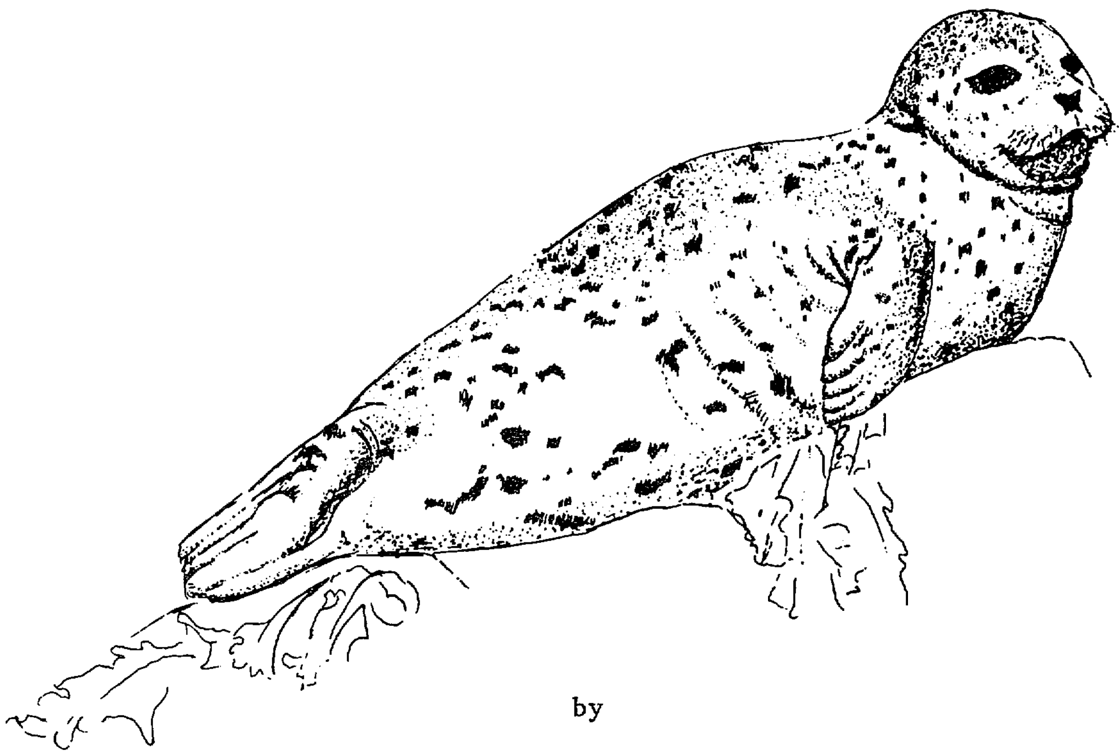
BIOLOGY OF THE HARBOR SEAL, PHOCA VITULINA RICHARDSI,

IN THE GULF OF ALASKA



by

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INTRODUCTION

Land breeding harbor seals, *Phoca vitulina richardsi*, (Shaughnessy and Fay 1977) are an abundant and ubiquitous resident pinniped along the coast of the Gulf of Alaska. Exploration for and development and transportation of petroleum reserves in the Gulf of Alaska appear to have a number of potentially harmful effects on harbor seal populations. Field studies were conducted from 1975 through 1978 on diverse aspects of harbor seal biology to obtain information which would be of value in guiding developmental activities in a direction which would minimize adverse impacts on harbor seal populations. These data would also serve as baselines against which future information could be compared. Our general strategy was to conduct a basic, ecological life history study of the harbor seal focusing on several specific areas which appeared to have the greatest potential for development related impacts. Explicit objectives included: (1) determination of food habits and identification of important prey items, (2) measurement of growth and physical condition and (3) delineation of the reproductive cycle with estimates of basic parameters including age specific pregnancy rates and age of sexual maturity. Secondary objectives included accumulation of data on distribution, locations of major haulout areas, population composition, mortality rates, timing of molting activities and effects of disturbance. During FY 1978 several additional aspects of harbor seal biology were examined including range of individual movements, haulout area fidelity, haulout patterns and counts of seals at key haulout areas in each lease area.

Bishop (1967) conducted the first life history study of harbor seals in the Gulf of Alaska. He combined a cementum annuli age determination technique with reproductive tract analyses to obtain information on the reproductive cycle of harbor seals. Bishop also collected information on behavior, population composition and productivity during observational studies on Tugidak Island. From 1956 to 1958 Mathisen and Lopp (1963) photographed and counted concentrations of harbor seals in conjunction with a census of Steller sea lions (*Eumetopias jubatus*). Imler and Sarber (1947) reported on stomach contents of seals collected on the Copper River Delta during the months of June and July. The Alaska Department of Fish and Game (ADF&G) conducted harbor seal studies on Tugidak Island from 1965-1972. Although the main emphasis of this work was monitoring a commercial harvest, over 4,000 pups were tagged providing information on dispersal and providing known age specimens used to evaluate age determination techniques. Seasonal distribution surveys were conducted in the Prince William Sound area by ADF&G in 1973 and 1974 (Pitcher and Vania 1973; Pitcher 1975). Additional studies provided information on population productivity, growth, condition and food habits in Prince William Sound (Pitcher 1977). The latter provided the first sizable sample of data from any area in the Gulf of Alaska and is useful for comparative purposes. A general discussion and maps of harbor seal distribution and abundance in the Gulf of Alaska were presented by Calkins et al. (1975). Fiscus et al. (1976) reported offshore observations of harbor seals in the Gulf of Alaska.

Broad limits of the study area were Yakutat Bay to the southeast and Sanak Island to the southwest (Figure 1). Little work was done in Prince William Sound or in Cook Inlet north of Kachemak and Kamishak Bays.

