ESTIMATED ANNUAL FOOD CONSUMPTION BY NORTHERN FUR SEALS IN THE CALIFORNIA CURRENT

GEORGE A. ANTONELIS, JR., AND MICHAEL A. PEREZ
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
National Marine Mammal Laboratory
7600 Sand Point Way NE., Bldg. 32
Seattle, Washington 98115

ABSTRACT

Most of the world's northern fur seals, *Callorhinus ursinus*, migrate southward into the eastern North Pacific Ocean during late fall and early winter, with adult females and juveniles of both sexes ranging as far south as southern California. Peak numbers occur in February off California (268,000), and in April off Oregon (45,500) and Washington (86,000). Northward migration begins by early spring, and fur seals are mostly absent from these regions from July through December, with the exception of a small breeding population of approximately 5,000 animals on San Miguel Island, California.

Estimates of total annual food consumption by the fur seal population off the coastal regions of California (51,000 MT) and Oregon-Washington (35,000 MT) were derived using data from the literature on diet, feeding rates, and migration. Fur seals consume an estimated 48,100 MT of pelagic schooling fish (74%) and squid (26%) during the first 6 months of the year, when they are present off the coast of California in greatest numbers, and approximately 33,600 MT of fish (76%) and squid (24%) from December to June off the Oregon-Washington coast. In California, the most important prey of the fur seal are northern anchovy, *Engraulis mordax* (20,900 MT); Pacific whiting, *Merluccius productus* (8,600 MT); market squid, *Loligo opalescens* (6,200 MT); and onychoteutid squids, *Onychoteuthis* spp (6,200 MT). Off Oregon and Washington, fur seals consume approximately 5,900 MT of herring, *Clupea harengus pallasi*; 5,500 MT of rockfish, *Sebastes* spp; 4,000 MT of northern anchovy; and 3,800 MT of market squid. The fur seals' combined annual consumption of northern anchovy in these areas is approximately 13% of the commercial fishery; for Pacific whiting, consumption is 10%; for Pacific herring, 15%; and for market squid, 50%.

RESUMEN

La mayor parte de las focas *Callorhinus ursinus* emigran al sur, avanzando hacia el este del Pacífico Norte a finales del otoño y principios de invierno, cuando hembras adultas y juveniles de ambos sexos llegan hasta el sur de California. La máxima abundancia en aguas de California ocurre en Febrero (268,000 individuos), y en Abril en Oregon y Washington (45,000 y 86,000 individuos respectivamente). La migración hacia el norte se inicia a principios de la primavera, ausentándose de las regiones mencionadas de Julio a Diciembre, exceptuando una pequeña población de cría, con unos 5,000 animales, que permanece en la Isla San Miguel, California.

Estimaciones sobre el alimento total que consumen anualmente estas poblaciones de focas en las zonas costeras de California asciende a 51,000 Tm, y a 35,000 Tm para Oregon y Washington. En estos cálculos se ha tomado como base los datos publicados sobre dieta, tasa de alimentación y migración. Se estima que estas focas consumen 48,000 Tm de cardúmenes pelágicos de peces y calamares (74% y 26% respectivamente) durante los primeros seis meses del año, cuando se encuentran presente en las zonas costeras de California, y aproximadamente 33,600 Tm de peces y calamares (76% y 24% respectivamente) de Diciembre a Junio en las zonas costeras de Oregon y Washington.

Las presas más importantes para *Callorhinus ursinus* en California son, la anchoveta *Engraulis mordax* (20,900 Tm), la merluza *Merluccius productus* (8,600 Tm) y los calamares *Loligo opalescens* y *Onychoteuthis* spp. (con 6,200 Tm para cada especie).

En aguas de Oregon y Washington, estas focas consumen aproximadamente 5,900 Tm de arenque *Clupea harengus pallasi*, 5,500 Tm de *Scorpaenidae*, 4,000 Tm de anchoveta del norte *Engraulis mordax* y 3,800 Tm de calamares.

En relación con el monto de la pesquería comercial, combinando las áreas geográficas consideradas el consumo anual por las focas corresponde aproximadamente al 13% para *E. mordax*, 10% para *M. productus*, 15% para *C. harengus pallasi* y al 50% para los calamares.

INTRODUCTION

Biological data on northern fur seals, *Callorhinus ursinus*, at sea have been recorded since the days of

[Manuscript received March 26, 1984.]

pelagic sealers in the late nineteenth century. Early literature describing fur seals' food habits and migration off the west coast of North America includes Townsend (1899), Clemens and Wilby (1933), Clemens et al. (1936), Scheffer (1950), Kenyon and Wilke (1953), Wilke and Kenyon (1954), and Taylor et al. (1955). Since 1958, intensive pelagic research on the northern fur seal has been conducted under the auspices of the North Pacific Fur Seal Commission (NPFSC).

The four member countries of the NPFSC (the United States, Canada, Japan, and the Soviet Union) designed this research to facilitate management of the fur seal by collecting information on its reproductive status, growth rates, migratory patterns, and food habits. After 17 years of pelagic research in the eastern North Pacific Ocean and Bering Sea, the United States and Canada suspended their programs to synthesize the accumulated data. Published literature containing summaries of these analyses of fur seals' food habits and migration includes NPFSC (1962, 1969, 1971); Fiscus (1979, 1980, 1982); and Kajimura (1982).

Despite this accumulation of information, few attempts have been made to estimate the biomass of prey consumed by northern fur seals off the western coast of North America south of 49°N latitude (exceptions include Food and Agriculture Organization of the United Nations—FAO 1978; and Bailey and Ainley 1982).

The objectives of this study are (1) to estimate the number of fur seals migrating into the coastal waters (defined as the oceanic region over the continental shelf slope, and not exceeding a distance of 300 km from shore) of California, Oregon, and Washington, and (2) to estimate the total biomass of pelagic fish and squid consumed by fur seals in the California Current. These foraging estimates will also be compared to recent commercial fisheries' catch statistics.

