assumed that an equal number of "poor" otoliths were present in all size categories.

In harbor seal feeding experiments, Harvey (1987) demonstrated that otoliths occurred in equal frequency throughout the gastrointestinal tract and that otolith erosion occurred in the stomach. Once otoliths passed through the stomach they were no longer eroded by digestive enzymes. Based on results from Harvey (1987) and on the application of quality categories established in this study, it was assumed that combining the results of intestinal and stomach analysis caused no further bias due to erosion of otoliths.

The keratinaceous cephalopod beaks are more resistant to digestion than otoliths and were typically in good condition. Chipped or broken beaks were rare and were not measured. The majority of cephalopod prey identified from beaks were of two major groups of the family Gonatidae. The individual species of each group are morphologically distinct but cannot be separated based on beak structure alone. They are referred to here as the Gonatopsis borealis-Berryteuthis magister group and Gonatus madokai-Gonatus middendorffi group. Berryteuthis magister was positively identified in some gastrointestinal samples by the rare presence of statoliths. Lower rostral lengths were taken on all beaks judged to be in good condition. Lower rostra are most commonly measured because they are more readily identified and less subject to wear than the upper rostra (Clarke 1986). A total of 302 Gonatopsis borealis-Berryteuthis magister and 87 Gonatus madokai-Gonatus middendorffi beaks were measured to obtain estimates of dorsal mantle lengths of prey for all three years of samples.

Trawl Collections of Seal Prey

Midwater and bottom trawl collections were conducted in the study area near seal collection locations (Figure 2; Appendix II). Trawling effort followed standard procedure

(Smith and Bakkala 1982). Trawl collections were made from the NOAA ship Miller Freeman, a 65m stern trawler, between 1900 and 0600 hours. In 1981 and 1982, bottom trawl locations were predetermined and conducted over the continental shelf throughout the study area (Appendix II). No midwater trawls were conducted in 1981 or 1982. In 1985, trawl locations were not predetermined, but were made in areas of fur seal collection or observation of that same day. The 1985 midwater and bottom trawl collections were made within 185km of the Pribilof Islands.

A total of 116 bottom trawls were made in 1981, 1982, and 1985 with an 83/112 Eastern bottom trawl (3.2cm codend liner mesh, 360 mesh circumference and 200 mesh depth with 30m bridles) (Appendix II). Thirty-nine bottom trawls were conducted from 14 October - 4 November in 1981; 51 were made from 24 September - 8 October in 1982; and 26 were made from 5 August - 22 August in 1985. Trawls were made at a speed of 6 km/hr over a 30 min time period at 52-498m depths.

The total bottom trawl catch was randomly split into a sample of about 2500 kilograms. Individual species of fishes were identified and weighed (wet). In 1981 and 1982 cephalopods were classified as squid or octopus and discarded. In 1985, cephalopods were identified, weighed, and frozen whole for later examination ashore. The lower rostral length and sex of gonatid squid were determined in the laboratory.

Sex and body length measurements of a subsample of up to 200 pollock from each trawl were made. Fork lengths were measured to the nearest centimeter. Saccular otoliths were collected from these individuals, stored in isopropanol and aged in the laboratory (see Smith and Bakkala 1982, for details of trawl collections and otolith ageing technique). Pollock age and length frequencies from bottom trawls were determined for all three years. For purposes of this study age/length frequencies for male and female pollock were combined, although age and length at maturity differ between males and females (Smith 1981).

Bottom trawl catch per unit effort (CPUE) was estimated for each species. Pollock CPUE by age and body length was calculated based on km trawled. Catch per unit effort estimates followed the procedure outlined in Smith and Bakkala (1982). Values for CPUE were determined by dividing the Kg weight (W) of each species (k) at each station (j) and within each subarea (i) sampled by the trawled distance (D) as measured in kilometers for each target species (k):

$$\mathrm{CPUE}_{ijk} = \frac{W_{ijk}}{D_{ij} \cdot k} \qquad \text{Mean } \mathrm{CPUE}_{ik} = \frac{\sum_{j=1}^{n_i} \mathrm{CPUE}_{ijk}}{ni}$$

Where n is the number of stations trawled in which data were collected. Kilometers surveyed were then translated to distance trawled within the subarea in units of hectare (ha). Values of CPUE in terms of the number of fish captured per hectare (no/ha) were calculated in a similar manner.

Midwater trawls were conducted only in 1985. Twenty-three midwater trawls were made in 1985 with a Diamond midwater net (3.2cm codend liner mesh, 354 mesh circumference and 160 mesh depth with 2m bridles) and a Marinovich herring trawl (1cm codend liner mesh, 150 mesh circumference and 350 mesh depth with 10m bridles) (Appendix II). Specific trawling positions were chosen within the vicinity of fur seal collection areas based on presence or absence of "sign" on 38kHz echosounders and a chromoscope used between trawl stations. Midwater towing depths ranged from 22-300m.

All species of fish and cephalopods collected in midwater trawls were identified and counted. The frequency of occurrence of each species, lower rostral length and sex of gonatid squid, and pollock frequency of occurrence by age and length were calculated.

In order to quantify the degree of overlap in the composition of midwater trawls and fur seal gastrointestinal contents, percent similarity values were calculated for the 23 midwater trawls, and gastrointestinal contents of the 43 seals collected in 1985. Percentage similarity (PS) was calculated as presented in Langton (1982):

$$PS = 100 - 0.5\Sigma\, a-b$$

where: a = %number of a given prey for seals
b = %number of the same prey for trawls

RESULTS

Seal Samples

Fishes were the most common prey group of northern fur seals. They occurred in all 73 seals that had prey in their gastrointestinal tracts (ten stomachs from the 1981 samples were empty) and comprised 100% of the number of prey in 1981, 88% in 1982, and 88% in 1985 (Tables 1-4). Walleye pollock was the most numerous and frequently occurring prey species, representing 72.3% of total prey, 81.6% of fishes, and found in 64.4% of all seals. Cephalopods occurred in 43.8% of all seals and comprised 11.4% of total number of prey. Cephalopods represented 11.8% of prey in 1982 and 11.6% in 1985, but no cephalopod remains were found in the 1981 prey sample. *Gonatus madokai*-*G. middendorffi* was the second most frequently occurring prey of the total sample (21.9%) followed by *Gonatopsis borealis*-*Berryteuthis magister* (17.8%). However, *Gonatopsis borealis*-*B. magister* composed a higher percentage of the cephalopod sample (68.6%) than *G. madokai*-*G. middendorffi* (23.5%).

Walleye pollock composed 54.4% of fishes in 1981, 89% in 1982, and 77.4% in 1985 (Tables 2-4). Pollock occurred in 100% of the stomachs containing food in 1981, 91.3% in 1982, and 67.4% in 1985 (Figure 4). These are minimum estimates based only on prey remains positively identified as pollock. Fish tentatively identified as small pollock (3-5cm length range) were also important overall but were

Table 1 - Gastrointestinal contents of 73 northern fur seals collected 1981, 1982, 1985

Prey item	Prey number	% of total prey	% of fishes	% of cephalopods	% frequency of occurrence
Total Prey	3919	100	----	----	----
Fish total	3473	88.6	100	----	100
Clupeidae					
Clupea pallasi	2	0.1	0.1	----	1.4
Salmoniformes					
Osmeridae (t)	8	0.2	0.2	----	4.1
Salmonidae	5	0.1	0.1	----	4.1
Bathylagidae					
Leuroglossus schmidti	279	7.1	8.0	----	5.5
Gadidae					
Gadus macrocephalus (t)	3	0.1	0.1	----	4.1

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Table 1 - (continued)

Prey item	Prey number	% of total prey	% of fishes	% of cephalopods	% frequency of occurrence
Theragra chalcogramma	2835	72.3	81.6	----	64.4
5-10cm fork length	(1079)				
10-20cm fork length	(1216)				
>20cm fork length	(95)				
T. chalcogramma (t)	286	7.3	8.2	----	41.1
3-5cm fork length	(268)				
unidentified Gadidae	18	0.5	0.5	----	12.3
Zoarcidae					
Lycodes sp.	1	0.03	0.03	----	1.4
Hexagrammidae					
Pleurogrammus monopterygius	23	0.6	0.7	----	8.2
P. monopterygius (t)	1	0.03	0.03	----	1.4
unidentified percoid	1	0.03	0.03	----	1.4
unidentified fish	11	0.3	0.3	----	5.5

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Table 1 - (continued)

Prey item	Prey number	% of total prey	% of fishes	% of cephalopods	% frequency of occurrence
Cephalopod total	446	11.4	----	100	43.8
Gonatidae					
Gonatus berryi	1	0.03	----	0.2	1.4
G. tinro	1	0.03	----	0.2	1.4
G. tinro (t)	3	0.1	----	0.7	1.4
Gonatus madokai cf. *middendorffi*	105	2.7	----	23.5	21.9
Berryteuthis magister	9	0.2	----	2.0	2.7
Gonatopsis borealis cf. *Berryteuthis magister*	306	7.8	----	68.6	17.8
unidentified Gonatidae	3	0.1	----	0.7	4.1
unidentified squid	16	0.4	----	3.6	11.0

(t) tentative identification

Table 2 - Gastrointestinal contents of 7 northern fur seals collected 17-28 October 1981.

Prey item	Prey number	% of total prey	% frequency of occurrence	Seal sample number
Total prey	92	100	100	1-7
Fish total	92	100	100	1-7
Salmoniformes				
Osmeridae (t)	8	8.7	42.9	1,2,6
Salmonidae	5	5.4	42.9	2,3,5
Gadidae				
Therargra chalcogramma	50	54.4	100	1-7
5-10cm fork length	(4)			
>20cm fork length	(35)			
Zoarcidae				
Lycodes sp.	1	1.1	14.3	1
Hexagrammidae				
Pleurogrammus monopterygius	22	23.9	71.4	1,3-5,7
unidentified percoid	1	1.1	14.3	3
unidentified fish	5	5.4	14.3	2

t = tentative identification

Table 3 - Gastrointestinal contents of 23 northern fur seals collected 24 September through 6 October 1982.

Prey item	Prey number	% of total prey	% Frequency of occurrence	Seal sample number
Total prey	1638	100	100	18-40
Fish total	1445	88.2	100	18-40
Clupeidae				
Clupea pallasi	2	.1	4.4	37
Gadidae				
Theragra chalcogramma	1286	78.5	91.3	19-23,25-40
5-10cm fork length	(1047)			
>20cm fork length	(23)			
T. chalcogramma (t) 3-5cm fork length	147	9.0	17.4	24,25,31 33
T. chalcogramma (t) (>5cm fork length)	2	0.1	8.7	18,28
Hexagrammidae				
Pleurogrammus monopterygius	1	.1	4.4	39
P. monopterygius (t)	1	.1	4.4	28
unidentified fish	6	.4	13.0	28,39,40

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Table 3 - (continued)

Prey item	Prey number	% of total prey	% Frequency of occurrence	Seal sample number
Cephalopod total	193	11.8	52.2	19,22,24,29-33,35, 38-40
Gonatidae				
Gonatus madokai cf. *middendorffi*	1	.1	4.4	31
Berryteuthis magister	9	.6	8.7	39,40
Gonatopsis borealis cf. *Berryteuthis magister*	167	10.2	17.4	19,24,30,39
unidentified squid	16	1.0	34.8	22,29-33,35,38

(t) = tentative identification

Table 4 - Gastrointestinal contents of 43 northern fur seals collected 6-16 August 1985.