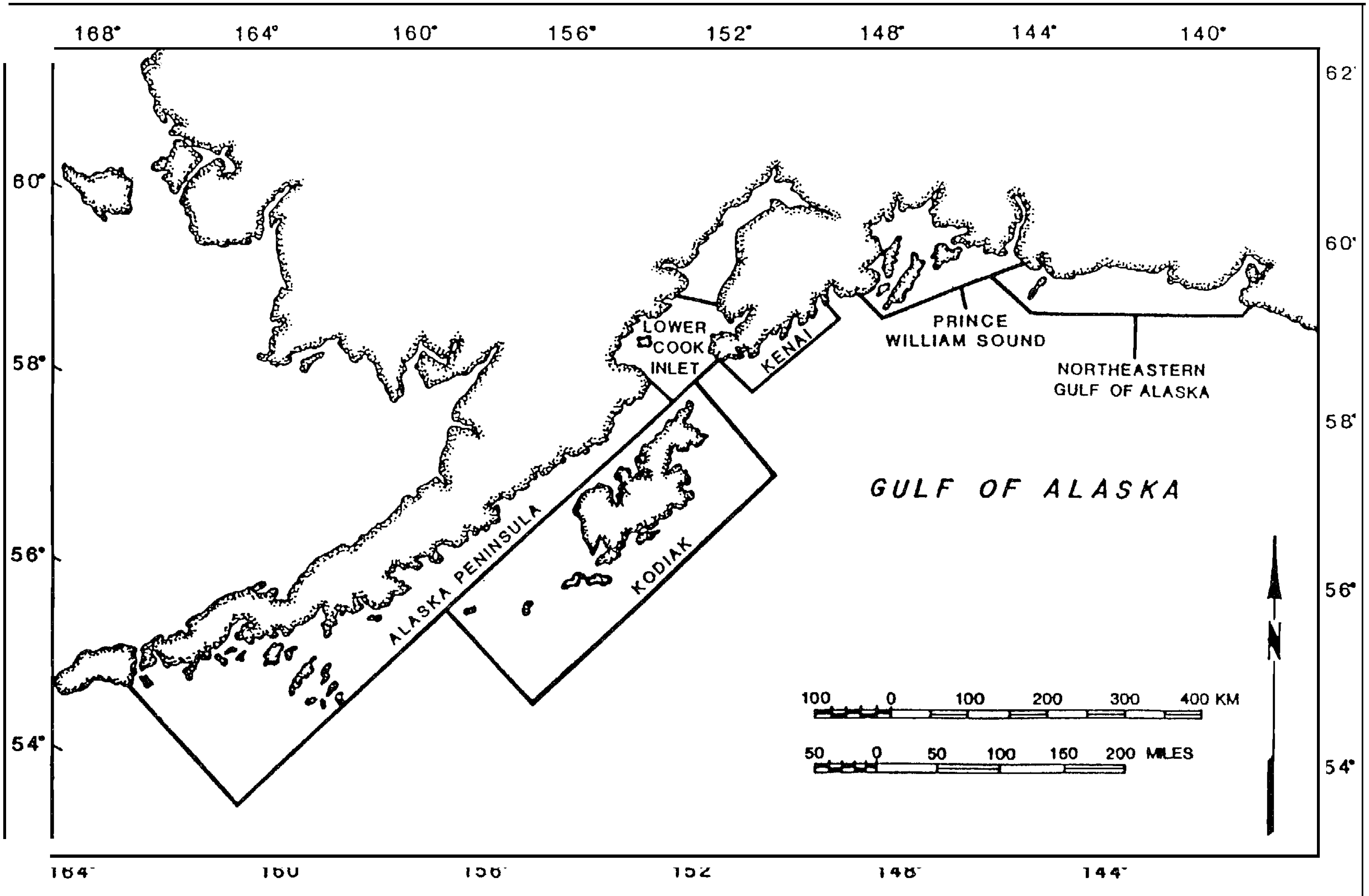

FIGURE 1. GULF OF ALASKA STUDY AREA SHOWING GEOGRAPHIC SUBDIVISIONS.

METHODS

Harbor seals were collected by shooting. Collections were scheduled to obtain representative seasonal and geographic coverage. Total weights and the following measurements were taken from collected animals: standard length, curvilinear length, axillary girth, hind flipper length and blubber thickness. All measurements except standard length were made as detailed by Scheffer (1967). Standard length measurements were made with the "back" or dorsal surface up rather than the "belly" or ventral surface up. A sample of 100 animals was measured using both methods and the paired measurements were subjected to linear regression analysis. There was a highly significant correlation between the two measurements ($r = 0.99$, $P<0.001$) and a formula ($Ye = 2.35 + 1.0(X)$ was derived to estimate "belly up" (Ye) from "back up" (X) standard length. All standard lengths in this report are the "back up" measurement. Persons wishing to compare data can use the formula for conversions.

Ages of collected animals were estimated by counts of cementum annuli in canine teeth. Teeth were decalcified, sectioned (about 48 microns) and stained with hematoxylin (Johnson and Lucier 1975). Annual deposition of cementum annuli was confirmed by examination of teeth from four known age seals (tagged as pups during the 1960's and collected on Tugidak Island during this study).

The ovaries and uterus from each female seal were preserved in formalin. Each uterus was opened and the presence of an embryo, fetus or placental scars was recorded. Ovaries were sectioned with a scapel at about 1 mm. The number and size of graffian follicles, corpora lutes and corpora albicantia were recorded thus allowing reconstruction of a partial reproductive history for each female. Testes and epididymides were taken from male seals and preserved in formalin. Microscopic examinations were made of epididymal fluid to determine whether sperm were present.

Stomach contents were preserved in a 10% formalin solution. In the laboratory, total volume was determined by water displacement. The contents were sorted by species when possible and volumes were determined for each taxon. Identifications were made by examination of recognizable individuals and skeletal materials, particularly fish otoliths (sagittae) and cephalopod beaks.

Pelage samples for analysis of progression of the molt were taken from the mid-dorsal line between the front flippers and preserved in formalin. Laboratory procedures followed Scheffer and Johnson (1963) in which thin slices were cut parallel to the lay of the roots in a plane midway between frontal and horizontal. Each slice was about 2/3 mm thick and 10 mm wide. Sections were allowed to dry then cleared with a drop or two of cedarwood oil. Stage of molt was determined by examining sections with a dissecting microscope at about 10x.

Concentrations of harbor seals seen during collecting cruises and radio tracking surveys were recorded. Personnel of other marine mammal projects and sea bird projects provided additional observations.

A field camp was manned on Tugidak Island from 15 May to 29 September 1976. Periodic censuses were made on the southwest hauling area. Instances of disturbances, both man-related and natural, were documented. Progression of life history events (i.e. birth, lactation, weaning and molting) was determined. A field camp was also manned on Tugidak Island from 15 April to 12 July and 31 July to 6 September 1978. Radio transmitters were attached around the ankles of the hind flippers of 35 seals. Daily checks were made on the southwest hauling area to determine how frequently the radio-tagged seals hauled out. Concurrent counts of total numbers of hauled out seals were made and notes on disturbances and observations on life history events taken. Periodic radio tracking surveys were flown from 8 June to 9 September 1978 to locate radio-tagged animals which had moved from their capture location on Tugidak Island.

Short term field camps were established on Elizabeth Island (LCI) and Channel Island (NEGOA), both of which are major harbor seal hauling areas. Daily counts of seals were made at low tide. From this series of counts, means and associated standard deviations were calculated.

Standard statistical techniques (Snedecor and Cochran 1967) were used in data analysis. Confidence intervals for proportions were calculated for pregnancy rates and for occurrences of prey species. Confidence intervals for means were calculated for weights, standard lengths and blubber thickness. One-way analysis of variance and t-tests were used to test for differences in independent samples of measurement data. A modified t-test was employed for comparing ages of sexual maturity. Statistical comparisons of frequency of occurrences of prey and of sex ratios were made with chi-square analysis when sample sizes were adequate. Linear regression analysis was used to derive a formula for estimating "belly up" standard length from "back up" standard length measurements and to estimate the amount of variance within counts of hauled out seals associated with stage of tide.

To consolidate the food habits data from both frequency of occurrence and volumetric analyses and to provide a single ranking of prey species a modified Index of Relative Abundance (IRI) was calculated (Pinkas et al. 1971). Because of the vast differences in size of harbor seal prey items the numerical analysis was eliminated. Therefore, the modified IRI was calculated as percentage of occurrences x percentage of volume.