BACKGROUND INFORMATION

Despite a 20% decline in the world's population of northern fur seals over the past 5 years, the total population has been estimated at 1.4 million (NPFSC 1983). During the summer months, most northern fur seals are found on or near the breeding islands. In the eastern portion of the fur seals' range, the population on the Pribilof Islands, Alaska, is approximately 975,000; fewer than 100 are on Bogoslof Island, Alaska, and about 5,000 are on San Miguel Island, California (Kozloff 1981, 1982, 1983; NPFSC 1983; T. R. Loughlin, National Marine Mammal Laboratory, National Marine Fisheries Service, Seattle, Wash., pers. comm. 1983; G. A. Antonelis, Jr., pers. obs.).

In the Pribilof herd, most adult males, some of the adult females, and juveniles of both sexes begin the pelagic stage of their life cycle in the fall. The remaining portion of the population goes to sea by early winter. Most adult males winter in waters at the northern portion of their range. Females and juveniles of both sexes migrate south into waters over the continental shelf and slope of the eastern North Pacific Ocean during winter and early spring, ranging as far south as 30°–32°N latitude (Lander and Kajimura 1982). Although some may migrate only over continental shelf waters, others may move directly across the North Pacific from the Bering Sea to southern wintering areas. Fur seals begin their return migration northward in midspring, and by early summer most have returned to their breeding islands.

Kenyon and Wilke (1953) were the first to suggest, from their review of the literature and pelagic sealing records, that most of the migrating fur seal herd were off the coasts of California, Oregon, and Washington during the month of February. Seal distribution data collected by the United States and Canada from 1958–74 support their opinion: the largest number of seals seen per research effort-hour during winter months occurred in these areas, with the highest concentration off California during February (Kajimura 1980; Bigg 1982).

Kajimura (1980) reported that fur seals are most frequently found from about 74 to 130 km from land and are usually in greatest numbers along the continental shelf and slope where pelagic schooling fishes and squid are generally most abundant. He also reports that fur seals are most frequently found in water which ranges from 8°C to 14°C.

While at sea, fur seals feed on a variety of species. The relative proportion of each prey species in the fur seals' diet varies monthly (Kajimura 1982; Perez and Bigg 1984). This is due to apparent changes in foraging locations, and to seasonal movements, abundance, and availability of the prey. An example of the way the fur seals' diet changes during their winter and spring sojourn off the coast of California is shown in Figure 1. This figure illustrates the average diet as it changes from January to June; fur seals forage primarily on seasonally abundant anchovy in winter and Pacific whiting in spring.

Unfortunately, relatively little is known about the size of prey consumed by northern fur seals. However, on the basis of currently available information (Spalding 1964; Fiscus et al. 1964; Perez and Bigg 1984), we estimate that fur seals usually eat prey that is approximately 10 to 30 cm in length, although they sometimes take larger prey that they must break up before swallowing.

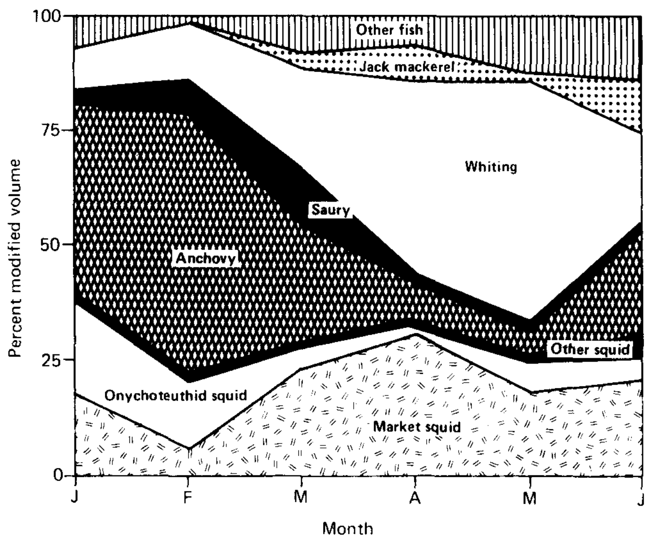

Figure 1. Monthly composition (percentage) of fur seals' diet by species off California from January to June, 1958-74 (modified from Perez and Bigg 1984).

METHODS

Estimates of fur seal abundance and food consumption in this paper were mainly calculated with data from the literature and unpublished manuscripts.

These estimates were based on pooled data for months and years during 17 years of pelagic research off the coasts of California, Oregon, and Washington (1958–74; no data for California after 1966). We assume there has been no change in the migratory behavior or feeding ecology of fur seals since these data were collected.

Population Estimates

Using data presented by Lander (1981) and NPFSC (1983), we calculate that there are about 340,000 adult female fur seals (age ≥ 5 yr) in the total Pribilof Islands stock (this estimate assumes that the current fur seal population decline is equal among all age groups, although there are no data to substantiate this). Using that estimate and data in Bigg (1982; his figures 5c–d) on the ratio of seals sighted at sea during 1958–74 by age, sex, and reproductive status, we calculated the total number of northern fur seals of the Pribilof Islands herd that migrate south of 49°N in the eastern North Pacific. We assume that at least 80% of all pregnant females from the Pribilof Islands population migrate to the west coast of North America between latitudes 32°N and 49°N (Kenyon and Wilke 1953; Kajimura 1980; Bigg 1982). We calculated the total number of seals off California, Oregon, and Washington by month from the 1958-74 pelagic data on seals sighted at sea per research-effort-hour on the basis of the total research area (km^2) between months and regions. (Kajimura 1980 and Bigg 1982 described the survey areas by month.) We also assumed most adult males (> 90%) and immature seals (> 70%) remain in the more northern latitudes, on the basis of sightings off British Columbia and in the Gulf of Alaska during February (Kenyon and Wilke 1953; Kajimura 1980; Bigg 1982).