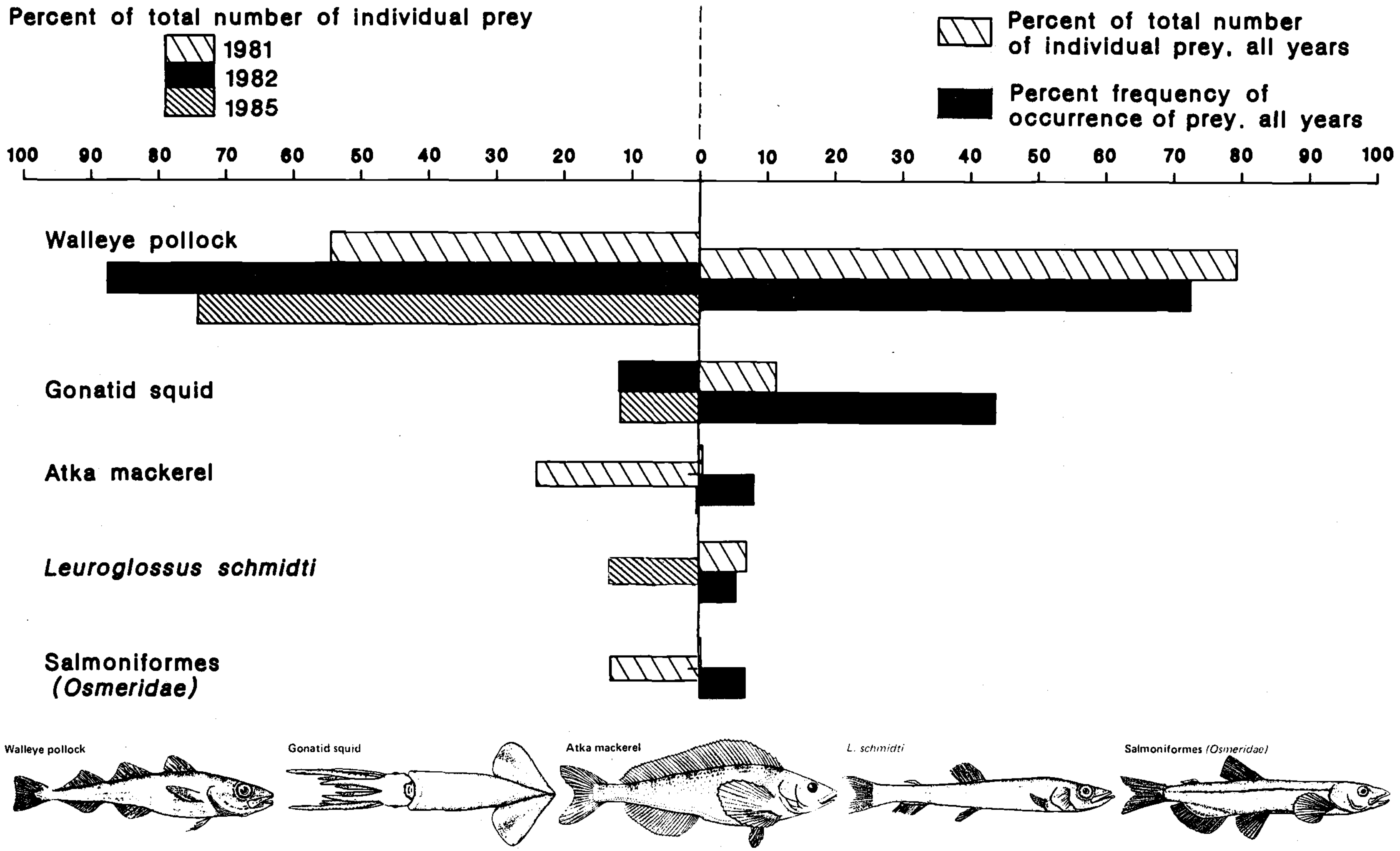
Prey item	Prey number	% of total prey	% Frequency of occurrence	Seal sample number
Total prey	2189	100	100	41-83
Fish total	1936	88.4	100	41-83
Bathylagidae				
Leuroglossus schmidti	279	12.8	9.3	43,53-55
Gadidae				
Gadus macrocephalus (t)	3	.1	7.0	52,68,71
Theragra chalcogramma	1499	68.5	67.4	41,44-46,48-52,57, 61,62,65,67-81,83
5-10cm fork length	(51)			
10-20cm fork length	(1216)			
>20cm fork length	(37)			
T. chalcogramma (t) 3-5cm fork length	124	5.7	23.3	50,55,61-63,67,68 75,78,83
T. chalcogramma (t) >5cm.fork length	2	.1	4.7	80,82
unidentified Gadidae	18	.9	20.9	45,46,50,53,68,72, 73,75,80
unidentified fish	11	.5	25.6	42,47,56,58-60,64, 66,70,76,81

(continued next page)

Table 4 - (continued)

Prey item	Prey number	% of total prey	% Frequency of occurrence	Seal sample number
Cephalopod total	253	11.6	46.5	41,42,44,53-57,60,62-64,67,68,70-73,77,78
Gonatidae				
Gonatus berryi	1	.1	2.3	54
G. pyros	1	.1	2.3	42
G. tinro	1	.1	2.3	54
G. tinro (t)	3	.1	2.3	53
G. madokai cf. middendorffi	104	4.8	34.9	41,53,55,57,60,62,64,67,68,70-73,77,78
Gonatus sp.	1	.1	2.3	54
Gonatopsis borealis cf. *Berryteuthis magister*	139	6.4	20.9	41,42,44,53-57,63
unidentified Gonatidae	3	.1	7.0	41,42,56

(t)=tentative identification



<u>Figure 4</u> - Percent frequency of occurrence and percent total number of primary prey in fur seal gastrointestinal tracts for sample years 1981, 1982, and 1985 combined, and percent total number of prey for each year separately.

not included in the total estimate of pollock.

Six species of fishes were identified (Table 1). The bathylagid Leuroglossus schmidti (northern smoothtongue) was the second most numerous fish, comprising 12.8% of total prey in 1985 (Figure 4; Table 4). Although it was not found in any other sample year, Leuroglossus schmidti was a higher percentage of total fish than adult pollock for all three years (Table 1). In 1981, nine percent of the total prey were unidentified Salmoniformes, possibly Osmeridae (Table 2). They were not found in any other year. Atka mackerel, Pleurogrammus monopterygius, composed 23.9% of the prey sample in 1981 and was present in five of seven stomachs that had prey remains in 1981, but was identified from the remains of only one other individual in 1982 (Figure 4; Tables 2 and 3).

Overall, juvenile pollock were the most highly represented prey in seal gastrointestinal contents. Adult pollock were uncommon (Table 1). Regression equations (Frost and Lowry 1981) applied to 2390 pollock otoliths measured from all years indicated that 60.8% were from the "0" age group (5-13cm in length), 34.6% were from age group "1" (13-19cm), and 4.6% were from age group 2^+, adults greater than 20cm in length (Figure 5). The 3-5cm gadids identified tentatively as "0" age pollock were present only in 1982 and 1985 samples (Figure 6).

Although walleye pollock were present in all three

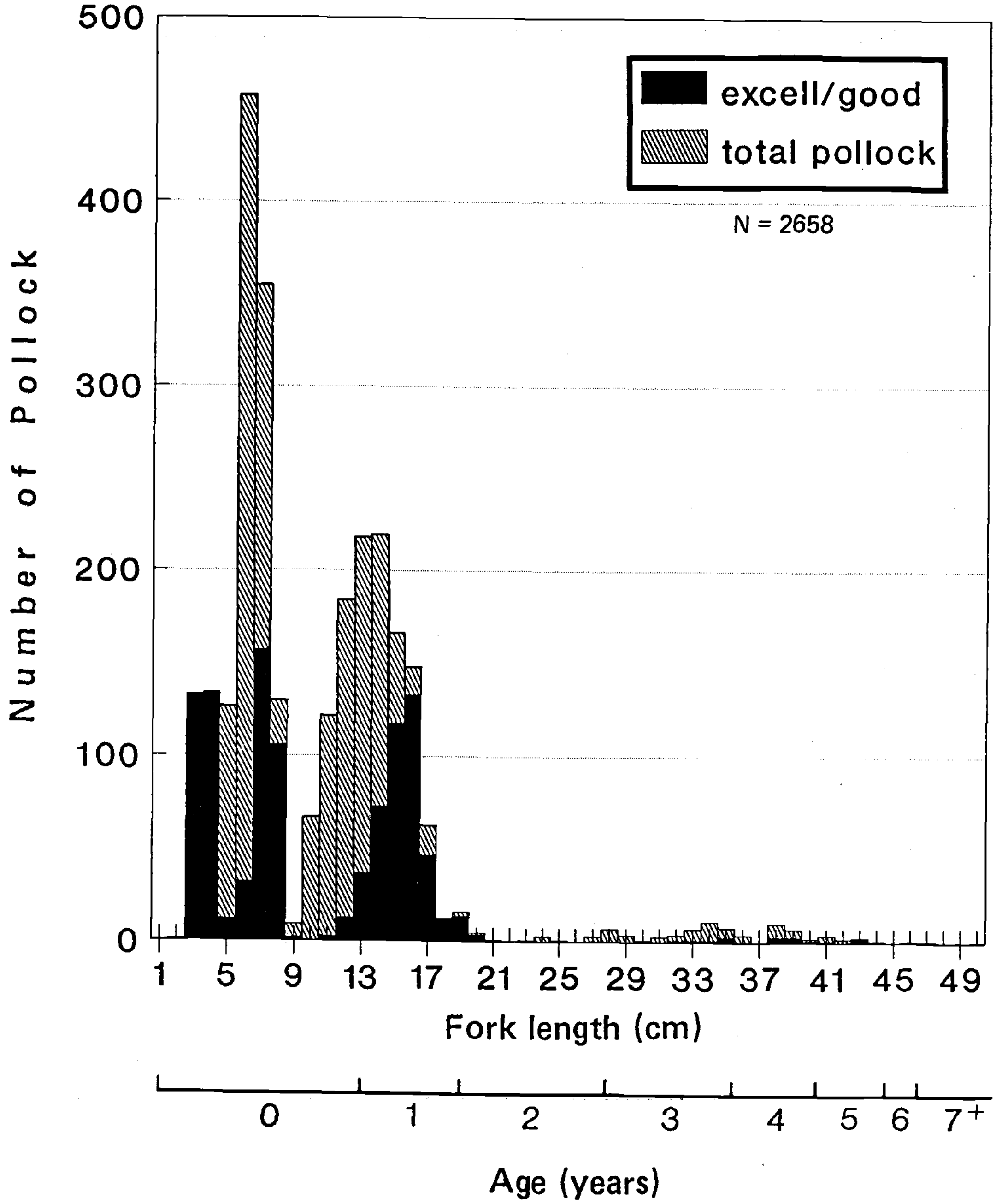


Figure 5 - Age-length frequencies of pollock and tentatively identified pollock (2-5cm) from seal gastrointestinal tracts collected in 1981, 1982, and 1985. Fork length was based on measurement of otolith length. The relative frequencies of otoliths in good and excellent condition to those in fair (eroded) condition caused an forward shift along the x-axis, further demonstrating the variable pollock year class frequencies between years.

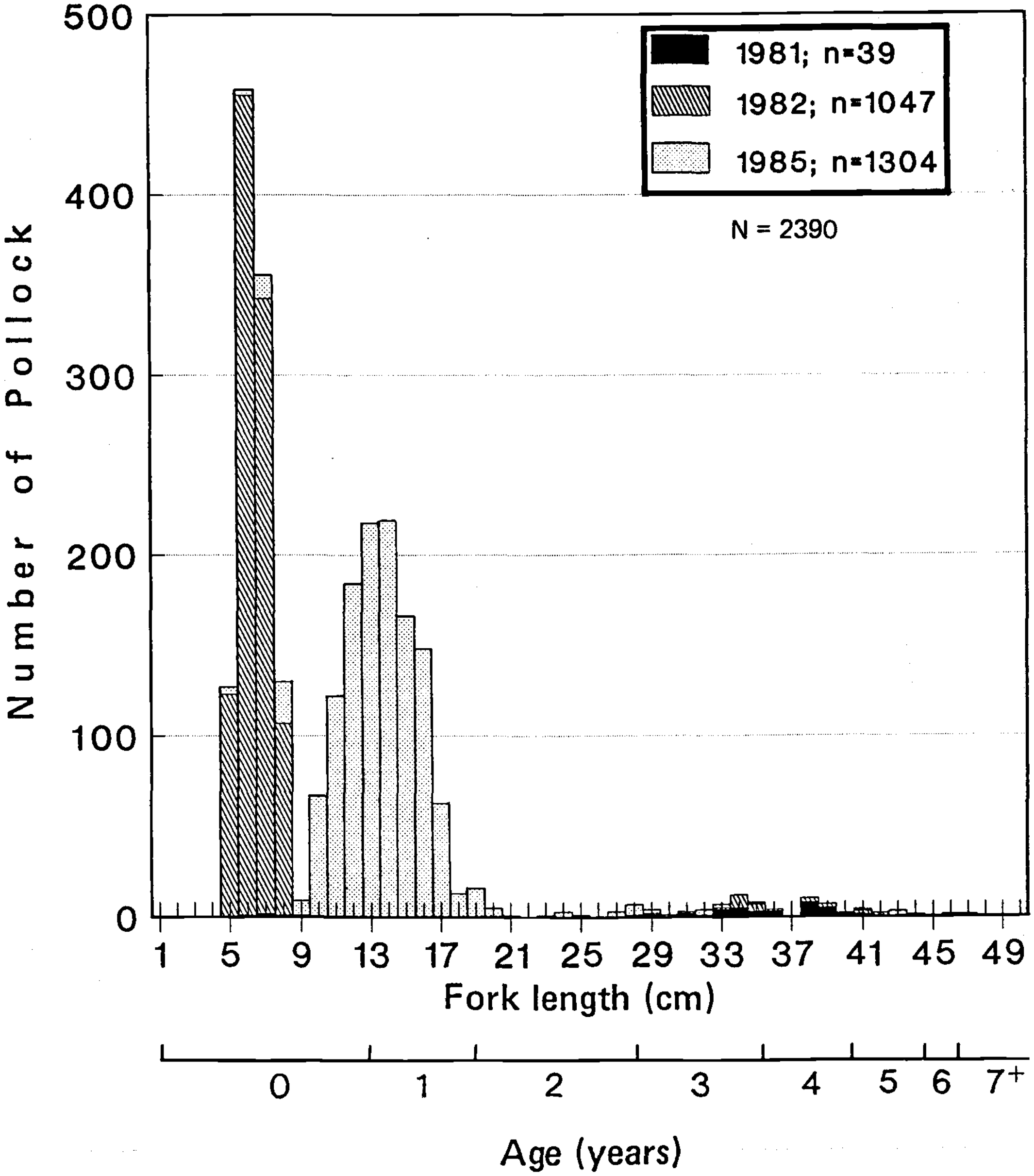


Figure 6 - Age-length frequencies of pollock based on otoliths in fur seal gastrointestinal tracts by year. All quality categories of otoliths are combined.