DISTRIBUTION OF HARBOR SEALS IN THE GULF OF ALASKA

Harbor seals have a continuous distribution along the coastal Gulf of Alaska. They occupy virtually all nearshore marine habitats and seasonally are found in certain rivers and lakes. Although harbor seals are generally considered a *coastal* species, sightings of animals up to 100 km offshore (Wahl 1977; Fiscus et al. 1976; Spalding 1964) suggest pelagic distribution of at least some individuals.

Collection of accurate and meaningful data on distribution is difficult because the only time harbor seals are easily seen is when they are hauled out. Surveys of hauled out animals do not provide information on aquatic distribution which is a critical component of their life history.

Because of this problem a formal program to collect distributional data was not conducted. Nevertheless, concentrations of harbor seals encountered during field operations were recorded. Observations by other workers, particularly Sears and Zimmerman (1977) and Arneson RU-003[1] were also compiled. Files of the Alaska Department of Fish and Game were searched for appropriate sightings. Because virtually all sightings were of hauled out animals and because there are thousands of haulout areas in the Gulf of Alaska, only major sites (where 25 or more seals were seen) are reported. Commonly used haulout substrates in the Gulf included offshore reefs, rocks and ledges, beaches of isolated islands, mainland or island beaches backed by cliffs, sand and mud bars (often located in estuaries), ice floes calved from tidewater glaciers and sea ice.

Geographical coverage included the coastal Gulf of Alaska north and west of Ocean Cape (Yakutat Bay) to Chirikof Island. Prince William Sound is not included since detailed results of surveys in that area were previously reported by Calkins et al. (1975). Cook Inlet north of Anchor Point and Chinitna Bay also is not included.

Attempts to classify critical habitat may not be appropriate for harbor seals in the Gulf of Alaska. The fact that harbor seals are widely distributed and are not restricted to a few limited localities in obtaining requirements for successful culmination of their life cycle reduces the value of critical habitat classification. On the basis of our current level of knowledge, the only criterion we could use to assign and rate critical habitats would be the number of animals observed at particular locations.

Figures 2–4 show the locations of major harbor seal concentrations in the Gulf of Alaska. Tables 1-5 summarize information on each of the concentration areas. It must be emphasized that the catalog of concentration areas is incomplete. No attempt should be made to relate the number hauled out at any particular site to total population for that area. Available information indicates that only a relatively small proportion of the total is hauled out at any given time (see discussion on haulout patterns in this report and Summers and Mountford 1975).

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1 Arneson, P. A. OCSEAP RU 003. Identification, Documentation and Delineation of Coastal Migratory Bird Habitat in Alaska.

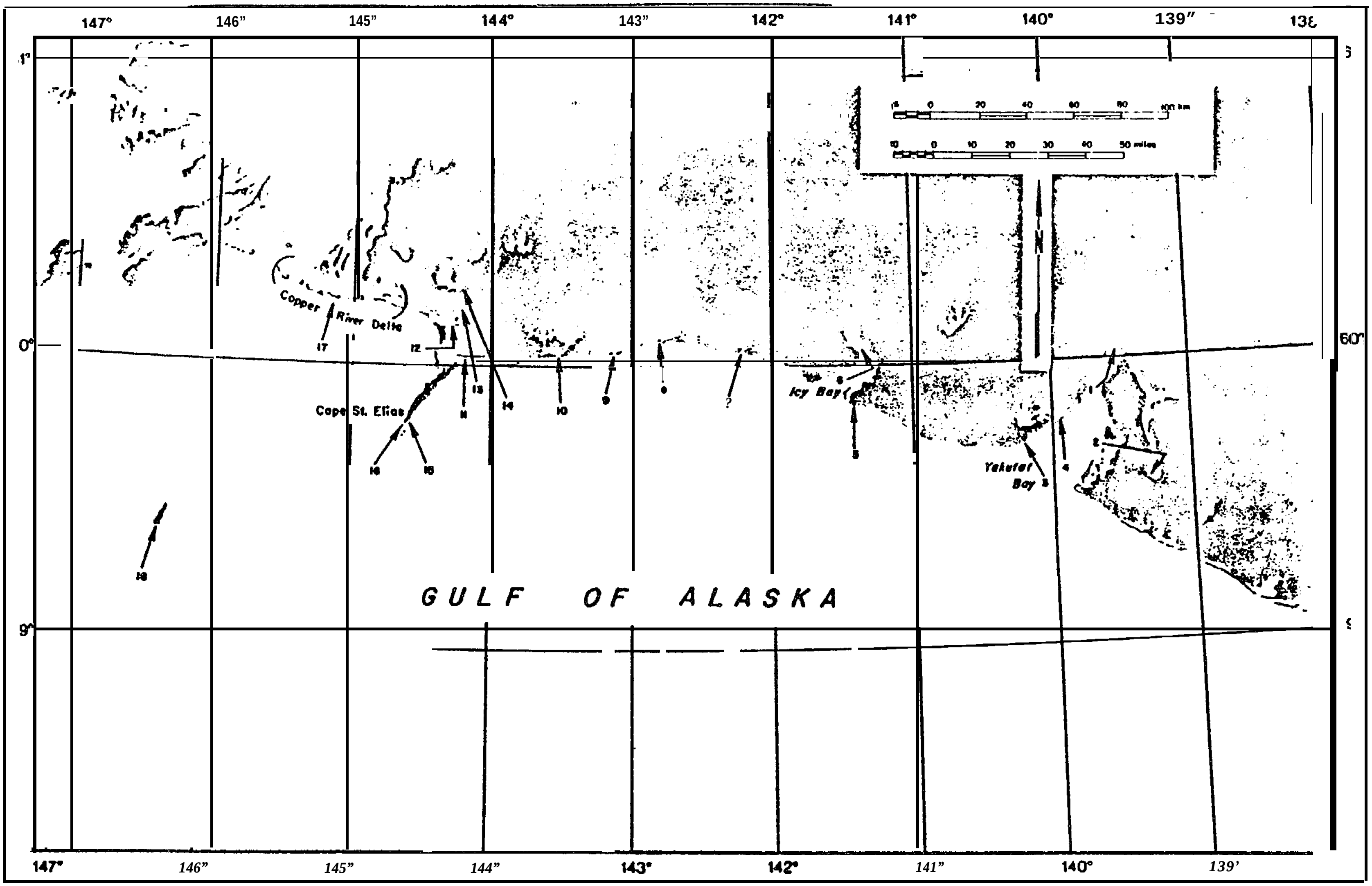

FIGURE 2. LOCATIONS OF MAJOR (≥25 SEALS) HARBOR SEAL CONCENTRATIONS ALONG THE NORTHEASTERN COAST OF THE GULF OF ALASKA! YAKUTAT BAY TO THE COPPER RIVER DELTA.