Our monthly regional estimates were subdivided into three classes: pregnant females (age ≥ 5 yr), nonpregnant females (age ≥ 5 yr), and other seals (immatures, adult males, and pregnant females aged 4 yr). The estimated numbers of seals by class were also calculated using data from Bigg (1982; his figures 5c–d).

For this report, we assumed that most of the resident population from San Miguel Island remains in the waters off California through the summer and fall, although we have little evidence to support this assumption.

Food Consumption

Total food consumption (C) was calculated as:

$$C = N \times D \times R$$

for each region, month, and seal class, where N is the estimated number of seals in each of the three classes, D is the number of days in the month (assumed 30 for all months), and R is the daily food ration of the average individual seal. The daily food ration (R) equals $M \times F$, where M is the average body mass and F is the estimated feeding rate (expressed as a percentage of body mass). We calculated average monthly body mass values for the three classes of seals by weighting the data for each age given by Lander (1979) according to the relative proportion of the population at any age expected to be present in each region per month using data from Bigg (1982; his figures 5c–d). Since body mass data for the San Miguel Island resident population are not available for October–December, we used the September and January average values from the Pribilof Island herd (Lander 1979) as an approximation.

We assumed that all seals present in a region fed daily throughout the entire month, including those seals off California, Oregon, and Washington during the beginning (November–January) and ending (June–July) months of the migratory phase. However, some individual variability is to be expected, and within-month migratory patterns are virtually unknown. In addition, an insignificant number of seals from the Pribilof herd (which we ignored) may be found south of 49°N during August–October.

Perez and Mooney (1984) calculated a feeding rate relationship from data given by Bigg et al. (1978)

based upon captive adult female fur seal feeding studies:

$$\text{Megajoules } (MJ) = 1.571\ M^{0.75}$$

where MJ is the daily energy consumption and M is the seal's body mass in kilograms. The daily energy consumption values calculated by this relationship were converted to feeding rates (F). This was done by calculating the monthly average energy value of the seal's diet, by region, using estimates of the energy content (MJ) of fur seal prey summarized by Perez and Bigg (1984). For the months of July–December (for which fur seal food data are unavailable in the California region), we used the average values calculated for other months.

We calculated feeding rates for all seals (including immatures and an insignificant number of adult males) using the above relationship, although it was based upon data from primarily adult females.

Because most of the seals expected in the North Pacific off California, Oregon, and Washington during winter are adult females, any possible difference in food consumption by age or sex was assumed not to be significant. We also assumed there was no significant increase in ingestion because of pregnancy. However, for lactating females of the San Miguel Island population, we increased the estimated feeding rate by 1.6 to account for milk production, based on data for the Pribilof Island herd (Perez and Mooney 1984).

We used percentage values (modified volume) of fish and squid species in the fur seal diet given by Perez and Bigg (Beddington et al. in press) to estimate biomass of individual prey species consumed by fur seals in each region during winter and spring and also to determine the average energy value of the diet. For Oregon, except for the month of April, we used data taken from subregion 8 (northern Oregon and southern Washington in Perez and Bigg, 1981) as an approximation. We estimated the total biomass of each prey species consumed by multiplying total food consumption by these percentages for each prey. There are no available data on the consumption of prey by the relatively low number of seals utilizing these regions during summer and fall.

RESULTS

Population Estimates

Monthly estimates of population abundance, average body mass, daily energy consumption, average feeding rate, and individual food consumption for the three study groups—pregnant females $\geq$ 5 years of age; nonpregnant females $\geq$ 5 years of age; and others (mostly juveniles of both sexes)—are shown in Table 1. Variations in individual food consumption for these three groups of fur seals are primarily due to differences in the estimated average body mass of individual seals in each group. The body mass estimates reflect the average value for all age classes in each group expected to be found in each region pooled by month (based on data in Bigg 1982 and Lander 1979), and do not necessarily indicate seasonal changes in body mass of any particular age class.

The estimated number of fur seals in the coastal waters of California and Oregon-Washington are shown in Figure 2. These estimates reflect the migratory patterns and relative proportions of fur seals seen by region and month as indicated by Bigg (1982). After the breeding season, about 1,000 fur seals are usually first seen off the coast of Oregon and Washington in November, while the resident population of about 5,000 from San Miguel Island presumably remains off California. By December about 5,600 fur seals are off California and 11,000 off the Oregon-Washington area. Fur seal abundance increases rapidly in California waters, from 68,000 in January to a peak of approximately 268,000 in February. However, some of these seals begin to return north during March, and their abundance off California declines to an estimated 85,000 in March and 24,000 in April. This northward movement is reflected in increased Oregon-Washington estimates, which also represent some southward-moving juveniles (Bigg 1982). After April there is a decreasing trend in the numbers of fur

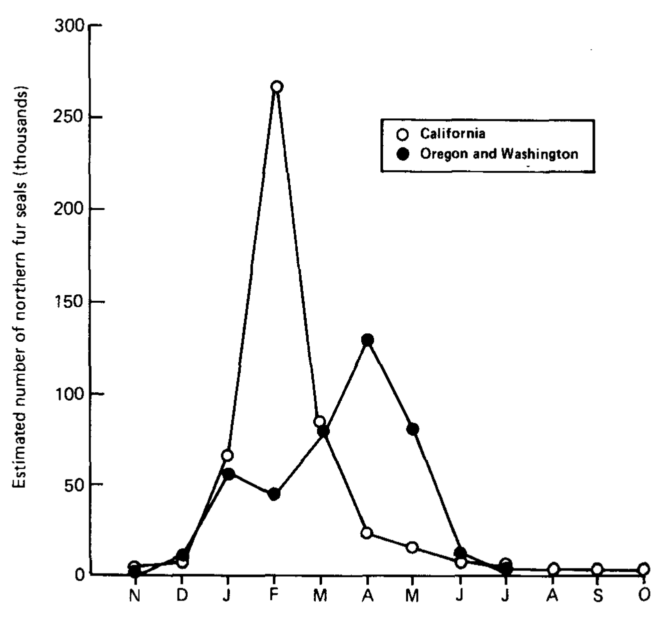

Figure 2. Monthly estimates of abundance of northern fur seals in the offshore waters of California, Oregon, and Washington.