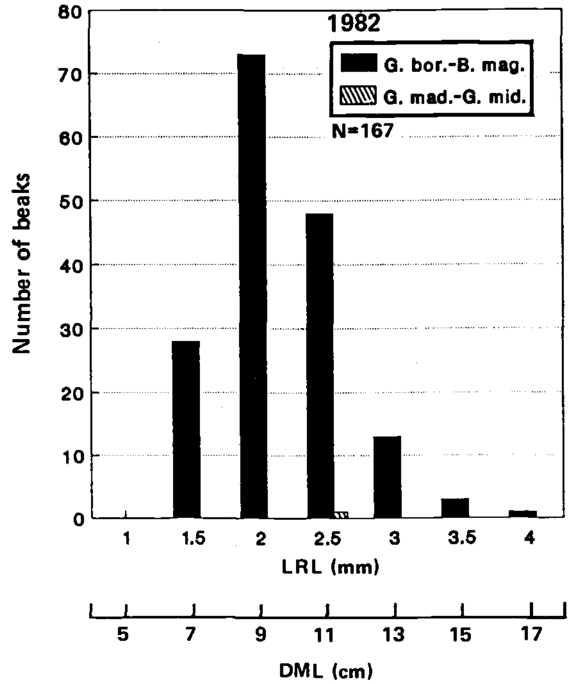
years, marked differences in age and body size were noted between years (Figure 6). Two dominant modes are obvious in the length frequency distribution of pollock based on the otoliths measured. In 1981, the few pollock found in gastrointestinal tracts were from adults 3-4 years of age. In 1982, 5-9cm fishes were the primary sizes consumed. No juvenile pollock from age group "1" were present in 1982. In 1985, mainly 10-18cm pollock were consumed. Both 1982 and 1985 had high numbers of tentatively identified 3-5cm pollock.

When measurements from otoliths in "fair" condition are excluded and only those in "excellent" and "good" condition are considered, the two modal peaks based on measurement of "excellent" and "good" otoliths clearly coincide with two age groups (Figure 5). This suggests that the otoliths for 10-13cm fish classified as "0" age fish in 1985 were actually eroded otoliths from age group "1" fish. Based on otolith measurement, seal gastrointestinal tracts contained primarily "0" age pollock in 1982 and age "1" pollock in 1985.

Gonatid squid were second only to walleye pollock in apparent importance as prey (Table 1). At least six species of gonatid squid were identified. Although no cephalopod remains were found in gastrointestinal contents from seals collected in 1981, many beaks were found in 1982 and 1985 (Tables 2-4). These represented primarily two species groups, Gonatopsis borealis-Berryteuthis magister and Gonatus madokai-Gonatus middendorffi. In 1982, 91.2% of cephalopods were G. borealis-B. magister or positively identified B. magister with a 17.4% frequency of occurrence, and only one was G. madokai-G. middendorffi (Figure 7; Table 3). In 1985, G. borealis-B. magister comprised 54.9% of cephalopod prey with a 20.9% frequency of occurrence, and G. madokai-G. middendorffi were 41% of cephalopod prey with 34.9% frequency of occurrence (Figure 7; Table 4). One stomach from the 1985 sample contained three gonatid squid species (Gonatus berryi, G. pyros, and G. tinro) not found in other samples.

Seventy-nine percent of cephalopod prey were 5-12cm dorsal mantle length. In 1982, 90% of the sample were within dorsal mantle lengths of 8-12cm and in 1985, 82% of both Gonatus makokai-G. midendorffi and G. borealis-B. magister had DML of 2-10 centimeters (Figure 7). A higher proportion of small squids (5-8cm DML) were found in 1985 than 1982 due to smaller body sizes of G. borealis-B. magister and the greater percentages of small juvenile G. madokai-G. middendorffi.

No differences in prey species or their frequencies were found between stomach and intestinal contents for 1985, with exception of otoliths from the 3-5cm gadids which were found in higher frequencies in the intestines than stomachs. Otoliths from these fish were nearly always in "excellent"



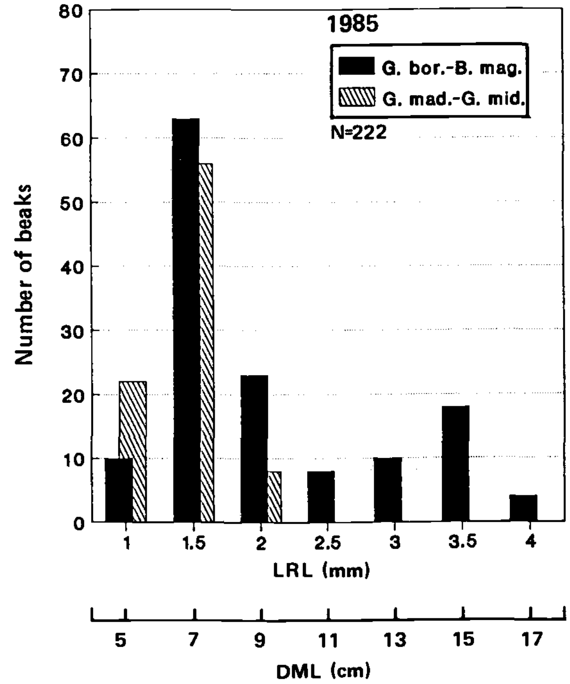


Figure 7 - Lower rostral length (LRL) frequencies of gonatid squid in seal gastrointestinal tracts in 1982 and 1985. Dorsal mantle length (DML) was estimated from the LRL/DML relationship of gonatid squid collected in bottom and midwater trawls.

condition suggesting that their predominance in the intestines was probably due to rapid movement of the small fish through the alimentary canal rather than retention and erosion of larger otoliths.

Intraspecific association was apparent between size classes of walleye pollock in gastrointestinal contents, but patterns of association varied between sample years (Table 5). Juvenile pollock and tentatively identified pollock of the "0" and "1" age groups were frequently found together. With the exception of 1985, juvenile pollock were infrequently associated with adults.

Interspecific association was apparent between Leuroglossus schmidti and gonatid squid (Figure 8). Four of the eight seals collected beyond the continental shelf contained both L. schmidti and Gonatopsis borealis-Berryteuthis magister. Gonatopsis borealis-B. magister was found without the bathylagids in the additional four seals collected offshore (>2500m) and on the outer shelf at 130m and 150m depths. Gonatus madokai-G. middendorffi was present in three of the four samples containing L. schmidti, but numbers of individuals were small relative to G. borealis-B. magister.

The species and size of prey found in seal gastrointestinal tracts were related to sampling location (Figure 8). Differences in species of prey occurred between seal sample locations on the continental shelf and over the

Table 5 - Association of age classes of walleye pollock and tentatively identified walleye pollock in fur seal gastrointestinal contents, by year. Numbers in parentheses represent the frequency of occurrence of the age class in each sample year. Numbers outside of parentheses represent the number of gastrointestinal tracts in which given year classes were found together. Asterisks indicate the lack of association due to absence of a year class in the given sample year.

	"0"	"1"	adult	3-5cm
"0"				
1981 (4)	2	*	2	*
1982 (19)	17	*	1	4
1985 (16)	0	14	10	5
"1"				
1981 (0)	*	*	*	*
1982 (0)	*	*	*	*
1985 (26)	14	6	14	8
Adult				
1981 (5)	2	*	3	*
1982 (5)	1	*	4	0
1985 (16)	10	14	2	2
3-5cm				
1981 (0)	*	*	*	*
1982 (5)	4	*	0	1
1985 (10)	5	8	2	2

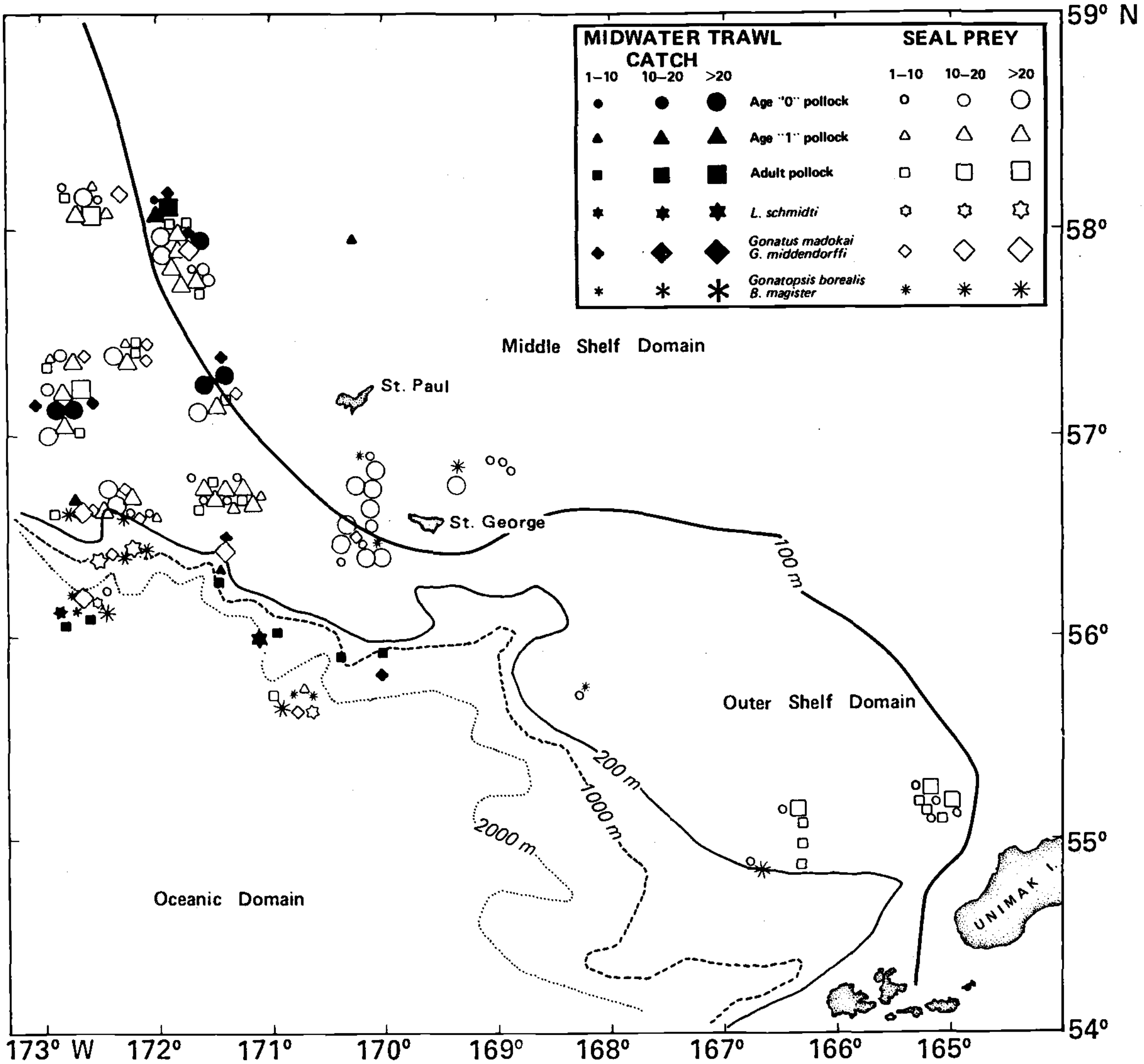


Figure 8 - Study area showing the similarity between prey identified from individual seal gastrointestinal tracts and midwater trawls collected in the same area.

continental slope and oceanic domain (Figure 8). Leuroglossus schmidti occurred only in 1985 in four seals, two of which were collected over the continental slope and two in oceanic waters. They were not represented in other sample years, probably because the 1985 seal collections were the only ones made beyond 200 meters. Leuroglossus schmidti is a deepwater species and has been described as fur seal prey only from seals collected over deep water (Kajimura 1984; Perez and Bigg 1986). Larvae of L. schmidti in the eastern Bering Sea are most abundant over the 200m shelf break in summer, and adults have been taken from 0-700 meters (Dunn 1983). Waldron (1981) reports L. schmidti larvae distributed over the continental slope and deep oceanic domain.