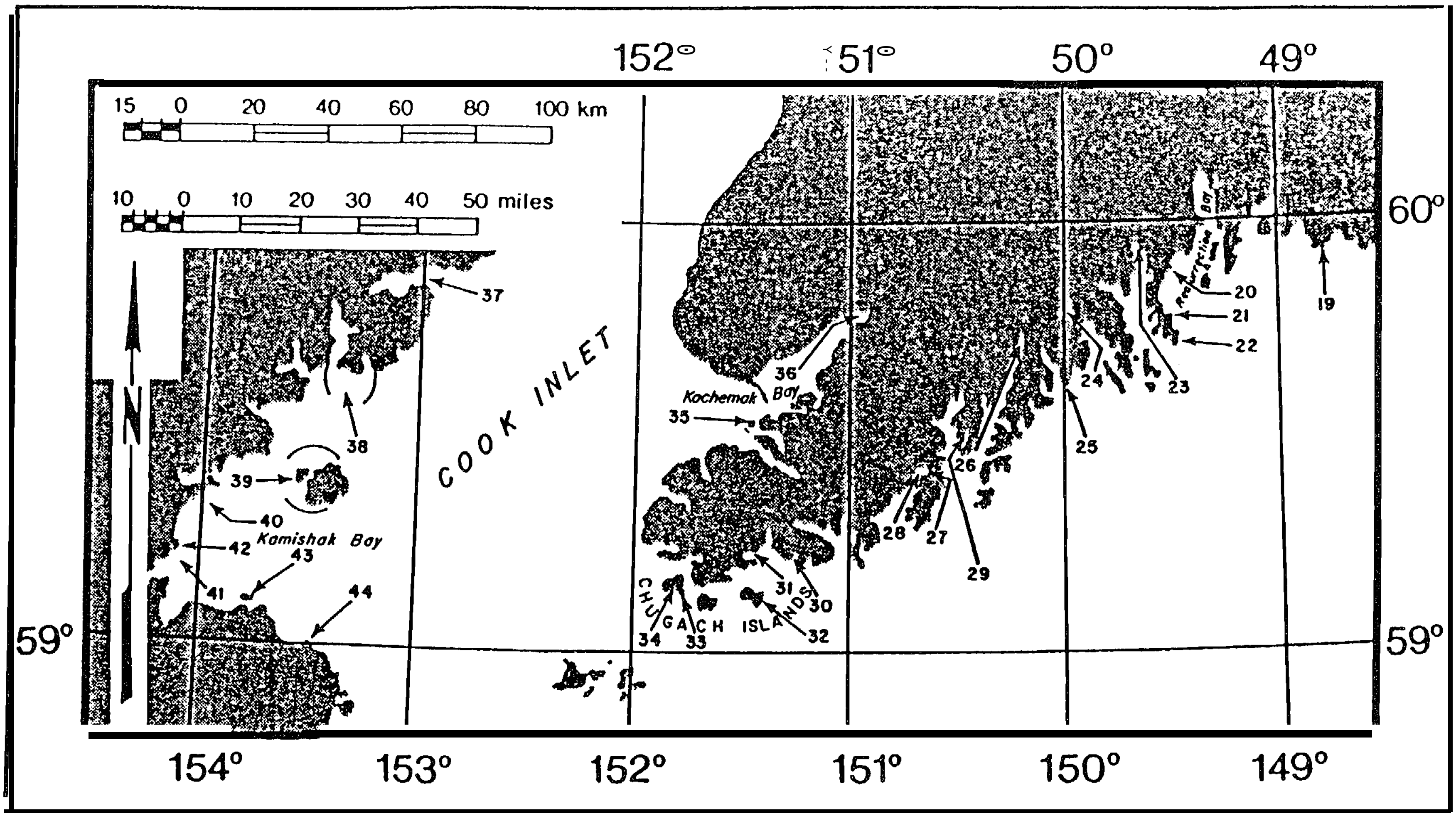

FIGURE 3. LOCATIONS OF MAJOR ($\geq$ 25 SEALS) HARBOR SEAL CONCENTRATIONS ALONG THE KENAI COAST AND IN LOWER COOK INLET.

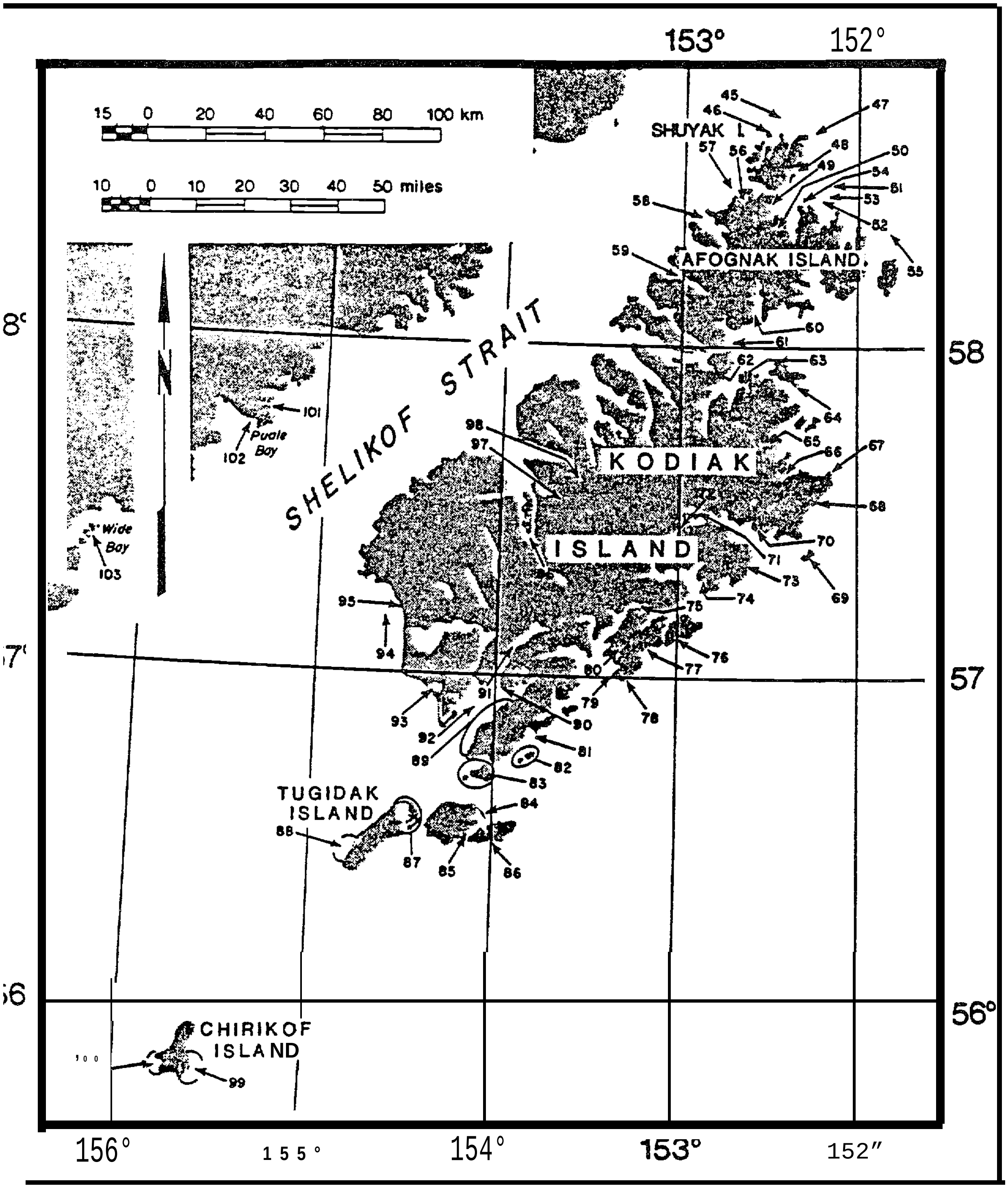

FIGURE 4. LOCATIONS OF MAJOR (≥25 SEALS) HARBOR SEAL CONCENTRATIONS IN THE KODIAK ISLAND SHELIKOF STRAIT AREA.