TABLE 1
Average Energy Value of Diet, Population Abundance, Average Body Mass, Feeding Rate, and Daily Food Consumption of Northern Fur Seals

State and month (average energy value of diet)	Fur seal classification (age in years)	Population abundance	Average body mass (kg)[a]	Daily energy consumption per seal (*MJ*)	Feeding rate (% of body mass)[b]	Daily food consumption per seal (kg)
California						
January (5.9 *MJ*/kg)	Preg. females (≥5)	47,600	35.5	22.8	11.0	3.9
	Nonpreg. females (≥5)	11,500	33.7	22.0	11.0	3.7
	Other	9,000	22.7	16.3	12.3	2.8
February (6.6 *MJ*/kg)	Preg. females (≥5)	189,000	35.2	22.7	9.7	3.4
	Nonpreg. females (≥5)	45,000	31.7	21.0	10.1	3.2
	Other	34,000	19.3	14.5	11.4	2.2
March (6.1 *MJ*/kg)	Preg. females (≥5)	50,600	36.3	23.2	10.5	3.8
	Nonpreg. females (≥5)	16,500	30.7	20.5	11.1	3.4
	Other	18,000	18.5	14.0	12.4	2.3
April (5.2 *MJ*/kg)	Preg. females (≥5)	12,600	38.4	24.2	12.2	4.7
	Nonpreg. females (≥5)	4,500	31.3	20.8	12.8	4.0
	Other	7,000	17.5	13.4	14.9	2.6
May (5.3 *MJ*/kg)	Preg. females (≥5)	7,100	42.8	26.3	11.7	5.0
	Nonpreg. females (≥5)	3,000	33.9	22.1	12.4	4.2
	Other	7,000	17.5	13.4	14.9	2.6
June (5.9 *MJ*/kg)	Preg. females (≥5)	2,100	42.8	26.3	10.5	4.5
	Lact. females (≥5)	1,600	34.0	35.7	17.9[c]	6.1
	Nonpreg. females (≥5)	1,900	33.2	21.7	11.1	3.7
	Other	3,900	20.3	15.0	12.8	2.6
July (5.8 *MJ*/kg)	Lact. females (≥5)	1,600	35.6	36.6	17.7[c]	6.3
	Nonpreg. females (≥5)	500	33.9	22.1	11.2	3.8
	Other	1,400	17.6	13.5	13.2	2.3
August (5.8 *MJ*/kg)	Lact. females (≥5)	1,600	36.5	37.3	17.6[c]	6.4
	Nonpreg. females (≥5)	500	34.0	22.1	11.2	3.8
	Other	1,400	23.1	16.5	12.3	2.8
September (5.8 *MJ*/kg)	Lact. females (≥5)	1,600	36.8	37.3	17.5[c]	6.4
	Nonpreg. females (≥5)	500	32.1	21.2	11.3	3.6
	Other	1,400	23.1	16.5	12.3	2.8
October (5.8 *MJ*/kg)	Lact. females (≥5)	1,600	36.2	37.3	17.6[c]	6.4
	Nonpreg. females (≥5)	500	33.3	21.8	11.2	3.7
	Other	1,400	23.1	16.5	12.3	2.8
November (5.8 *MJ*/kg)	Preg. females (≥5)	1,600	36.9	23.5	11.1	4.1
	Nonpreg. females (≥5)	500	35.5	22.8	11.0	3.9
	Other	3,000	19.8	14.7	12.6	2.5
December (5.8 *MJ*/kg)	Preg. females (≥5)	1,950	36.7	23.4	10.9	4.0
	Nonpreg. females (≥5)	600	33.4	21.8	11.1	3.7
	Other	3,050	19.7	14.7	12.7	2.5
Oregon						
January (7.0 *MJ*/kg)	Preg. females (≥5)	1,000	34.8	22.5	9.3	3.2
	Nonpreg. females (≥5)	500	32.4	21.3	9.5	3.1
	Other	500	18.1	13.8	11.0	2.0
February (6.5 *MJ*/kg)	Preg. females (≥5)	1,000	34.5	22.4	10.0	3.4
	Nonpreg. females (≥5)	500	31.4	20.8	10.2	3.2
	Other	1,000	14.3	11.5	12.2	1.8
March (6.2 *MJ*/kg)	Preg. females (≥5)	4,000	35.9	23.0	10.3	3.7
	Nonpreg. females (≥5)	2,000	30.3	20.3	10.7	3.3
	Other	5,000	14.2	11.5	13.0	1.9
April (5.4 *MJ*/kg)	Preg. females (≥5)	22,500	37.4	23.8	11.7	4.4
	Nonpreg. females (≥5)	8,000	29.0	19.6	12.5	3.6
	Other	15,000	16.4	12.8	14.4	2.4
May (6.4 *MJ*/kg)	Preg. females (≥5)	700	39.8	24.9	9.7	3.9
	Nonpreg. females (≥5)	300	28.9	19.6	10.5	3.1
	Other	1,500	17.0	13.1	12.0	2.1
June (4.1 *MJ*/kg)	Preg. females (≥5)	100	43.1	26.4	14.9	6.4
	Nonpreg. females (≥5)	200	31.5	20.9	16.2	5.1
	Other	1,700	18.6	14.1	18.5	3.4
July-November	Preg. females (≥5)	—	—	—	—	—
	Nonpreg. females (≥5)	—	—	—	—	—
	Other	—	—	—	—	—
December (7.6 *MJ*/kg)	Preg. females (≥5)	500	38.2	24.1	8.3	3.2
	Nonpreg. females (≥5)	250	33.2	21.7	8.6	2.8
	Other	250	24.4	17.2	9.2	2.3