Cephalopods represented in gastrointestinal samples also demonstrated a relationship with sampling area (Figure 8). Gonatopsis borealis-Berryteuthis magister were found with highest frequency in seals collected from the continental slope and near slope oceanic waters. Eighty-eight percent of G. borealis-B. magister were found in seals collected over the slope in depths greater than 1400m, and 11.1% were from near slope sampling areas in 1985. Gonatus madokai-G. middenforffi were widespread across the sample area but most frequently found in seals collected on the shelf. They were identified from only three samples collected over the oceanic domain in 1985 samples.

The high frequency of occurrence of atka mackerel in 1981 is related to the sample location north of Unimak Island over the outer shelf domain. Atka mackerel is an open water species that moves coastward during the spawning season in early summer. Peak abundances of atka mackerel occur north of Aleutian passes in June-August where they are preyed upon by sea lions, fur seals, cod, and halibut. Adults return to offshore waters in autumn (Andriyashev 1954). Seasonal factors may be associated with the absence of atka mackerel in 1982 samples which were collected three weeks earlier and 83km west of the 1981 samples. Sample location may explain the absence of atka mackerel in 1985. Andriyashev (1954) states that atka mackerel is infrequent off the Pribilof Islands where most seals were collected in 1985, however, seal stomachs collected northwest of the Pribilof Islands contained atka mackerel in previous reports and in 1962 atka mackerel was second in importance as fur seal prey from Unimak pass to the Pribilof Islands (Fiscus et al. 1964). Kajimura (1985) also described atka mackerel as fur seal prey from pelagic sampling regions equivalent to this study. Conflicting evidence regarding density distribution of atka mackerel may be due to high interannual variability.

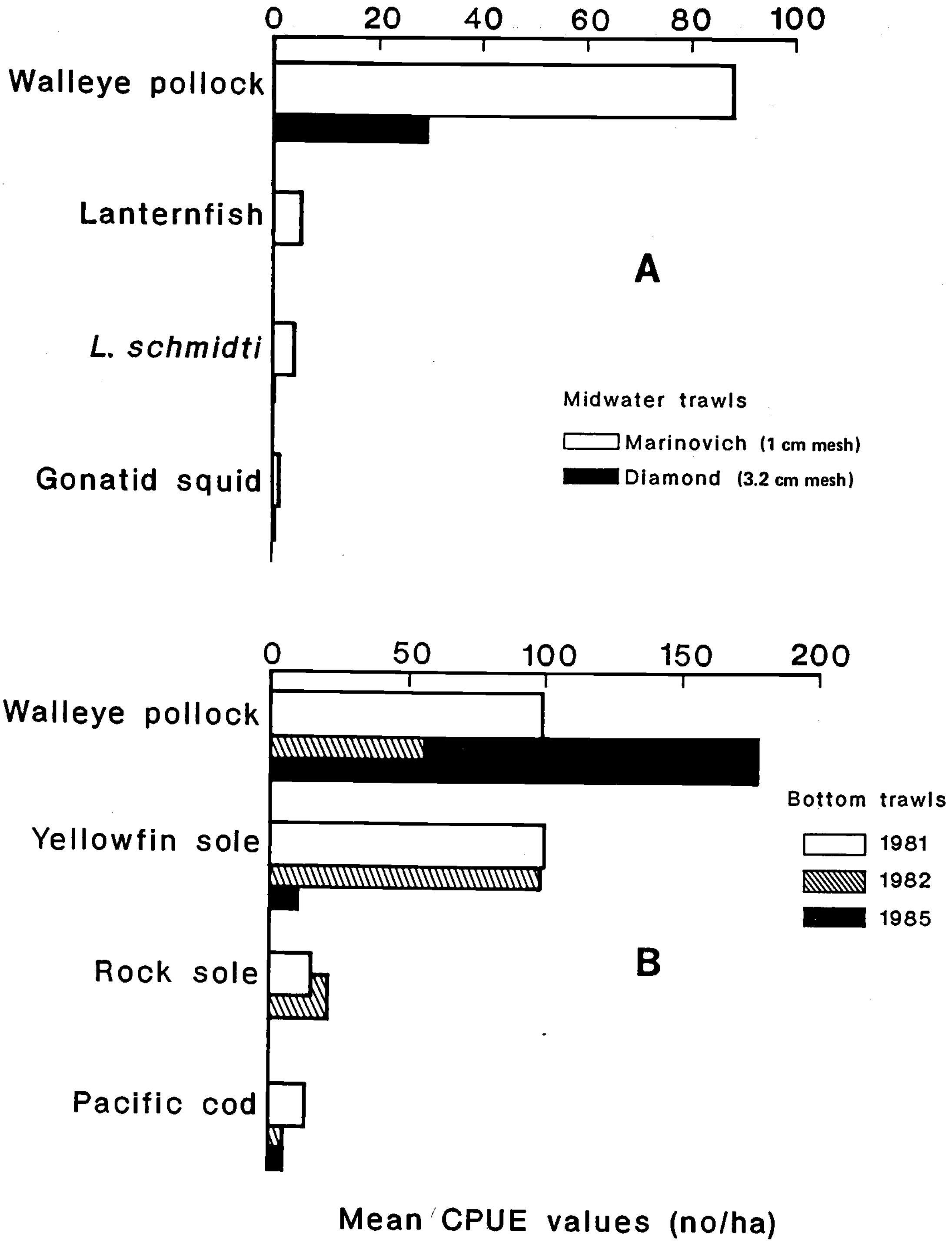
The size of pollock prey varied with seal sample location. The greatest percentage of walleye pollock for all three sample years was from seals collected over the continental shelf (Tables 2-4; Figure 2). Juvenile pollock were abundant as prey in seals collected over both the middle and outer shelf domain, while adult pollock were uncommon as prey in the middle shelf domain. Both adults and juveniles were rare in samples collected over the oceanic domain. Smith (1981) and Lynde (1984) reported high concentrations of adult pollock over the outer shelf region during the spawning season (February-June) and again with the onset of winter at 100-300m depths.

In summary, the gastrointestinal tracts of seals collected over oceanic and continental slope regions contained primarily bathylagid smelt and squid, especially *Gonatopsis borealis*-*Berryteuthis magister*. Seals collected over the continental shelf contained the remains of pollock of all ages and squid, especially *Gonatus madokai*-*G. middendorffi*. Adult pollock were found in greatest frequency in seals collected from the outer domain of the continental shelf. Juvenile pollock were more widely distributed than adults over the outer and midshelf domains of the shelf.

Trawl Samples

No single net can provide a complete picture of faunal composition because nets are size selective and thus exclude some portion of the sampled population. The catches of bottom trawls conducted within the diving range of northern fur seals were dissimilar to fur seal gastrointestinal contents, but the species composition of midwater trawl catches and seal gastrointestinal contents in 1985 were very similar (Figures 4 and 9). Seals fed on three of the four top ranked species caught in midwater trawls. A similarity value of 81% was calculated for the 1985 gastrointestinal samples and midwater trawls. Midwater trawls caught predominantly juvenile pollock. Gonatid squid were second in frequency of occurrence in midwater trawls, but had low CPUE values. Cephalopods represented in midwater trawls were Gonatus madokai, Gonatus middendorffi, and three tentatively identified Gonatopsis borealis.

Midwater trawl catches and fur seal gastrointestinal contents were also very similar in terms of prey size. The major modal length of pollock and gonatid squid was 5-20cm in both midwater trawl and gastrointestinal samples in 1985 (Figures 3, 6, 7, and 10). Few adult pollock and no large squid were collected in midwater trawls. Although the "0" age 5-10cm pollock were the predominant size in 1985 midwater trawl samples (Figure 10), they were poorly represented in 1985 seal samples (Figure 6). When the age "0" pollock were found in 1985 GI tracts, the greatest numbers were from areas where midwater trawls indicated large numbers of age "0" fish (Figure 8). The tentatively identified 3-5cm walleye pollock were not present in trawls, probably because the mesh size was too large to retain them. Midwater and bottom trawling are subject to bias by faunal



<u>Figure 9</u> - Catch per unit effort (CPUE) number/hectare (no/ha) values for species caught in 1985 midwater trawls (A); and bottom trawls in 1981, 1982, and 1985 (B).

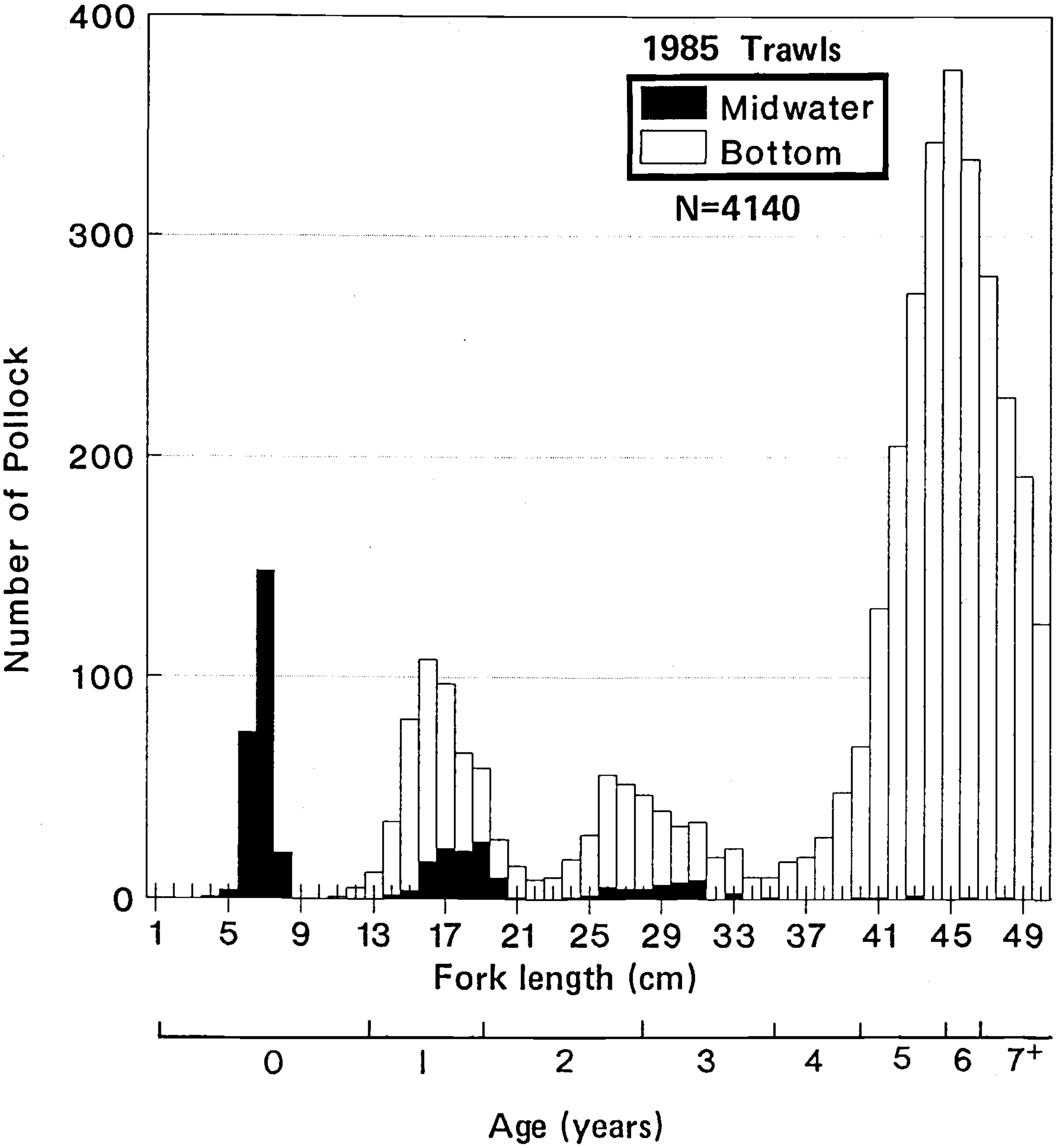


Figure 10 - Fork length of walleye pollock collected in bottom and midwater trawls in 1985. Age was estimated based on the known age/length relationship (Smith 1981; Walline 1983) of pollock in the Bering Sea.

escapement and avoidance of the net and extrusion of fauna through net mesh by water pressure (Pearcy 1975).