't'able 1. Listing of major harbor seal concentrations along the northeastern coast of the Gulf of Alaska; Yakutat Bay to the Copper River Delta.

Location	(Map No.)	Maximum number of seals observed	Date	Remarks
Disenchantment Bay 60 01 10 N 139 31 53 w	(1)	331	31 May 1976	Hauled on glacial ice floes, ADF&G survey
Russell Fiord 59 34 57 N 139 18 31 W	(.2)	75	26 June 1975	Hauled on rock islet, ADF&G survey
Manby Stream 59 41 35 N 140 18 41 W	(3)	45	29 May 1976	Stream mouth, ADF&G survey
Sudden Stream 59 46 13 N 140 02 20 w	(4)	40+	29 May 1976	Stream mouth, ADF&G survey
Yahtse River 59 51 49 N 181 22 58 W	(5)	41	24 July 1976	Arneson (RU 003)
Icy Bay 60 00 00 N 141 19 40 w	(6)	5,000	Summer 1975	Hauled on glacial ice floes, Sears & Zimmerman (1977)
Duktoth River 60 05 32 N 142 35 57 W	(7)	25+	6 June 1975	Hauled on sandbar at river mouth, USGS pers. comm.
Kaliakh River 60 06 21 N 142 44 03 W	(8)	200	28 May 1976	Hauled on sandbars at river mouth, ADF&G survey
Tsiu River 60 03 59 N 143 05 57 w	(9)	25+		Hauled on sandbars at river mouth, ADF&G report
Seal River 60 02 50 N 143 00 21 w	(lo)	25+		Hauled on sandbars at river mouth, ADF&G report
Controller Bay 60 00 26 N 144 08 30 W 60 06 35 N 144 15 29 W	(11,12)	186	26 July 1973	Hauled on sandbars, ADF&G survey

Table 2. (cont.)

Location	(Map No.)	Maximum number of seals observed	Date	Remarks
Pony Cove 59 45 04 N 149 32 50 w	(22)	40	31 Aug. 1976	Ameson (RU 003)
Aialik Bay 59 56 45 N 149 43 40 w	(23)	400	14 Aug. 1970	Hauled on glacial ice floes, ADF&G survey
Harris Bay 59 47 06 N 150 01 33 w	(24)	200-300	Nov. 1970	Hauled on glacial ice floes, ADF&G survey
Surok Point 59 36 50 N 150 01 33 w	(25)	25	4 Oct. 1975	ADF&G survey
McCarty Arm 59 43 06 N 150 13 25 W	(26)	100	12 Nov. 1970	Hauled on glacial ice floes, ADF&G survey
Division Island 59 25 23 N 150 41 50 w	(27)	50	6 June 1978	Hauled on intertidal rocks, ADF&G survey
Nuka Island, NW 59 23 24 N 150 42 00 W	(28)	37	31 Aug. 1976	Hauled on intertidal rocks, Arneson (RU 003)
Suprise Cove 59 31 40 N 150 28 32 W	(29)	25	21 March 1977	ADF&G survey
No Name Bay 59 14 07 N 151 17 25 W	(30)	176	24 June 1976	Ameson (RU 003)
Windy Bay 59 13 42 N 151 26 50 W	(31)	26	24 June 1976	Arneson (RU 003)
East Chugach Island 59 06 55 N 151 25 47 W	(32)	40	1 Oct. 1976	Hauled on sand beach, Arneson (RU 003)
Elizabeth Island 59 08 15 N 151 47 37 w 59 08 37 N 151 50 25 W	(33,34)	619	22 Aug. 1978	Hauled on gravel-cobble beach and intertidal rocks, ADF&G field camp, daily counts

Table 4. Listing of major harbor seal concentrations in the Kodiak Island Group.

Location	(Map No.)	Maximum number of seals observed	Date	Remarks
Latax Rocks 58 40 15 N 152 30 45 W	(45)	175	26 July 1978	Hauled on rocky beach, ADF&G survey
Dark Island 58 39 00 N 152 31 50 W	(46)	45	12 June 1978	ADF&G survey
NE Shuyak Island, offshore rocks 58 35 31 N 152 16 43 W	(47)	25	12 June 1978	ADF&G survey
Andreon Bay 58 30 36 N 152 23 33 W	(48)	25	April 1976	ADF&G survey
Big Waterfall Bay 58 25 46 N 152 28 15 W	(49)	50	21 May 1977	ADF&G survey
Phoenix Bay 58 22 07 N 152 28 20 W	(50)	25	22 May 1977	ADF&G survey
Sea Otter Island area 58 30 33 N 152 10 25 W 58 29 48 N 152 16 28 W	(51)	30	12 June 1978	ADF&G survey nearby tidal rocks
Seal Island 58 26 19 N 152 16 07 W	(52)	40	12 June 1978	ADF&G survey
Seal Bay-offshore rocks 58 24 13 N 152 12 04 W 58 23 35 N 152 10 14 W	(53)	35	22 May 1977	ADF&G survey

Table 4. (cont.)

Location	(Map No.)	Maximum number of seals observed	Date	Remarks
Womens Bay 57 42 40 N 152 31 42 W	(65)	31	1 March 1978	Arneson (RU 003)
Kalsin Bay 57 38 35 N 152 21 02 W	(66)	200		Sears and Zimmerman (1977)
Cape Chiniak 57 37 50 N 152 08 10 W	(67)	100	10 June 1978	ADF&G survey, hauled on tidal rocks
Sacramento River- mainland beach 1 mile north 57 32 17 N 152 14 35 W	(68)	140	11 June 1978	ADF&G survey hauled on gravel beach
Ugak Island 57 22 18 N 152 16 15 W	(69)	1,600	29 July 1978	ADF&G survey hauled on gravel beach
NE Ugak Bay-offshore rocks 57 25 50 N 152 33 50 W	(70)	410	24 July 1978	ADF&G survey
Hidden Basin- entrance 57 30 12 N 152 54 40 W	(71)	107	1 March 1976	Ameson (RU 003)
Ugak Bay-head 57 26 43 N 153 01 04 w	(72)	200+	10 Nov. 1976	ADF&G survey
Ugak Lagoon 57 20 06 N 152 38 15 W	(73)	50	6 Sept. 1978	ADF&G survey, hauled on sand bar
NE Kiluda Bay 57 18 48 N 152 54 17 W	(74)	160	24 July 1978	ADF&G survey

Table 4. (cont.)