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Table 1—*continued*

State and month (average energy value of diet)	Fur seal classification (age in years)	Population abundance	Average body mass (kg)[a]	Daily energy consumption per seal (*MJ*)	Feeding rate (% of body mass)[b]	Daily food consumption per seal (kg)
Washington						
January (7.6 *MJ*/kg)	Preg. females (≥5)	28,000	34.8	22.5	8.5	2.9
	Nonpreg. females (≥5)	11,000	32.4	21.3	8.6	2.8
	Other	15,000	18.1	13.8	10.0	1.8
February (6.6 *MJ*/kg)	Preg. females (≥5)	19,000	34.5	22.3	9.9	3.4
	Nonpreg. females (≥5)	7,000	31.4	21.0	10.1	3.2
	Other	18,000	14.3	11.9	12.3	1.8
March (6.4 *MJ*/kg)	Preg. females (≥5)	28,000	35.9	23.0	10.1	3.6
	Nonpreg. females (≥5)	12,000	30.3	20.3	10.5	3.2
	Other	34,000	14.2	11.5	12.7	1.8
April (6.8 *MJ*/kg)	Preg. females (≥5)	34,000	37.0	23.6	9.3	3.5
	Nonpreg. females (≥5)	14,000	29.7	20.0	9.9	2.9
	Other	38,000	15.5	12.3	11.6	1.8
May (6.8 *MJ*/kg)	Preg. females (≥5)	22,000	39.8	24.9	9.1	3.6
	Nonpreg. females (≥5)	10,000	28.9	19.6	9.9	2.9
	Other	49,000	17.0	13.1	11.3	1.9
June (7.9 *MJ*/kg)	Preg. females (≥5)	500	43.1	26.4	7.7	3.3
	Nonpreg. females (≥5)	1,000	31.5	20.9	8.4	2.6
	Other	8,500	18.6	14.1	9.5	1.7
July (7.0 *MJ*/kg)	Preg. females (≥5)	50	36.0	23.1	11.0	4.0
	Nonpreg. females (≥5)	100	34.7	22.5	11.1	3.9
	Other	850	19.2	14.4	12.9	2.5
August-October	Preg. females (≥5)	—	—	—	—	—
	Nonpreg. females (≥5)	—	—	—	—	—
	Other	—	—	—	—	—
November (7.0 *MJ*/kg)	Preg. females (≥5)	500	38.2	24.1	10.9	4.2
	Nonpreg. females (≥5)	200	33.2	21.7	11.2	3.7
	Other	300	24.4	17.2	12.1	3.0
December (7.6 *MJ*/kg)	Preg. females (≥5)	5,000	38.4	24.2	8.3	3.2
	Nonpreg. females (≥5)	2,500	33.0	21.6	8.6	2.8
	Other	2,500	24.3	17.2	9.3	2.3

[a]Average body mass for all ages combined expected to be present in the region by month. Body mass values at each age (Lander 1979) were weighted by the expected population abundance of each age group (based on data in Bigg 1982).
[b]Feeding rates were calculated after estimating daily energy consumption based upon the seal's average body mass, and accounting for the average energy content of the seal's diet in the region by month.
[c]The feeding rate for lactating females (pregant females during June-September) of the San Miguel Island population was estimated to be 1.6 times that of the feeding rate for postpartum females (same age and body mass) not producing milk, based upon data from the Pribilof Island population in Perez and Mooney (1984).

seals in both areas, and by July approximately 1,000 fur seals remain off the coast of Oregon and Washington, representing the last of the northward migrating seals. These estimates account for migration of 80% of the entire adult female (age ≥ 5 yr) fur seal population south of 49°N latitude, with peak numbers occurring in February. In addition, approximately 20% of all juvenile fur seals from the Pribilof herd were estimated to migrate into this region during winter, reaching their peak abundance in March.

Estimates of Food Consumption

Estimates of the total annual consumption of pelagic schooling fish and squid by northern fur seals in the coastal waters of California, Oregon, and Washington are given in Figures 3 and 4. Off the coast of California, fur seals consumed an estimated 51,000 MT, and off Oregon-Washington they consumed about 35,000 MT.

In the regions considered, the greatest biomass is consumed during winter and spring, when fur seals are most abundant in offshore waters. Estimates of the monthly biomass of the most common prey consumed

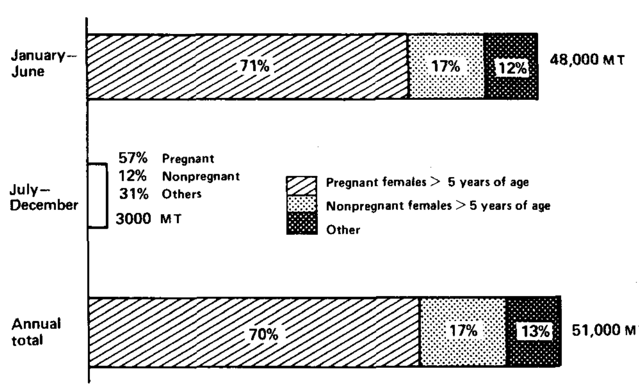

Figure 3. Biomass estimates of food consumed by northern fur seals in California coastal waters.