The capture location of juvenile walleye pollock, bathylagid smelt, and gonatid squid in midwater trawls was very similar to sample locations in which these species occurred in seals (Figure 8). Age "0" and "1" walleye pollock were collected in midwater trawls made on the middle and outer shelf and near the continental slope. *Gonatopsis borealis* or *Berryteuthis magister* were found on the continental slope and near slope and *Gonatus madokai* or *Gonatus middendorffi* were found throughout the sampling area, but primarily on the outer shelf and near slope sampling areas. In 1985, *Leuroglossus schmidti* was caught in two midwater and two bottom trawls near the continental slope and just off the 2000m contour line over the oceanic domain. The two bottom trawls containing *L. schmidti* also contained *Berryteuthis magister*, 19.5-31.2cm dorsal mantle length, however, no cephalopods were associated with *L. schmidti* in midwater trawls.

Of the top five ranked species collected in bottom trawls, the only one found in seal gastrointestinal contents was walleye pollock. Walleye pollock had the highest mean CPUE values (no/ha) in bottom trawl collections in 1985, but ranked equally with yellowfin sole in 1981, and ranked second to yellowfin sole in 1982 (Figure 9). Although pollock was a predominant species in bottom trawls, fork lengths were larger than the predominant size range consumed by fur seals or caught in midwater trawls (Figures 5 and 10). The pollock caught in all three years of bottom trawl collections ranged from one to over twelve years of age. Mean body length was 38.9cm in 1981, 39.7cm in 1982, and 44cm in 1985. Juvenile pollock were rarely caught in bottom trawls. The highest mean number of pollock per hectare was obtained for three and four year old fish in 1981, four and five year old fish in 1982, and five and six year old pollock in 1985. In 1981 and 1982, sample areas were limited to the outer and midshelf domains and adult pollock occurred throughout. In 1985, adult pollock were collected by bottom trawls primarily over the outer continental shelf and slope.

Catch per unit effort values of cephalopods in bottom trawls were low relative to fishes. In 1981 and 1982 cephalopods were identified only as "squid" and "octopuses" and were not separated by species. Based on distribution, the octopus were probably adult Octopus dofleini. The squid were probably adult Berryteuthis magister or Gonatopsis borealis. In 1985, Berryteuthis magister was the primary cephalopod in bottom trawls. All positively and tentatively identified B. magister were collected from bottom trawls over the continental slope. With the exception of two tentatively identified Gonatus middendorffi and two Octopoda, the remaining cephalopods were collected in midwater trawls.

Cephalopods caught in bottom trawls were also larger than the size consumed by seals. *Berryteuthis magister* caught in bottom trawls ranged 11-34.5cm dorsal mantle length with a mean of 20.3cm for both positively and tentatively identified individuals (Figure 3). Positively identified *Berryteuthis magister* ranged 17.5-31.2cm DML ($\bar{x}$=21.6). They were collected in trawls conducted over the outer continental shelf domain along the 200m contour or over the continental slope between 200m and 1000m.

DISCUSSION

Seal Consumption and Pollock Recruitment

The modal size distribution of walleye pollock in fur seal gastrointestinal contents reflected year class strength projections of walleye pollock, particularly within the first two years after recruitment (Figure 11). Pollock have highly variable recruitment rates (Smith 1981) and year class strength varied five fold between 1977-1982 (Bakkala et al. 1987). Population estimates based on bottom trawl and midwater acoustic surveys (Bakkala et al. 1987) in the eastern Bering Sea indicated that the 1980 year class (age "1" in 1981) was about half the average year class size; the 1981 year class (age "0" in 1981) was the weakest observed prior to 1983 (Bakkala et al. 1987); and the 1978 year class (age "3" in 1981) was the strongest observed. The 1982 and 1984 year classes were strong. The 1985 year class was considered "average".

These year class strength predictions are consistent with the age/size frequencies of pollock in seal gastrointestinal tracts in this study (Figure 11). In 1981 seal gastrointestinal contents, "0" age juvenile pollock were poorly represented and age "1" pollock were absent. Although there were few pollock as prey in 1981, most were adults 3 and 4 years of age from the 1977 and 1978 year classes. Age 1 pollock were absent in the gastrointestinal tracts of seals collected in 1982. Large numbers of age

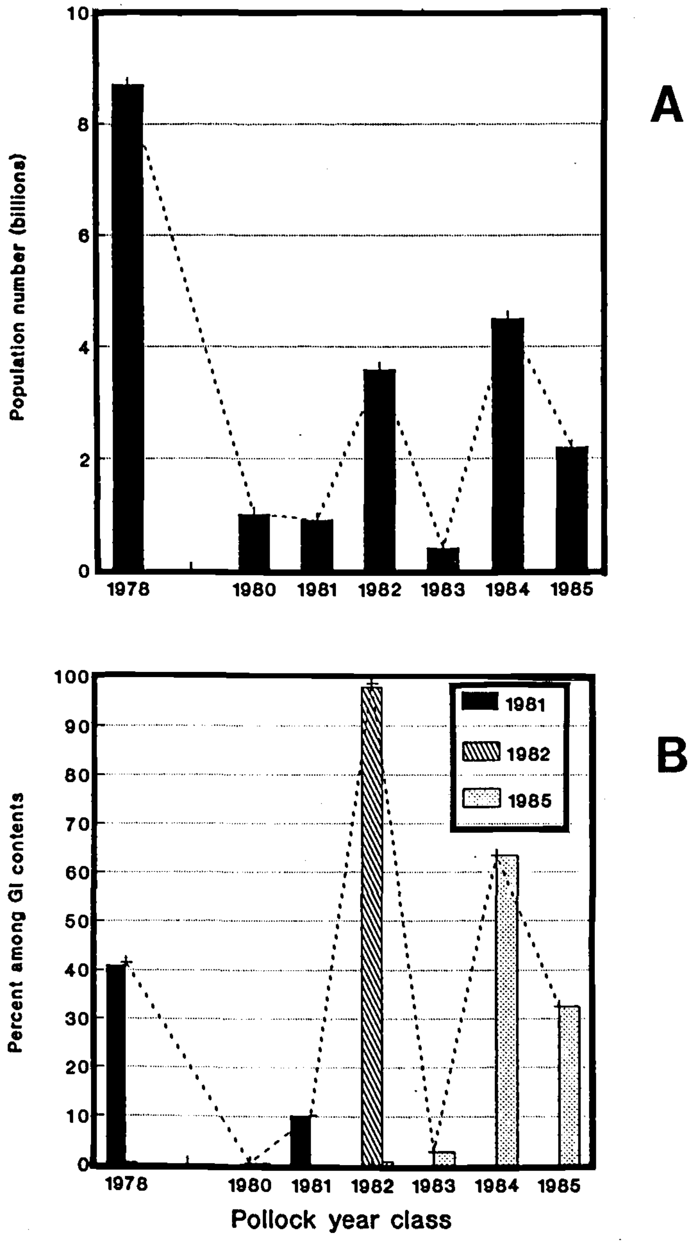


Figure 11 - Published estimates of pollock year class strength 1978-1985 (Bakkala et al. 1987) (A), and relative abundance of specific year classes in fur seal gastrointestinal tracts (B). The 3-5cm gadids tentatively identified as pollock were not included.

group "0" in 1982 and age group "1" in 1985 (1984 year class) were found in seal samples. The concordance of these trends indicates that variable recruitment of pollock affects the feeding habits of fur seals.

The close relationship between pollock recruitment and fur seal prey patterns may have also occurred in the early pelagic collections (1958-1974). Although detailed information on prey age and body size of seals collected prior to 1981 has not been reported, Swartzman and Haar (1983) noted that the percent volume of pollock was markedly higher in stomach samples collected in 1973-1974 than in previous collections (1960, 1962-1964, 1968) from the eastern Bering Sea. This high volume of prey pollock may be directly related to the strength of the 1972 year class which was estimated the second strongest year class between 1962-1980 (Bakkala et al. 1987).

Intraspecific and Interspecific Association

Sampling Bias vs. Selectivity

The presence of both 3-5cm gadids tentatively identified as pollock, and 5-8cm "0" age pollock in 1982 gastrointestinal contents probably resulted from association of the two sizes in the water column and direct consumption by seals. Based on what is known of spawning and migration patterns in walleye pollock (Smith 1981), 3-5cm pollock may be in the same schools as their larger cohorts (5-10cm). Pollock in the southeastern Bering Sea spawn from February through June (Smith 1981). The suspected center of spawning activity is the outer continental shelf between the Alaska Peninsula and Pribilof Islands. Northwest drift carries larvae from the Peninsula to the Pribilof Islands within 2-4 months, by which time they are 4-8cm fork length (Smith 1981). Spawning also occurs on the continental shelf northwest and southeast of the Pribilof Islands (Bailey et al. 1986; Bakkala et al. 1987). If larvae spawned directly off the Pribilof Islands remain in the area, then the mix of small newly spawned and larger 2-4 month old juvenile pollock as seal prey is predictable. Although pollock are highly cannibalistic (Dwyer et al. 1986) and juvenile pollock 5-10cm fork length are probably capable of consuming larval fish, it is unlikely that they consume siblings just 2-5cm smaller than themselves.

The association of 3-5cm gadids with age group "1" pollock in 1985 gastrointestinal contents (Table 5) may be due to secondary introduction by cannibalism. Dwyer et al. (1986) demonstrated that significant cannibalism of age "0" pollock (average 7cm fork length) by older (24-39cm) pollock occurs in autumn. The low numbers of 5-10cm pollock in 1985 gastrointestinal contents (Table 4; Figure 6) relative to the high numbers in midwater trawls (Figure 10) suggests seals were not directly targeting the "0" age group in 1985. If the 3-5cm gadids and 10-20cm pollock were ingested only because they were associated spatially, 5-10cm pollock should have been more highly represented in the gastrointestinal tracts. Juvenile pollock 5-10cm fork length are probably too large for consumption by 10-20cm juveniles. However, it is plausible that "1" year olds are cannibalistic on 3-5cm "0" age fish when their distributions overlap, and that 3-5cm fish were introduced secondarily by age "1" pollock into seal gastrointestinal contents. Cannibalism on young-of-the-year pollock by one year old fish (10-20cm) has not been reported. However, secondary introduction by anything other than age "1" pollock was unlikely since there was little association of the 3-5cm fish with adult pollock, squid, or other fish species in 1985.

Adult pollock and age "1" juveniles appeared together frequently in 1985 gastrointestinal tracts (Table 5), either as the result of association in the water column or secondary introduction. The higher association of age "0" juveniles and adults in 1985 relative to other years (Table 5), may be the result of warmer water temperatures. Based on measurements of maximum ice cover taken near the Pribilof Islands and in the central Bering Sea in March, 1985 was one of the warmest years since 1972 (NOAA Weekly Ice Reports). Warmer water may have resulted in a lower thermocline, bringing juveniles and adults into closer proximity in 1985.

The association between _Leuroglossus_ _schmidti_ and gonatid squid in 1985 prey samples collected offshore over the continental slope was probably not one of secondary introduction, but spatial association. The fish were in good condition indicating recent and primary ingestion. Perez and Bigg (1986) also noted this association between the two prey types. Since they accounted only for whole prey in their analysis, the relationship was, again probably not one of secondary introduction. Perez and Bigg (pers. comm.) also reanalyzed data from Lucas (1899) and found that 78% of the bathylagid smelt were significantly associated with squid in fur seal stomachs collected pelagically in the Bering Sea. Both L. schmidti and Berryteuthis magister are deep water forms. Berryteuthis magister is present in the upper water column during juvenile growth stages (Kubodera and Jefferts 1984), and L. schmidti is a diel vertical migrator into near surface waters (Waldron 1981).

Fur Seal Foraging Behavior

Influencing Factors - Prey Behavior and the Environment

Individual seals may have specific preferences for prey type, prey size, and foraging location. Gentry et al. (1986) found that the depth and pattern of feeding dives measured by time-depth recorders (TDR) on fur seals from St. George Island differ between individual seals and by time of day. Individual seals may specialize either as deep (>125m) or shallow (≤75m) divers or a combination of both, but shallow diving was the predominant strategy among the seven seals examined in Gentry et al. (1986). Most shallow diving occurred at night beginning with dusk and ceasing at dawn with rest during the day. The most common dive depth associated with shallow diving was 50-60 meters, dive depths changed over the course of a dive series in a manner that suggested seals were following vertically migrating prey. Typical patterns of vertical migration in marine animals are a rise from the depths (<1000m) to the surface at dusk then a descent back to depth at dawn. Highest stomach volumes have been reported for seals collected at dawn (Mead 1953; Taylor et al. 1955; Spalding 1964; Wada 1971; Kajimura 1984) which would be expected for a predator consuming vertically migrating prey. These peak hours of stomach fullness, in conjunction with experimental results on fur and phocid seals that demonstrate a stomach clearance time of 12 hours (Miller 1978; Bigg 1981; Bigg and Fawcett 1985; Murie and Lavigne 1985), are in agreement with Gentry et al's. (1986) measurements of peak dive times for shallow water divers.