Location	(Map No.)	Maximum number of seals observed	Date	Remarks
Sitkalidak Straits 57 12 07 N 153 10 37 w	(75)	35	2 May 1977	ADF&G survey, hauled on tidal rocks
NE Sitkalidak-mouth lagoon 57 07 32 N 153 00 43 w	(76)	125	27 Aug. 1978	ADF&G survey, hauled on sand bar
Ocean Beach 57 05 30 N 153 07 18 W	(77)	40		Sears and Zimmerman (1977)
Sitkalidak Island, Ocean Beach to Black Point 57 00 00 N 153 15 54 w	(78)	48		Sears and Zimmerman (1977)
Puffin Island 57 00 25 N 153 21 11 w	(79)	90	27 Aug. 1978	ADF&G survey
Natalia Bay 57 05 48 N 153 17 47 w	(80)	30		Sears and Zimmerman (1977)
Flat Island 56 49 53 N 153 44 20 w	(81)	100	27 July 1978	ADF&G survey
Geese Islands 56 43 42 N 153 54 03 w	(82)	670	27 July 1978	ADF&G survey
Aiaktalik-Sundstrom Islands 56 41 53 N 154 07 45 w	(83)	635	27 July 1978	ADF&G survey
Sitkinak Bar 56 33 04 N 154 01 10 w	(84)	250	9 Sept. 1978	ADF&G survey, hauled on sand bar
Sitkinak Lagoon 56 31 27 N 154 07 20 w	(85)	200	1 July 1978	ADF&G survey, hauled on sand bar

Table 4. (cont.)

Location	(Map No.)	Maximum number of seals observed	Date	Remarks
SE Sitkinak 56 30 28 N 154 01 30 W	(86)	1,000	27 July 1978	ADF&G survey, hauled on gravel beach
NE Tugidak Island 56 36 05 N 154 28 55 W 56 31 35 N 154 27 25 W	(87)	4,660	2 Sept. 1976	ADF&G survey, hauled on gravel beaches and sand bars, many locations
SW Tugidak Island 56 27 04 N 154 46 35 W	(88)	9,300	31 Aug. 1976	ADF&G field camp, ground count, hauled on gravel beach
Aliulik Peninsula-west side 56 51 35 N 154 01 05 W	(89)	200	10 June 1978	ADF&G survey, hauled on tidal rocks, many locations
Cape Hepburn 56 52 25 N 154 05 08 W	(90)	50	2 May 1977	ADF&G survey, hauled on tidal rocks
Deadman Bay 57 04 18 N 154 56 38 W	(91)	100		Sears and Zimmerman (1977)
Middle Reef 56 54 36 N 154 02 28 W	(92)	150	2 May 1977	ADF&G survey, hauled on tidal rocks
Sukhoi Lagoon 56 56 52 N 154 20 43 W	(93)	350	28 Aug. 1978	ADF&G aerial survey, hauled on sand bar
Ayakulik Island 57 13 03 N 154 35 00 W	(94)	75		Sears and Zimmerman (1977)
Ayakulik River 57 12 17 N 154 32 30 W	(95)	100	9 Oct. 1976	Hauled on mainland gravel beach, ADF&G survey
Alf Island-Uyak Bay 57 24 45 N 153 49 50 W	(96)	250	1 Sept. 1978	Hauled on gravel spit, ADF&G survey

Table 4. (cont.)

Location	(Map No.)	Maximum number of seals observed	Date	Remarks
Zachar Bay-Head 57 32 31 N 153 42 18 W	(97)	30	5 Nov. 1976	ADF&G survey
Spiridon Bay-Head 57 36 50 N 153 35 41 w	(98)	50	5 Nov. 1976	ADF&G survey
SW and SE Chirikof Island 155 32 45 W 55 48 16 N 155 43 50 w	(99,100)	353	30 June 1978	ADF&G survey, hauled on offshore rocks, many locations

Table 5. Listing of major harbor seal concentrations along the Alaska Peninsula coast of Shelikof Strait; Cape Douglas to Wide Bay*.

Location	(Map No.)	Maximum number of seals observed	Date	Remarks
Alinchak Bay 57 45 50 N 155 15 00 w	(101)	200	16 June 1976	ADF&G survey
Puale Bay 57 41 40 N	(102)	150	24 June 1978	Hauled on tidal rocks, ADF&G survey
Wide Bay 57 23 40 N 155 12 00 w	(103)	117	24 June 1978	Hauled on rocks and islands at mouth of bay, ADF&G survey

* Coverage of this area was extremely sparse.

REPRODUCTION

Pupping

Pupping activities of harbor seals in the Gulf of Alaska were not restricted to large discrete rookeries. Pupping seemed to take place at nearly all locations where animals hauled out. Major hauling areas where many pups were born included: Disenchantment Bay, Icy Bay, Copper River Delta, Aialik Bay, Harris Bay, McCarty Arm, Augustine Island, Seal Island, Ugak Island and Tugidak Island.

Observations on Tugidak Island in 1976 and 1978 showed that most pups were born between 5 and 25 June. The height of pupping activity was about 15 June. Collecting activities in other areas of the western Gulf of Alaska supported these observations. Between 20 and 27 May 1977, 23 reproductive females were collected. Twenty-one were pregnant and two were postpartum. All 19 mature females collected from 21 June to 1 July 1978 had already given birth. Pupping in the eastern Gulf of Alaska may be about one week earlier. Numerous mother-pup pairs were seen in the Yakutat-Icy Bay area between 28 May and 1 June 1976. In the Prince William Sound-Copper River Delta area pupping began about 20 May, peaked during the first week of June and was completed by early July (Pitcher 1977) .

Premature pupping was documented in the Gulf of Alaska. The remains of a pup were found in Kamishak Bay on 8 April 1978. Another dead, premature pup was found in Alitak Bay on 2 May 1977. Premature pups were seen on Tugidak Island on 28 April, 2May and 8May 1978. It appeared that all early pups were abandoned by the female and died. Premature pupping was observed on Tugidak Island in 1964 by Bishop (1967) who believed that desertion by the female was the rule in instances of early pupping.

Lactation and Weaning

Seventeen of 19 postpartum females collected between 21 June and 1 July were lactating. The other two had apparently completed lactation. An adult female collected on 30 July 1978 had produced a pup earlier in ‘the summer and was not lactating. These data are not sufficient to determine the length of the lactation period, but do appear to fit within the ranges presented in the literature: Bishop (1967), 3 weeks; Bigg (1969), 5-6 weeks; Knudtson (1974), 5-6 weeks and Johnson (1976), 3-5 weeks. Johnson (1976) reported a gradual weaning period of about 1 week.

Ovulation

Ovulation in harbor seals reportedly takes place shortly after weaning in reproductive females (Fisher 1954, Bishop 1967 and Bigg 1969). None of 25 lactating females collected during this study had ovulated. A postpartum female collected on 21 June 1978 was not lactating and had a newly formed corpus luteum. The rupture site on the outside of the ovary was visible. Another nonlactating, postpartum female collected on

28 June had a single large follicle (16 mm in diameter) and was apparently nearing ovulation, Four females which had never pupped (4-6 years old) were collected between 21 and 23 June. All had large follicles (7, 14, 18 and 19 mm in diameter) and appeared to be nearing ovulation. Two mature females collected on 30 July 1974 had ovulated. From these observations it appears that ovulation occurs between mid-June and mid to late July.