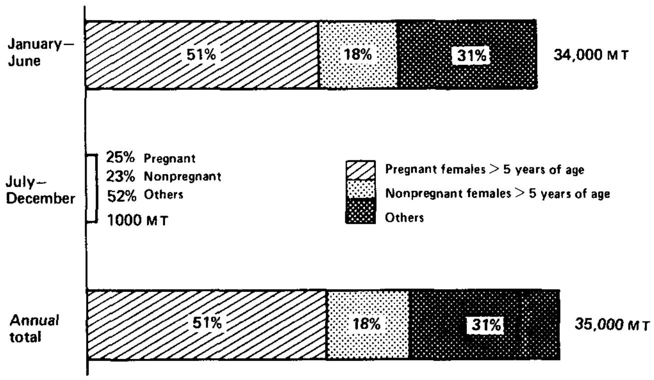

Figure 4. Biomass estimates of food consumed by northern fur seals in Oregon-Washington coastal waters.

during this time are shown in Tables 2 and 3. From January to June, fur seals consumed an estimated 48,100 MT of fish (74%) and squid (26%) in California waters, while approximately 33,600 MT of fish (76%) and squid (24%) were consumed in the Oregon-Washington region from December–June.

In Figures 5 and 6 the biomass of each prey is expressed as a percentage of the total biomass consumption estimates for the two regions. In California, northern anchovy (*Engraulis mordax*) is clearly the most important prey, and accounts for 20,900 MT (43.4%) of the population's estimated consumption in that region (Figure 5). This was followed by Pacific whiting (*Merluccius productus*) at 17.8% (8,600 MT) of the estimated consumption, and both market squid and onychoteuthid squids (mainly *Onychoteuthis borealijaponicus*) at 12.8% (6,200 MT). Each of the four remaining species (Pacific saury, *Cololabis saira*; jack mackerel, *Trachurus symmetricus*; rockfish, *Sebastes* spp; and sablefish, *Anoplopoma fimbria*) appear to be relatively unimportant in California waters, contributing less than 10% of the total estimate.

TABLE 2
Estimated Consumption of Prey by Fur Seals off California

Prey	January	February	March	April	May	June
	Estimated biomass (metric tons) of food consumed					
Northern anchovy	3,120	15,060	2,042	243	130	248
Pacific saury	158	1,801	1,033	42	22	18
Pacific whiting	776	3,367	1,953	1,222	1,064	191
Jack mackerel	—	157	208	215	8	122
Rockfish	173	209	139	1	136	75
Sablefish	—	26	—	1	105	53
Other fishes	332	104	625	170	2	1
Subtotal (fish)	4,559	20,724	6,050	1,894	1,467	708
Market squid	1,319	1,436	1,997	862	349	209
Onychoteuthid squids	1,605	3,941	434	71	138	52
Other squids	53	1	200	3	20	39
Subtotal (squid)	2,977	5,378	2,631	936	507	300
TOTAL	7,536	26,102	8,681	2,830	1,974	1,008

A somewhat different and more diverse group of prey species was observed off the Oregon-Washington coasts (Figure 6). In this region, Pacific herring (*Clupea harengus pallasi*) and rockfish were the two most important prey, accounting for 5,900 MT (17.7%) and 5,500 MT (16.3%) of the estimated biomass, respectively. The next three most important species—northern anchovy, salmonids, and market squid—all had similar estimates ranging from 3,800 to 4,000 MT, which represented 11% to 12% of the estimated biomass. The remaining prey species that contributed less significantly (< 10%) to the biomass consumed off the Oregon-Washington area were onychoteuthid squids, Pacific whiting, capelin (*Mal-*

TABLE 3
Estimated Consumption of Prey Species by Fur Seals off Oregon and Washington

Prey	December	January	February	March	April	May	June
	Estimated biomass (metric tons) of food consumed						
Pacific herring	290	1,593	363	618	1,114	1,554	400
Northern anchovy	6	204	777	1,727	983	341	—
Salmonids	69	935	531	630	858	848	26
Capelin	91	109	401	341	177	88	—
Eulachon	93	117	168	58	170	1	—
Pacific whiting	66	46	1	1	828	420	49
Rockfish	—	270	853	2,078	2,139	136	—
Sablefish	152	231	1	6	347	158	—
Other fishes	34	109	143	449	1,089	233	1
Subtotal (fish)	801	3,614	3,238	5,908	7,705	3,779	476
Market squid	57	744	351	860	1,702	1	103
Onychoteuthid squids	1	1	18	133	1,056	1,586	223
Other squids	1	17	155	35	152	859	4
Subtotal (squid)	59	762	524	1,028	2,910	2,446	330
TOTAL	860	4,376	3,762	6,936	10,615	6,225	806

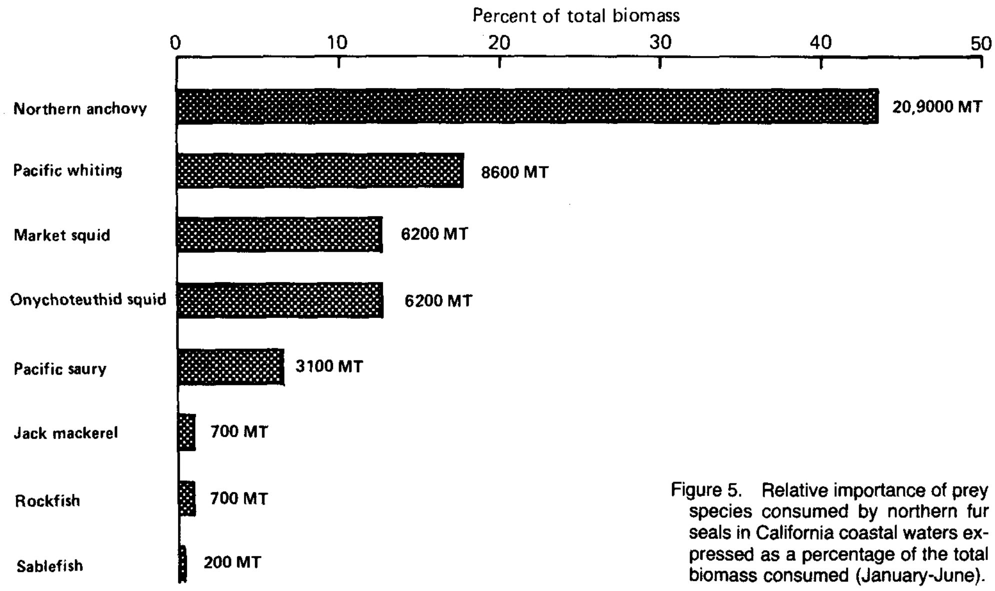

Figure 5. Relative importance of prey species consumed by northern fur seals in California coastal waters expressed as a percentage of the total biomass consumed (January-June).

lotus villosus), sablefish, and eulachon (*Thaleichthys pacificus*).