Loughlin et al. (1987) found that shallow diving occurred primarily at night beyond the continental shelf. Shallow nighttime divers over the continental slope and oceanic domain are probably targeting different prey than seals diving to shallow depths over the continental shelf. The 50-60m dive depths described by Gentry et al. (1986) coincide with depth distribution of juvenile pollock over the continental shelf (Smith 1981; Lynde 1984). Juvenile pollock begin schooling when they are greater than 2cm body length and remain in schools in the upper 40m of the water column day and night during their first spring and summer (Smith 1981). Based on distributional information (Smith 1981; Dunn 1983; Kubodera and Jefferts 1984; Lynde 1984) and prey patterns in this study, shallow divers over the continental shelf probably concentrate on juvenile walleye pollock and juvenile gonatid squid (*Gonatus madokai*-*G. middendorffi* type), while shallow divers offshore probably target juvenile gonatid squid (*Berryteuthis magister*-*Gonatopsis borealis* type) and bathylagid smelt.

Individual seals specializing in deep dives, most commonly to 175m, dove throughout the day (Gentry et al. 1986). A deep diving strategy at night over the continental slope could take advantage of non-vertically migrating prey or diel migrating prey that only ascend to depths below 125 meters. But, records indicate that deep diving takes place on the continental shelf (Loughlin et al. 1987). Daytime deep diving over the continental shelf would be an advantage to seals concentrating on adult walleye pollock (or adult *B. magister*). Adult pollock school at or near the bottom during the day during the non-spawning season and disperse as they rise in the water column at night (Smith 1981). Schooling prey are probably more accessible to seals than dispersed prey. Thus, the highest feeding gain for a predator eating walleye pollock over the continental shelf would be deep diving for adult pollock during the day and shallow diving for juveniles night and day.

Foraging efficiency could be maximized if seals take advantage of the hydrographic characteristics of the Bering Sea continental shelf, such as a two-layered midshelf and a three layered outer shelf domain that may stratify and concentrate prey by species and age in a vertical plane. Nishiyama et al. (1986) propose that vertical stratification within the eastern Bering Sea shelf serves as a "nursery layer" to confine young-of-the-year pollock in the upper 40 meters of the water column within the boundary region between the upper and lower layers. Copepod nauplii are also concentrated in this area providing a ready source of food for larval pollock (Bailey et al. 1986). Wada (1971) determined that primary foods of fur seals off the Sanriku Coast in Japan consisted of migrating species closely related to boundary regions, especially transition zone regions between the Oyashio and Kuroshio currents and between the Oyashio and its frontal zone. The horizontal temperature and salinity structures that occur on either side of frontal regions within this study area may also form boundaries to prey. Diving depths of 175m reported by Gentry et al. (1986) coincide with boundary depths between the continental shelf and slope. Diving depths of 50-60m coincide with the boundary between the midshelf and inner shelf frontal systems.

Comparison with Previous Analyses

Prey species identified in this study are similar to prior studies of fur seal diet in the eastern Bering Sea, despite variation in sample size and analytical technique between studies. Walleye pollock have been consistently cited as major prey of northern fur seals in the Bering Sea, as have gonatid squids and bathylagid fish (Scheffer 1950a; Wilke and Kenyon 1952, 1957; Kajimura 1985; Perez and Bigg 1986). Swartzman and Haar (1983) suggest that percent volume of pollock in northern fur seal stomachs from Bering Sea pelagic collections prior to 1968 were variable and markedly lower than the 1970's, but based on the consistent listing of pollock in historical accounts of fur seal stomach contents and spewings, pollock have always been a primary prey. Also, the extent to which year class strength appears to determine the interannual frequency of pollock as prey in this study suggests that a larger data base is needed to clearly define trends in the importance of pollock as prey.

While a shift in the importance of pollock as a prey species is not evident, the size of pollock prey consumed by fur seals may have decreased since the 1960's. Swartzman and Haar (1983) suggest that intensive commercial fishing of adult (cannabilistic) pollock since 1964 may have resulted in increased numbers of juvenile pollock and subsequent predation by seals. Prey pollock body lengths were rarely provided in earlier studies, however reference was commonly made to "large" or "small" and "offshore" vs. "inshore" pollock. Based on present day distributions, pollock recovered from seals collected "offshore" in summer and autumn were probably adults while those collected "inshore" were a mix of adults and juveniles. The importance of walleye pollock cited as "offshore" vs. "inshore" prey varies between studies based on collections made prior to or after the early 1960's. Kajimura (1985) and Perez and Bigg (1986) described pollock as primary fur seal prey on the continental shelf and shelf edge near the Pribilof Islands, but Wilke and Kenyon (1957) found walleye pollock important in offshore areas of the eastern Bering Sea. Lucas (1899) reported that few seals were collected or observed over the continental shelf, but were most frequently seen over the continental slope and oceanic domain. Lucas (1899) also described pollock of a "good size" (five 45cm specimens) found in a stomach from the Pribilof Islands and "small" pollock (15cm) found in another. Wilke and Kenyon (1952) described a 38cm specimen from spewings on the Pribilofs, and "small" (10-30cm) fishes of the gadid family, some of which were pollock, based on otoliths collected on the rookeries. Although, observations based on spewings may be biased if only oversized prey are spewed, it seems that "offshore" or adult pollock were more often cited as prey prior to the 1960's.

If seals have switched from large to small pollock in their diet, then the duration of feeding trips could be expected to decrease, both because of the "increased" availability of juvenile pollock, and because juvenile pollock are available on the midshelf closer to the Pribilof Island rookeries. Gentry and Holt (1986) reported no consistent change in female feeding trip duration. Their conclusions were based on observations of attendance on St. George Island and St. Paul Island, compared with 26 years of data from St. Paul Island. Based on information collected from radio-tagged females, Loughlin et al. (1987) report that female fur seals on St. Paul rookeries are spending less time foraging at sea relative to the 1960's and 1970's. The findings of Loughlin et al. (1987) and earlier references to the predominance of offshore pollock suggest that a prey switch in terms of the size of pollock consumed by seals may have occurred.

Prey species absent or poorly represented in this study that were considered important in prior reports included capelin, Pacific herring, and atka mackerel. Capelin were described in prior studies as frequent prey in stomach contents from seals collected in Unimak Pass and along the Aleutian Islands during June-October (Wilke and Kenyon 1957; Fiscus et al. 1964; Kajimura 1986; Perez and Bigg 1986). Salmoniformes identified from otoliths in 1981 samples collected near Unimak Pass may have been capelin. The 1982 samples contained no capelin, even though they were collected northwest of Unimak Pass, an area of known high spawning concentrations of capelin spring through fall (Andriyashev 1954; Favorite et al. 1977) and a favored fur seal foraging area for capelin in the past (Fiscus et al. 1964). The absence of capelin in 1985 seal samples was likely due to sampling in areas where capelin have not been reported to be abundant. Abundance of large spawning groups of capelin inshore varies year to year and may be cyclical in nature with 3-5 year patterns (Turner 1886; Meek 1916) which could also have contributed to their absence in this study.

Although herring have been cited as primary prey of fur seals in the Bering Sea and northeast Pacific Ocean, close examination shows that herring vary in importance as fur seal prey in the Bering Sea. Kajimura (1985) considered herring primary prey in fur seal diet in the Bering Sea in seals collected in August north and east of St. Paul Island in 1963-1964, but Wilke and Kenyon (1957) found no herring in seals collected in mid-July between Unimak Pass and the Pribilof Islands, despite high numbers of herring near Unalaska Island and the Aleutian Island chain, and record catches of herring during the time of seal collection. Scheffer (1950a) noted the importance of herring in coastal waters between Washington State and Southeast Alaska in the spring and summer, and its apparent importance during the migration of seals, but makes no mention of herring as fur seal prey in the Bering Sea. Favorite et al. (1977) noted that Pacific herring are variable in interannual abundance and regional concentration and it can be concluded that they are also a variable prey source.

Capelin, herring, and atka mackerel may be variable as fur seal prey depending upon the abundance of other prey. Fur seals may rely, or may have relied historically, on herring, capelin, and atka mackerel only as alternate prey during the years following poor recruitment classes of pollock. The high percent frequency of occurrence of atka mackerel and tentatively identified Osmeridae as prey in 1981, and the absence of both in 1982 samples collected in the same area may be associated with low recruitment of walleye pollock in 1981 and low availability as prey, while in 1982 pollock were probably highly available to seals due to the strong 1982 year class. Pelagic collections during the years 1960 and 1962-1964 had low volumes of pollock as prey, but high volumes of atka mackerel, capelin, and herring (Fiscus et al. 1964; Kajimura 1984). Scheffer (1950) cites records from Lucas (1899) listing high numbers of pollock as prey in the Bering Sea with no reference to herring.

The variable nature of abundance of Pacific herring and atka mackerel within foraging range of the Pribilof Island fur seals, and their inconsistent reliability as potential prey may have been accentuated by the removal of stocks through commercial fishing efforts. Herring declined from an estimated 1.7 million tons to 250,000 tons between 1963-mid 1970's (Wespestad and Fried 1983). Herring catch increased in the late 1970's (Wespestad and Barton 1981) immediately followed by a sharp decline (Figure 12). The Soviet Union conducted a large scale fishery for atka mackerel off the Aleutians in the mid-1970's (Macy et al. 1978), but no updated information is available on the population status.

The rapid increase in CPUE for eastern Bering Sea pollock in the mid-1960's was coincident with the initial decline in herring stocks. Bakkala et al. (1987) suggest that pollock numbers may have expanded due to the increased niche space provided by this initial herring decline. Peak catches of pollock were made in 1970-1975, but CPUE values peaked and began a rapid downward trend by 1970 (Figure 12) (Bakkala et al. 1987). The continued decline in pollock CPUE values was coincident with the decline in CPUE values of Pacific herring (Figure 12) and the downward trend in population numbers of the northern fur seal (Figure 13).

The combined effect of naturally occurring interannual variability in prey resources other than pollock, and the decreased availability of these potential alternate prey may have forced seals to switch completely to the "newly abundant" (Swartzman and Haar 1983; Bakkala et al. 1987) juvenile pollock as prey in the 1970's. It is possible that seals suffer food limitation in years of low pollock

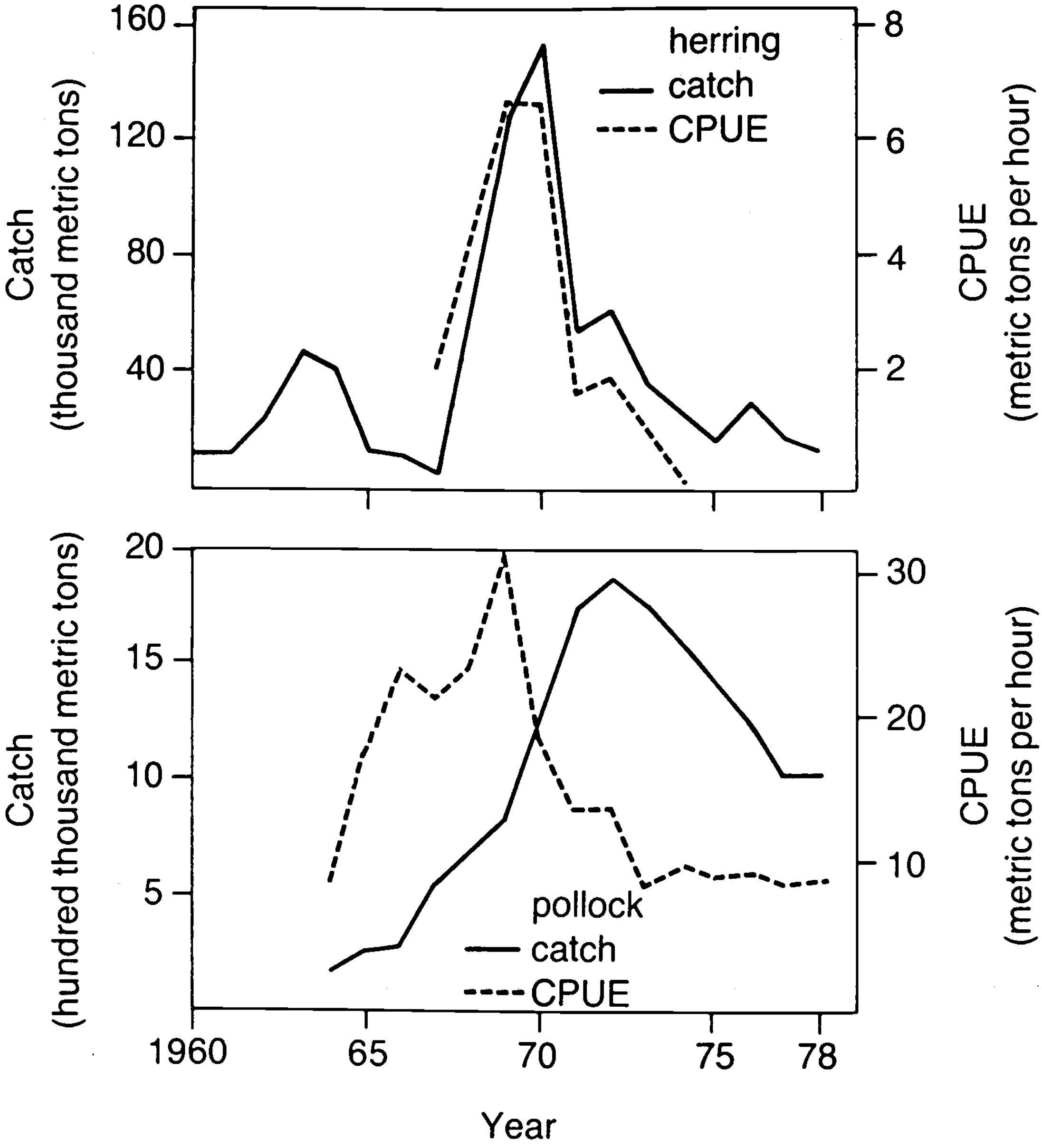


Figure 12 - Pacific herring and walleye pollock depletion patterns based on catch and catch per unit effort (CPUE) values between 1960 and 1978 (*from*: Swartzman and Haar 1983).