Delay of Implantation

Thirteen mature females collected between 30 July and 9 September were apparently all in the delay of implantation as each had an ovary with a corpus luteum but no visible evidence of embryos or implantation sites in the uteri. Five of 6 mature females collected between 6 and 12 October either had newly implanted embryos (<0.1 g) or developing implantation sites. A female collected on 6 October was apparently still in the delay as no sign of an implantation site was visible, while a large, normal appearing corpus luteum was present in one ovary. Four of 5 mature females taken between 29 and 31 October had implanted embryos. The other appeared to be in the process of implantation as there was a small swelling in one uterine horn. All twelve mature females collected between 5 and 10 November had implanted embryos. These observations indicated that implantation occurs during October, primarily early in the month. It appears that the period of delayed implantation is approximately 11 weeks.

Literature reports for length of delay of implantation in harbor seals are: Fisher (1954), 11 weeks; Harrison (1960), 2 to 3 months; Bishop (1967), 1.5 to 2 months; and Bigg (1969), 2 months.

Female Age of Sexual Maturity

Age at first ovulation (Bigg 1969) and age at which a female first produces offspring (McLaren 1958) are the two criteria commonly used to assign age of sexual maturity. The age at which offspring are first produced (productive maturity) is more meaningful when population dynamics are the primary concern. Nonetheless age of first ovulation can be more accurately determined (it requires less interpretation during ovarian analysis) and this parameter may have value as an indicator of population status.

Female harbor seals collected during this study ovulated for the first time between the ages of 3 and 7 years. The average age {with 95% confidence limits) of first ovulation was estimated at 4.96 $\pm$ 0.43 years using the technique of DeMaster (1978). Productive maturity, or the average age of first pregnancy, was calculated at 5.51 $\pm$ 0.46 years. Initial pregnancies occurred between 4 and 9 years of age.

Average ages of first ovulation and initial pregnancy calculated from data presented by Bigg (1969) for harbor seals in British Columbia and Pitcher (1977) for seals in Prince William Sound were significantly lower ($P<0.05$) than for those collected in the Gulf of Alaska during this study (Figure 5). The reasons for these differences are not known, but they may be related to differences in population status at the times the collections were made. Age of sexual maturity in many species generally drops when population levels are reduced and may serve as an indicator of population status (Sergeant 1966, 1973; Eberhardt 1977; Laws 1959).

Ovulation and Pregnancy Rates

Age specific ovulation and pregnancy rates were calculated after examination of 194 female reproductive tracts (Table 6). Pregnancy rates were based only on those animals collected between implantation and ovulation because of the findings of Bigg (1973) who demonstrated that a normal appearing corpus luteum persisted for several months after ovulation even if fertilization did not occur.

Ovulation rates increased from 7% at 3 years to 100% by 7 years. Every female 7 years old and older had ovulated during the reproductive year in which it was collected. Pregnancy rates increased from 17% at 4 years to 100% at 8 years old. The pregnancy rate for females 8 years old and older was 92%. Bigg (1969) reported a pregnancy rate of 97% for animals of comparable ages from British Columbia. Pitcher (1977) found that all 15 females, 8 years old and older, taken in Prince William Sound were pregnant. These rates did not differ significantly ($P>0.10$) from those in this study.

Reproductive Failures

Reproductive failures in pinnipeds have been classified in three categories (Craig 1964; Bigg 1969): (1) missed pregnancies where the female ovulated and either fertilization did not occur or the blastocyst failed to implant, (2) resorption of an embryo, and (3) abortion in which the fetus was expelled from the uterus.

Reproductive failures were found in 14 (10.6%) of 132 reproductive females collected between implantation and birth (Table 7). The most common reason for failure was abortions (6) followed by missed pregnancies (4) and resorption (l). Seven (50%) of these failures occurred during initial pregnancies. Of five initial failures which could be classified to cause, four were missed pregnancies. This appears to follow the same pattern described by Craig (1964) in northern fur seals (*Callorhinus ursinus*). Craig found that missed pregnancies were most common in young females whereas abortions and resorption occurred in all ages.