DISCUSSION

Comparisons with Other Estimates

Our estimates of population size by month (Table 1) should reflect patterns in fur seals' migrating behavior during winter and spring, assuming there has been no significant change in this behavior during the past 30 years. In other words, the estimated values may change over time, but the migrating patterns as shown in Figure 2 should be similar during the foreseeable future.

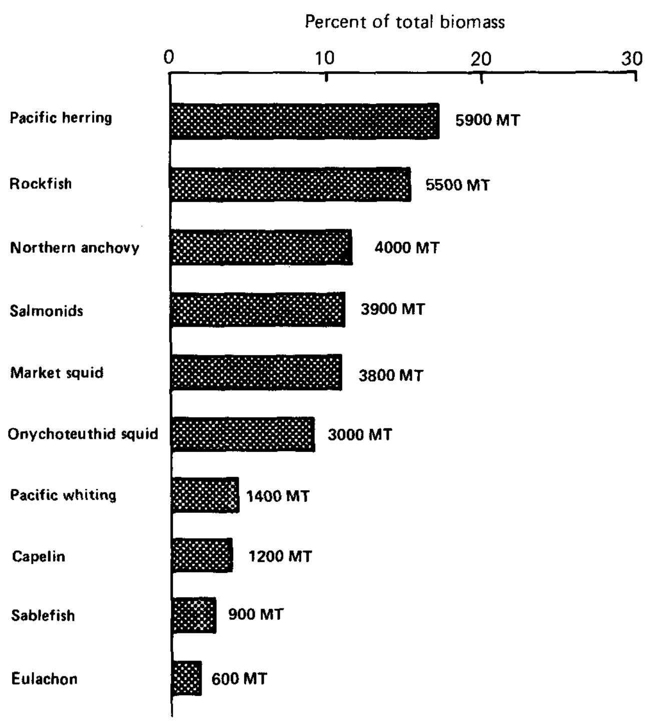

Figure 6. Relative importance of prey species consumed by northern fur seals in coastal waters of Oregon-Washington expressed as a percentage of the total biomass consumed (December-June).

Our peak estimate of 309,000 fur seals migrating south of 49°N latitude during the month of February is lower than the estimate of 500,000 given by Fiscus (1980). This is probably due in part to the decline in the fur seal population that has occurred in recent years. Additionally, Fiscus based his estimate on the number of fur seals that occurred within the range of the Pacific whiting, an area that included some seals north of our area of interest.

In a more recent study of the distribution of pinnipeds off the central and northern California coast, Bonnell et al. (1983) estimated the peak abundance of northern fur seals at 25,000 (±8,500) during February–March. Although their report is consistent with previous reports on the occurrence of peak fur seal abundance (Kajimura 1980; Bigg 1982) off California, their estimated numbers are 87% lower than our peak estimates. The apparent reason for this discrepancy is that we examined a larger study area, extending offshore 300 km, whereas they surveyed the coastal waters only to 185 km.

Our estimate of food consumption by fur seals off California at 12,200 MT. Our estimate (8,600 MT) MT reported by FAO (1978). We assume the FAO estimate is higher than ours because it treated the entire population of migrants as a single unit, presumed to be present during all winter and spring months. Furthermore, their population estimates were made