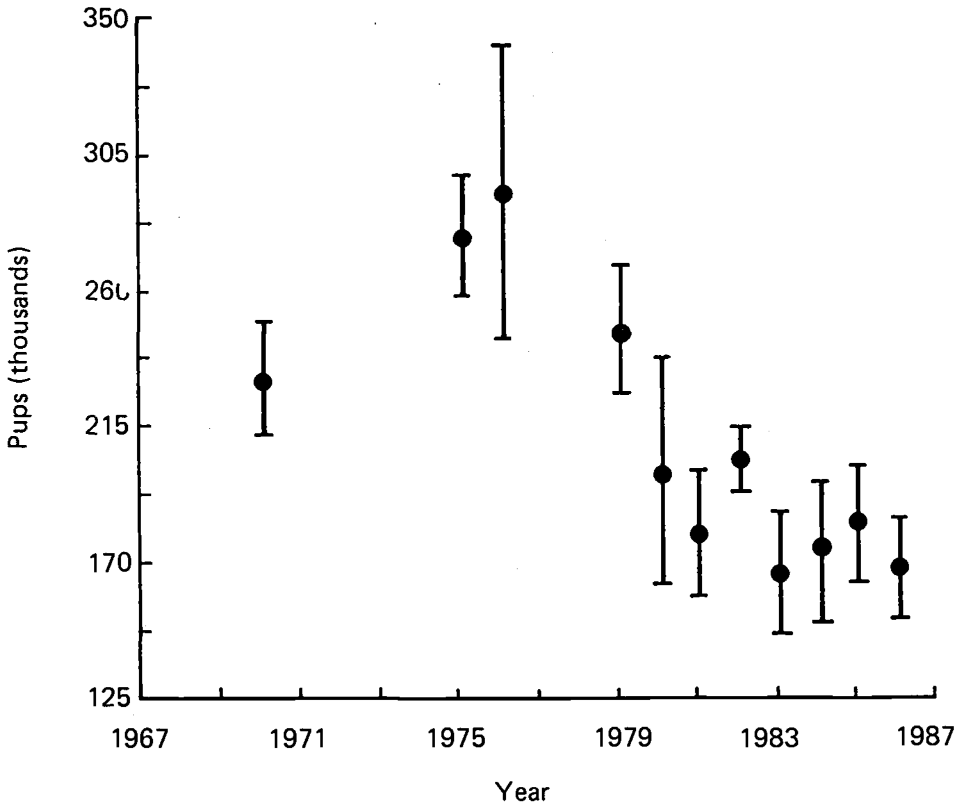


Figure 13 - Pattern of decline in northern fur seal numbers on St. Paul Island between 1970 and 1986 (from: York and Kozloff 1987). The pattern represent a decrease of 7.5% per year between 1975 and 1981, with a standard error of 2% and a 95% confidence interval. Estimates are based on counts of pups.

recruitment if other sources of nutrition are no longer available. A series of low recruitment years of pollock could have a disastrous effect on a predator with no alternate prey resources. Other species that rely on pollock as primary prey reportedly declined in years of low pollock recruitment (Lynde 1984) (Figure 14). Food deprivation at any developmental stage can have long-lasting negative effects on the reproductive success of a population. If food limitation is a direct or indirect cause of the northern fur seal decline, it could occur in any portion of the migratory route. But, the ready availability of food would seem especially critical to both newly weaned pups and territorial males as they leave the breeding rookeries in the eastern Bering Sea.

Seal Selectivity of Prey

Migration of *Callorhinus ursinus* from as far south as California to the eastern Bering Sea breeding rookeries is probably associated with feeding as well as reproduction. The Bering Sea ecosystem is one of the richest in the world oceans, and the biomass of potential prey is very high near the Pribilof Island breeding rookeries. Northern fur seals consume the most abundant and available fish and squid in the eastern Bering Sea. Walleye pollock compose an estimated 50% of the groundfish biomass in the eastern Bering Sea and Aleutian Islands area (Loughlin and Livingston 1986) and the densest shoals of 2-4 month old

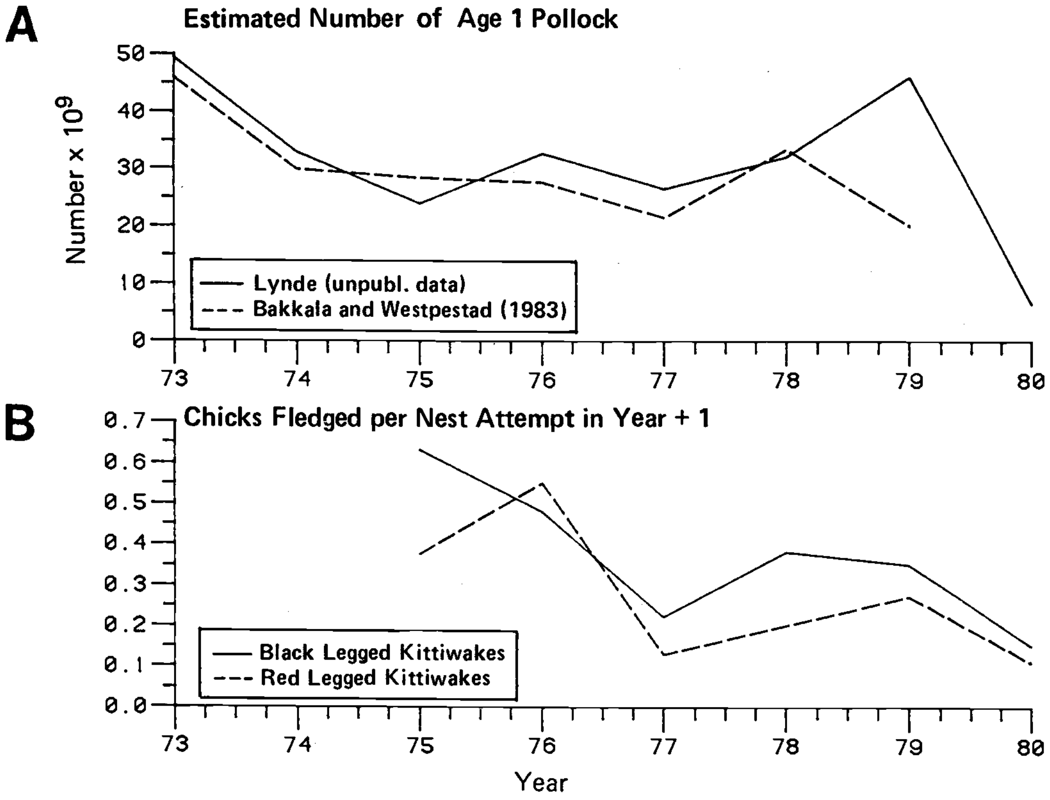


Figure 14 - Year class success of walleye pollock (A) relative to kittiwake nesting failure (B) between 1975 to 1980 (from: Lynde 1984).

pollock have been found in midwater and near bottom layers of the shelf, due west of the Pribilof Islands (Smith 1981) in spring and early summer. Rapid increases in abundances of larval and post larval gonatid squid occur early June in the Bering Sea (Kubodera and Jefferts 1984). Based on larval net samples, Kubodera and Jefferts (1984) considered gonatids the major pelagic cephalopod group in the northern North Pacific and especially the Bering Sea, and both *Gonatopsis borealis* and *Berryteuthis magister* among the most numerically dominant gonatids in the Bering Sea (Jefferts 1983; Kubodera and Jefferts 1984).

The selection of such numerically dominant species as prey, and the variation in prey type throughout their migratory range has led to the general conclusion that fur seals are non-specific, opportunistic feeders (Kajimura 1985). *Callorhinus ursinus* is flexible in its feeding habits as indicated by the variation in gastrointestinal contents of seals collected between California and Alaska. Nonetheless, seals concentrate on an average of three primary species within each oceanographic subregion (Perez and Bigg 1986), and seal consumption of pollock, gonatid squid, and bathylagid smelt in the eastern Bering Sea is consistent throughout historical records, despite the wide variety of prey available to seals within their diving range. Selectivity of prey is likely to shift with availability of prey (Emlen 1966; Morse 1980), as is apparent in the interannual variation in pollock size classes consumed by seals. But, seals appear to preferentially select juvenile and small sized fishes and squids, despite the availability of larger prey types within their diving range. Selective feeding by northern fur seals may occur most strongly in terms of the size of prey rather than the species of prey consumed.

While midwater trawl survey and pollock year class strength estimates suggest seals eat what is most available, or that they may be opportunistic in their feeding habits, bottom trawls demonstrate that fur seals are size selective midwater shelf and mesopelagic feeders, at least through the duration of the breeding and haul-out season in the eastern Bering Sea.

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APPENDICES

APPENDIX I

<u>Callorhinus</u> <u>ursinus</u> collection data, 1981

Seal sample #	Sex	Age	Date	Position		Area	Depth (m)	Time	GI contents	
				N°	W°				Vol(cc)	Wt(gms)
1	F	14	10-17	55 14′	165 08	III	114	0956	3100	3403
2	F	2	10-17	55 13′	165 09	III	114	1014	760	802
3	F	5	10-17	55 10′	165 09	III	114	1140	395	411
4	F	7	10-17	55 08′	165 02	III	114	1342	640	1056
5	F	8	10-17	55 09′	165 03	III	114	1415	240	334
6	F	8	10-17	55 09′	165 03	III	114	1416	850	970
7	F	7	10-17	55 09′	165 02	III	114	1519	trace	trace
8	F	6	10-17	55 09′	165 02	III	114	1538	empty	empty
9	F	4	10-28	57 13′	170 15	I	29	1110	empty	empty
10	M	0	10-28	57 13′	170 15	I	29	1012	empty	empty
11	F	0	10-28	57 13′	170 15	I	29	1054	empty	empty
12	F	0	10-28	57 13′	170 15	I	29	1110	empty	empty
13	F	0	10-28	57 13′	170 15	I	29	1255	empty	empty
14	F	0	10-28	57 13′	170 15	I	29	1303	empty	empty
15	F	0	10-28	57 13′	170 15	I	29	1305	empty	empty
16	M	0	10-28	57 13′	170 15	I	29	1310	empty	empty
17	M	0	10-28	57 13′	170 13	I	29	1324	empty	empty

Callorhinus ursinus collection data, 1982

Seal sample #	Sex	Age	Date	Position N°	Position W°	Area	Depth (m)	Time	GI tract Vol.(cc)	GI tract Wt.(gms)
18	F	15	9-24	55 10′	165 08′	III	114	1241	700	697
19	F	11	9-26	54 50′	166 37′	III	182	1408	120	119
20	F	unk	9-26	54 50′	166 24′	III	162	1547	trace	trace
21	F	unk	9-26	54 57′	166 20′	III	152	1710	90	80
22	F	13	9-26	55 02′	166 20′	III	149	1745	2100	2229
23	F	13	9-26	55 08′	166 21′	III	139	1922	220	221
24	M	3	10-01	56 52′	169 17′	I	80	1349	trace	trace
25	M	3	10-01	56 51′	168 58′	I	86	1653	trace	trace
26	F	2	10-01	56 51′	168 55′	I	86	1708	75	75
27	F	15	10-01	56 51′	168 54′	I	86	1723	trace	trace
28	F	5	10-03	56 26′	170 21′	I	114	1005	970	963
29	M	2	10-03	56 27′	170 11′	I	114	1017	trace	trace
30	F	3	10-03	56 27′	170 11′	I	112	1035	320	306
31	F	4	10-03	56 28′	170 11′	I	112	1053	unk	unk
32	M	2	10-03	56 30′	170 12′	I	110	1120	trace	trace
33	F	4	10-03	56 31′	170 12′	I	110	1916	trace	trace
34	F	10	10-03	56 34′	170 12′	I	110	1205	trace	trace
35	M	3	10-03	56 39′	170 12′	I	105	1246	trace	trace
36	M	2	10-03	56 41′	170 12′	I	103	1331	trace	trace
37	F	5	10-03	56 42′	170 12′	I	103	1347	120	118
38	M	2	10-03	56 45′	170 13′	I	99	1419	trace	trace
39	F	10	10-03	56 49′	170 13′	I	97	1502	trace	trace
40	M	unk	10-06	55 45′	168 12′	II	141	1006	trace	trace

Callorhinus *ursinus* collection data, 1985

Seal sample #	Sex	Age	Date	Position N°	Position W°	Area	Depth (m)	Time	GI tract Vol(cc)	GI tract Wt(gms)
41	F	7	8-06	55 43′	170 44′	I	3073	1515	200	200
42	F	6	8-06	55 45′	170 43′	I	3018	1538	trace	trace
43	F	4	8-06	55 45′	170 42′	I	3000	1544	trace	trace
44	F	5	8-06	55 46′	170 41′	I	2972	1611	1150	1180
45	F	7	8-10	56 40′	171 39′	I	115	1827	185	210
46	M	3	8-10	56 42′	171 32′	I	122	1935	trace	trace
47	F	9	8-10	56 43′	171 28′	I	123	2024	trace	trace
48	F	5	8-10	56 44′	171 26′	I	123	2046	trace	trace
49	F	7	8-10	56 46′	171 20′	I	123	2124	trace	trace
50	F	7	8-10	56 46′	171 18′	I	121	2145	480	380
51	M	3	8-10	56 46′	171 17′	I	121	2155	200	200
52	M	2	8-10	56 46′	171 17′	I	121	2155	trace	trace
53	F	7	8-12	56 26′	172 23′	I	1417	0841	800	800
54	M	2	8-12	56 25′	172 24′	I	1555	0851	1280	1260
55	F	6	8-12	56 14′	172 39′	I	2325	1104	700	700
56	F	7	8-12	56 14′	172 43′	I	2560	1300	180	150
57	F	7	8-12	56 37′	172 43′	I	136	1930	700	700
58	F	9	8-12	56 38′	172 35′	I	142	2030	trace	trace
59	F	7	8-12	56 38′	172 35′	I	142	2049	trace	trace
60	F	5	8-12	56 38′	172 32′	I	150	2106	trace	trace
61	F	9	8-12	56 38′	172 31′	I	163	2118	trace	trace
62	F	4	8-12	56 38′	172 30′	I	165	2126	trace	trace
63	F	5	8-12	56 38′	172 20′	I	159	2219	trace	trace
64	F	7	8-12	56 37′	172 18′	I	166	2230	trace	trace
65	F	7	8-12	56 38′	172 17′	I	154	2244	trace	trace
66	F	7	8-12	56 37′	172 17′	I	159	2253	trace	trace
67	F	7	8-13	57 06′	172 48′	I	121	0904	3000	2990

Callorhinus *ursinus* collection data, 1985 (continued)

Seal sample #	Sex	Age	Date	Position N°	Position W°	Area	Depth (m)	Time	GI tract Vol(cc)	GI tract Wt(gms)
68	F	7	8-13	57 10′	172 48′	I	119	0944	7000	7120
69	F	7	8-13	57 24′	172 41′	I	123	1330	700	760
70	F	8	8-13	57 24′	172 41′	I	123	1345	trace	trace
71	F	8	8-13	57 24′	172 39′	I	121	1403	1000	1020
72	F	7	8-13	57 24′	172 39′	I	121	1411	trace	trace
73	F	8	8-13	57 13′	171 31′	I	106	1952	trace	trace
74	F	8	8-16	58 08′	172 15′	I	112	1914	trace	trace
75	F	5	8-16	58 08′	172 15′	I	112	1926	trace	trace
76	F	7	8-16	58 07′	172 13′	I	112	1959	625	700
77	F	9	8-16	58 07′	172 12′	I	112	2005	trace	trace
78	F	9	8-16	58 02′	172 05′	I	112	2107	trace	trace
79	M	4	8-16	58 01′	172 01′	I	112	2147	trace	trace
80	F	7	8-16	58 00′	172 00′	I	108	2158	trace	trace
81	F	7	8-16	58 00′	172 00′	I	108	2208	trace	trace
82	F	7	8-16	58 00′	172 00′	I	108	2216	trace	trace
83	F	7	8-16	57 58′	171 57′	I	108	2251	trace	trace

APPENDIX II

83-112 Eastern bottom trawl collection data, 1981

Sample #	Date	Trawl Depth (m)	Sample Area N°	Sample Area W°	Bottom Depth (m)
1	10/14	74	54 42′	165 02′	76
2	10/15	120	55 01′	165 08′	120
3	10/15	110	55 19′	164 34′	110
4	10/15	66	55 01′	164 36′	66
5	10/15	84	55 21′	164 00′	84
6	10/16	104	55 40′	164 42′	104
7	10/16	54	55 21′	163 26′	54
8	10/16	102	55 39′	164 03′	102
9	10/17	102	55 59′	164 35′	102
10	10/17	118	55 20′	165 10′	118
11	10/17	120	55 02′	165 09′	120
12	10/17	138	55 02′	165 45′	138
13	10/18	128	55 20′	165 48′	128
14	10/18	124	55 41′	165 49′	124
15	10/19	128	54 23′	165 46′	128
16	10/20	172	54 50′	165 42′	172
17	10/20	214	54 50′	166 32′	214
18	10/21	158	54 59′	166 28′	158
19	10/26	106	56 41′	168 56′	106
20	10/26	114	56 41′	168 17′	114
21	10/27	82	57 01′	168 56′	82
22	10/27	64	57 01′	169 33′	64
23	10/27	68	57 24′	169 36′	68
24	10/28	56	57 20′	170 12′	56
25	10/28	70	56 59′	170 02′	70
26	10/28	96	57 03′	170 41′	96
27	10/29	102	56 40′	170 04′	102
28	11/1	116	53 54′	164 32′	116
29	11/1	84	53 58′	165 50′	84
30	11/1	170	55 01′	166 57′	170

83-112 Eastern bottom trawl collection data, 1981 (continued)

Sample #	Date	Trawl Depth (m)	Sample Area		Bottom Depth (m)
			N°	W°	
31	11/1	150	55 21′	166 59′	150
32	11/2	144	55 21′	166 23′	144
33	11/2	136	55 40′	166 24′	136
34	11/2	156	55 21′	167 26′	156
35	11/2	192	55 20′	167 47′	192
36	11/3	148	55 40′	168 14′	148
37	11/3	154	55 42′	168 38′	154
38	11/4	104	54 02′	164 34′	104
39	11/4	102	55 47′	164 15′	102

83-112 Eastern bottom trawl collection data, 1982

Sample #	Date	Trawl Depth (m)	Sample Area		Bottom Depth (m)
			N°	W°	
40	9/24	72	54 41′	165 01′	72
41	9/24	78	54 41′	165 01′	78
42	9/24	56	55 00′	164 33′	56
43	9/25	112	55 20′	164 34′	112
44	9/25	78	55 22′	163 60′	78
45	9/25	52	55 21′	163 26′	52
46	9/25	124	55 02′	165 10′	124
47	9/26	136	55 02′	165 44′	136
48	9/26	158	54 59′	166 27′	158
49	9/26	160	55 04′	166 58′	160
50	9/26	120	55 20′	165 10′	120
51	9/27	132	55 20′	165 47′	132
52	9/27	144	55 21′	166 23′	144
53	9/27	142	55 21′	166 27′	142
54	9/27	104	55 40′	164 42′	104
55	9/28	116	55 40′	165 11′	116
56	9/28	126	55 41′	165 49′	126
57	9/28	138	55 40′	166 24′	138
58	9/28	102	55 40′	164 02′	102
59	9/28	102	55 40′	164 03′	102
60	9/29	100	56 00′	164 34′	100
61	9/29	104	56 00′	165 10′	104
62	9/29	94	56 20′	165 12′	94
63	9/29	100	56 20′	165 47′	100
64	9/30	116	56 00′	165 46′	116
65	9/30	138	55 56′	166 25′	138
66	9/30	114	56 40′	168 15′	114
67	10/1	86	57 03′	168 56′	86
68	10/1	108	56 41′	168 55′	108
69	10/1	84	56 43′	169 31′	84

83-112 Eastern bottom trawl collection data, 1982 (continued)

Sample #	Date	Trawl Depth (m)	Sample Area		Bottom Depth (m)
			N°	W°	
70	10/1	64	57 01′	169 33′	64
71	10/2	72	57 24′	169 36′	72
72	10/2	56	57 20′	170 10′	56
73	10/2	104	56 58′	170 48′	104
74	10/3	74	57 00′	170 11′	74
75	10/3	110	56 40′	170 12′	110
76	10/3	120	56 20′	170 11′	120
77	10/3	172	56 20′	168 17′	172
78	10/4	144	56 20′	168 52′	144
79	10/4	162	56 21′	169 26′	162
80	10/4	144	56 22′	169 28′	144
81	10/4	138	56 20′	167 39′	138
82	10/5	122	56 20′	167 02′	122
83	10/5	112	56 19′	166 25′	112
84	10/5	144	56 00′	167 00′	144
85	10/6	142	56 01′	167 37′	142
86	10/6	164	56 00′	168 14′	164
87	10/6	150	55 40′	168 16′	150
88	10/6	150	55 22′	166 58′	150
89	10/6	146	55 40′	166 58′	146
90	10/7	146	55 40′	167 35′	146
91	10/7	158	55 21′	167 26′	158
92	10/8	116	54 15′	166 02′	116
93	10/8	126	54 22′	165 45′	126

83-112 Eastern bottom trawl collection data, 1985

Sample #	Date	Trawl Depth (m)	Sample Area		Bottom Depth (m)
			N°	W°	
94	8/5	210	56 05′	169 32′	210
95	8/6	220	56 07′	169 31′	220
96	8/6	210	56 02′	170 15′	210
97	8/6	332	55 59′	170 08′	332
98	8/7	324	55 59′	170 08′	324
99	8/7	500	56 10′	170 52′	500
100	8/8	160	56 22′	171 18′	160
101	8/9	300	56 21′	171 23′	300
102	8/9	460	56 20′	171 25′	460
103	8/11	130	56 46′	171 21′	130
104	8/11	498	56 32′	172 01′	498
105	8/12	196	56 33′	171 59′	196
106	8/13	170	56 38′	172 22′	170
107	8/13	178	56 38′	172 21′	178
108	8/13	122	57 09′	171 43′	122
109	8/14	100	57 16′	171 24′	116
110	8/14	118	57 57′	171 57′	118
111	8/14	118	57 59′	172 04′	118
112	8/15	82	57 58′	170 05′	82
113	8/16	86	57 56′	170 21′	86
114	8/21	460	56 02′	170 17′	460
115	8/21	130	57 08′	172 56′	130
116	8/22	134	57 05′	172 55′	134

Midwater trawl collection data, 1985

Sample #	Type	Date	Trawl Depth (m)	Sample Area	Bottom Depth (m)
1	Marinovich	8/5	210	continental slope	526
2	Marinovich	8/8	172	oceanic domain	2240
3	Marinovich	8/8	170	continental slope	600
4	Marinovich	8/8	160	continental slope	280
5	Marinovich	8/10	160	oceanic domain	3200
6	Marinovich	8/9	300	oceanic domain	3400
7	Diamond	8/10	180	oceanic domain	3320
8	Diamond	8/14	22	outer shelf domain	114
9	Diamond	8/14	30	outer shelf domain	116
10	Diamond	8/15	80	outer shelf domain	116
11	Diamond	8/15	18	outer shelf domain	116
12	Diamond	8/15	20	outer shelf domain	110
13	Diamond	8/15	16	mid shelf domain	82
14	Diamond	8/17	180	continental slope	240
15	Marinovich	8/20	330	oceanic domain	2780
16	Marinovich	8/20	340	continental slope	1930
17	Marinovich	8/20	200	continental slope	1750
18	Marinovich	8/20	160	oceanic domain	3200
19	Marinovich	8/20	240	continental slope	1200
20	Marinovich	8/21	120	outer shelf domain	144
21	Marinovich	8/21	100	outer shelf domain	148
22	Marinovich	8/21	48	outer shelf domain	132
23	Marinovich	8/21	24	outer shelf domain	130