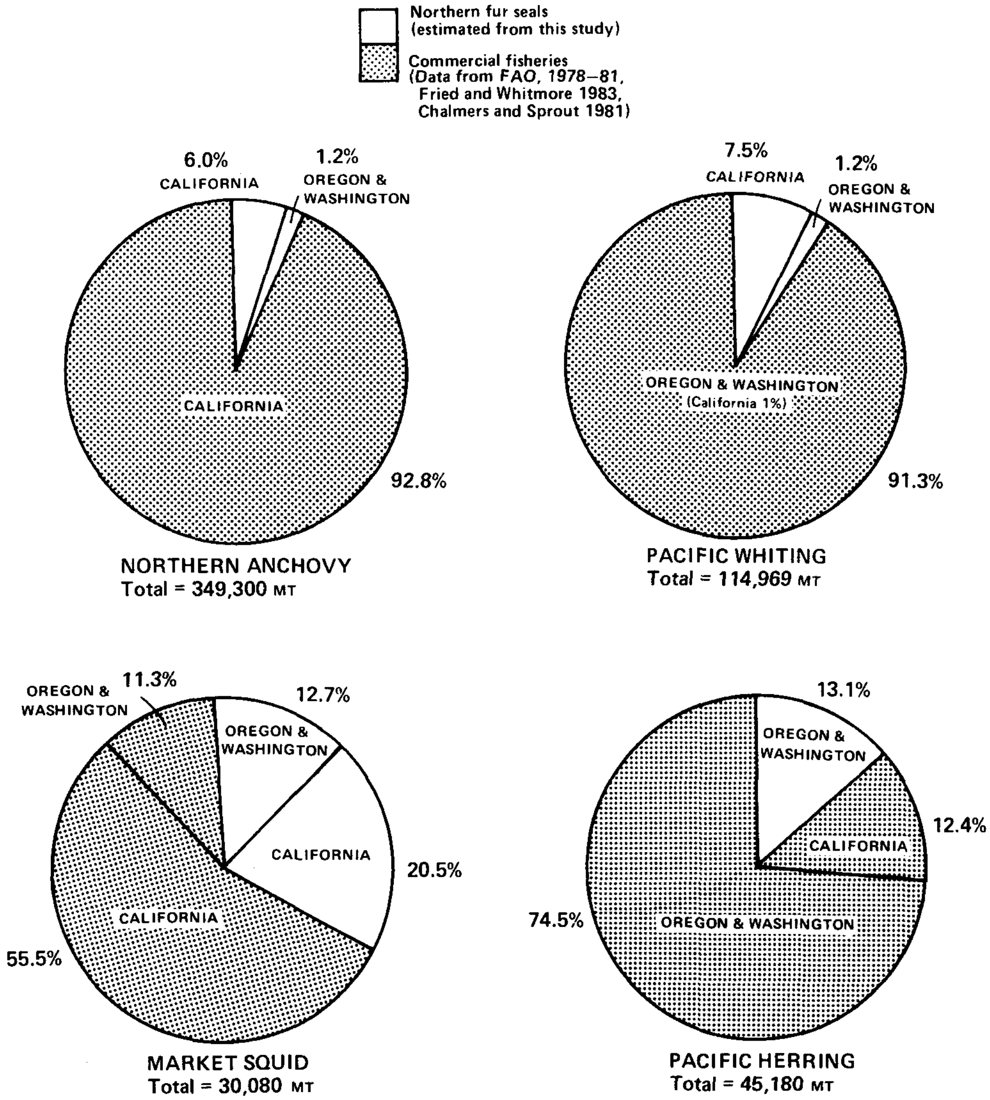

Figure 7. Annual take of biomass (MT) by northern fur seals and commercial fisheries off California, Oregon, and Washington.

several years before the recent 20% decline in the population was reported (NPFSC 1983).

In another study, Bailey and Ainley (1982) estimated the Pacific whiting consumption by fur seals off California at 12,200 MT. Our estimate (8,600 MT) was 70% of their value, because of differences in estimating the percentage of Pacific whiting in the diet and the time northern fur seals remain in the waters off California.

Potential Competition between Fur Seals and Man

Figure 7 illustrates the proportion of four prey species (northern anchovy, Pacific herring, Pacific whiting, and market squid) taken by fur seals and commercial fisheries. It is apparent that fur seals remove only a small percentage of the total anchovy taken in this comparison, yet this is their most important prey off the coast of California. It should be noted, moreover, that the majority of fur seals forage in areas north of the important commercial southern California fishing grounds for northern anchovy, further reducing the potential for direct competition.

The most important commercial harvest of Pacific whiting is off Oregon-Washington, whereas central California is the area with the most significant take by northern fur seals. Pacific whiting, like the northern anchovy, appears to be most heavily preyed upon by northern fur seals in areas that have the least commercial fishing activity.

There are also differences in the location of Pacific herring taken by commercial fisheries and northern fur seals, even though both take greatest quantities from Oregon-Washington waters. Commercial fisheries concentrate their harvest in nearshore waters, including bays and estuaries; northern fur seals forage most frequently in offshore waters. The seals forage most heavily on Pacific herring in the northern portion of the Oregon-Washington region, around the U.S.-Canadian border (Taylor 1974).

Market squid is the only species in our comparison whose overall take by fur seals approaches that of the commercial fisheries. However, this relationship could change in the future because market squid is currently considered an underutilized fisheries resource (Kato and Hardwick 1976). Like Pacific herring, market squid are primarily taken in the offshore waters by fur seals and nearshore by commercial fisheries.

Considering these four prey species, it appears that the potential for direct competition between fisheries and fur seals is low because of the geographical separation in the main areas of harvest. It should be pointed out, however, that there may be a slight bias in the commercial fisheries information resulting from an underestimation of the take off California and an overestimation of the take off Oregon and Washington. This resulted when FAO catch statistics off the west coast of North America were summarized into only two regions (the area north of Eureka, California, is included with Oregon in one region, whereas the rest of California is in a second region). Nevertheless, we believe our comparisons are not compromised by this bias.

Implications of Dietary Habits

The northern fur seal is not a specialized predator (Bonner 1982) and feeds on a wide range of seasonally abundant prey species (Antonelis and Fiscus 1980; Kajimura 1982). However, it routinely forages on a relatively small number of these prey within a specific region at any given time (Kajimura 1982; Perez and Bigg 1984). Monthly, and possibly interannual, changes in the proportion of different prey in the diet are primarily due to availability and abundance. This might result from a variety of factors such as depletion of resources by commercial fisheries, interspecific competition, disease, or climatic changes (MacCall 1983; Moyle and Cech 1982).

It has been suggested by Perez and Bigg (1984) that some food types may be more important than others because of their energy content. Consequently, in addition to the quantity, the "quality" (energy content) of various prey may affect the foraging success of fur seals. The importance of quality food has also been discussed by Geraci (1975). This may be especially important if we consider the large numbers of pregnant females that migrate to the coastal waters off California, Oregon, and Washington. The level of nutrition obtained by these females should have a physiological effect on their fetuses. For fur seals, such an effect could result in reduced size of the fetus or inability to bring the offspring to full term, phenomena which have been reported for other mammals (Sadleir 1976; Millar 1977; Payne and Wheeler 1968).

Future studies on fur seals should closely investigate factors affecting their migratory patterns and food habits. This kind of research is important because fur seals spend at least 88% of their life at sea. Thus the quality and quantity of food available to pregnant northern fur seals foraging in the eastern North Pacific is of great importance to the growth of the population, and any perturbation in the ecosystem, including overexploitation from commercial fisheries or major climatic disturbance (e.g., El Niño), could directly or indirectly affect their reproductive success.

ACKNOWLEDGMENTS

We thank the many research biologists who collected migration and food-habit information on the northern fur seal. Valuable comments on early drafts of the manuscript were provided by Robert DeLong, Clifford Fiscus, Hiroshi Kajimura, Thomas Loughlin, and R.V. Miller. Vickie Menshouse typed the manuscript and Jim Peacock assisted in preparing the figures.

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