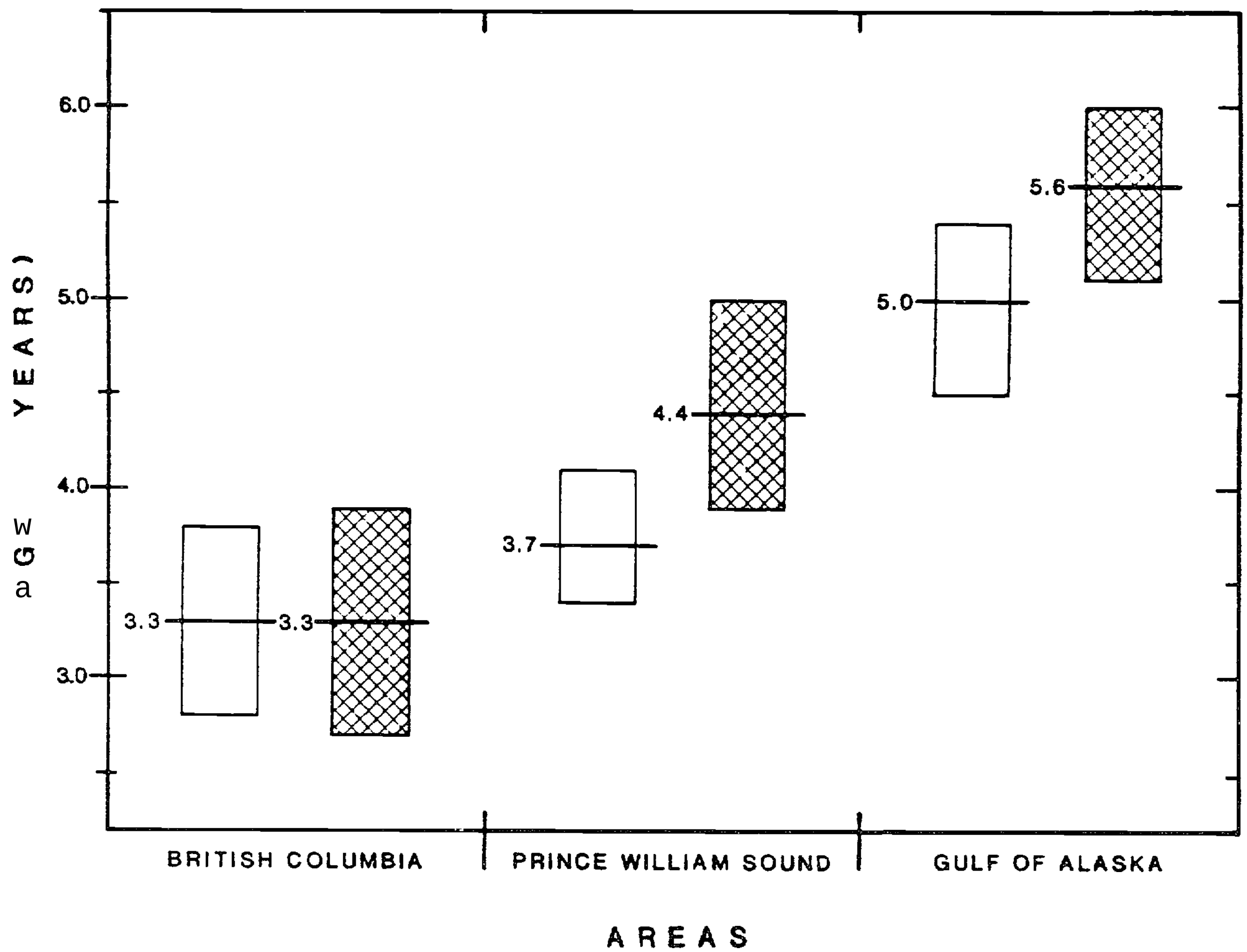

FIGURE '5. MEAN AGES OF FIRST OVULATION AND FIRST PREGNANCY OF HARBOR SEALS COLLECTED IN BRITISH COLUMBIA (BIGG 1969), PRINCE WILLIAM SOUND (PITCHER 1 977) AND THE GULF OF ALASKA. HORIZONTAL LINE, MEAN; BOX, 95% CONFIDENCE INTERVAL; ▭, OVULATION; ▨, PREGNANCY.

Table 6. Ovulation and pregnancy rates for female harbor seals collected in the Gulf of Alaska.

Age	Number in Sample	Number Ovulated	Ovulation Rate (%)	Number in Sample	Number Pregnant	Pregnancy Rate (%)
0-12 months	14	0	0	14	0	0
1 year	11	0	0	11	0	0
2	4	0	0	4	0	0
3	14	1	7	13	0	0
4	12	6	50	12	2	17
5	10	8	80	8	5	63
6	8	7	88	8	7	88
7	9	9	100	9	8	89
8	6	6	100	6	6	100
9	17	17	100	17	15	88
10	14	14	100	14	11	79
11-15	35	35	100	33	32	97
16-20	20	20	100	16	15	94
21-25	16	16	100	15	15	100
26-30	4	4	100	3	2	67
TOTALS	194	143		183	119	

Table 7. Summary of reproductive failures in female harbor seals collected in the Gulf of Alaska.

Age of Female	Initial Pregnancy	Missed Pregnancy	Resorption	Abortion	Indeterminable
4 yrs.	yes	x			
4	yes	x			
4	yes	x			
4	yes	x			
5	yes			x	
7	yes				x
9	no				x
9	yes			x	
10	no			x	
10	no			x	
10	no				x
12	no			x	
18	no		x		
30	no			x	

Male Age of Sexual Maturity and Seasonal Spermatogenic Activity

Sexual maturity in males was defined as the presence, in quantity, of epididymal sperm (Hewer 1964; Bigg 1969). During adolescence small quantites of sperm are present. However, because high concentrations of sperm are necessary for fertilization (Laws 1956) these animals cannot be considered mature.

Males were considered mature if abundant epididymal sperm were present during the period of 20 May through 31 July which brackets the normal ovulation period of female harbor seals in the area. The youngest mature male was 5 years old (Table 8). Thirty of 31 males older than 6 years had abundant epididymal sperm. The one exception was a 22 year old animal collected on 27 May. In Prince William Sound males matured between 3 and 7 years of age (Pitcher 1977); in British Columbia they matured between 3 and 6 years, most by 5 years (Bigg 1969).

Sperm were not found in the epididymides of mature (7 years old or older) males between 9 October and 11 February (Table 9). All but one of 31 mature males had abundant sperm from 20 May through 31 July. Considerable individual variation was apparent in both initiation and cessation of sperm production. Most males were apparently capable of breeding in advance and probably somewhat beyond the normal ovulation period of females.

Table 8. Age of sexual maturity in 54 male harbor seals based on the presence of abundant epididymal sperm during the period of 20 May-31 July.

Age	No. of Males	(Epididymal sperm) Absent	Trace	Abundant	Mature %
0-12 mos.	3	3			0
1 year	1	1			0
2	7	7			0
3	4	4			0
4	4	2	2		0
5	1		1		0
6	3	1	1	1	33
7	3			3	100
8	2			2	100
9	1			1	100
10	1			1	100
11-15	16			16	100
16-20	5			5	100
21-26	3			2	67

Table 9. Seasonal spermatogenic activity in male harbor seals, 7 years and older, collected in the Gulf of Alaska.

Time Period	No. of Animals	(Epididymal Sperm) None	Trace	Abundant	Percentage with Abundant Sperm
7-11 February	2	2			0
18-25 March	18	11	4	3	17
8-25 April	32	4	4	24	75
20 May-31 July	31	1		30	97
28 Aug.-9 Sept.	4	3		1	25
9-12 October	3	3			0
5-10 November	6	6			0

GROWTH

Birth Size

Weights and measurements were obtained from 23 near-term fetuses and newly born pups in the Kodiak Island area which were collected between 20 May and 10 June. Mean standard lengths were 78.6 ± 2.7 cm (95% C.L.) for males and 76.5 ± 1.9 cm for females. Mean weights were 12.0 ± 1.0 kg for males and 11.5 ± 0.6 kg for females. No significant differences were apparent ($P>0.1$) between sexes for either length or weight. With both sexes combined, mean standard length was 77.7 ± 1.7 cm and mean weight was 11.7 ± 0.61 kg.

Weights and measurements were also obtained from seven near term fetuses and newly born pups collected between 28 May and 1 June in NEGOA, primarily the Icy Bay area. Average standard length (both sexes) was 73.0 ± 4.7 cm and average weight was 10.0 ± 1.7 kg. A t-test was used to test for differences between this sample and that obtained from Kodiak. Both mean weight and length were significantly less ($P<0.05$) for the NEGOA sample.

Bigg (1969) presented a summary of birth lengths and weights from his research and a literature review. Average length and weight for males and females combined from his British Columbia sample were 81.6 ± 6.2 cm and 10.2 ± 1.5 kg, respectively.

Postnatal Growth

Insight into growth during the first year of life was gained through examination of weights and measurements from 20 seals between the ages of birth and 12 months collected in the Kodiak area (Figure 6). Initial rapid growth occurred. Bigg (1969) found that pups more than doubled their weight during the suckling period. Rate of growth then decreased, possibly reflecting difficulty associated with nutritional independence (Pitcher 1977).

Growth patterns of harbor seals collected in Kodiak waters are portrayed in Figures 7 and 8. Growth, as measured by standard length, was rapid for both sexes through 4 to 5 years of age. Growth slowed after this and by 7 years of age skeletal growth appeared to be completed. Weight increased rapidly through about 5 years of age and then more slowly until 10 years. Little if any weight gain occurred after this.

The average standard length for adult male harbor seals (7 years old and older) for all areas of the Gulf of Alaska was 155.4 ± 1.4 cm (95% C.L.). The average length for females was 144.8 ± 1.1 cm. Adult males were significantly longer than adult females ($P<0.001$). The same pattern persisted in all geographic areas where adequate samples sizes were available (Tables 10 and 11).

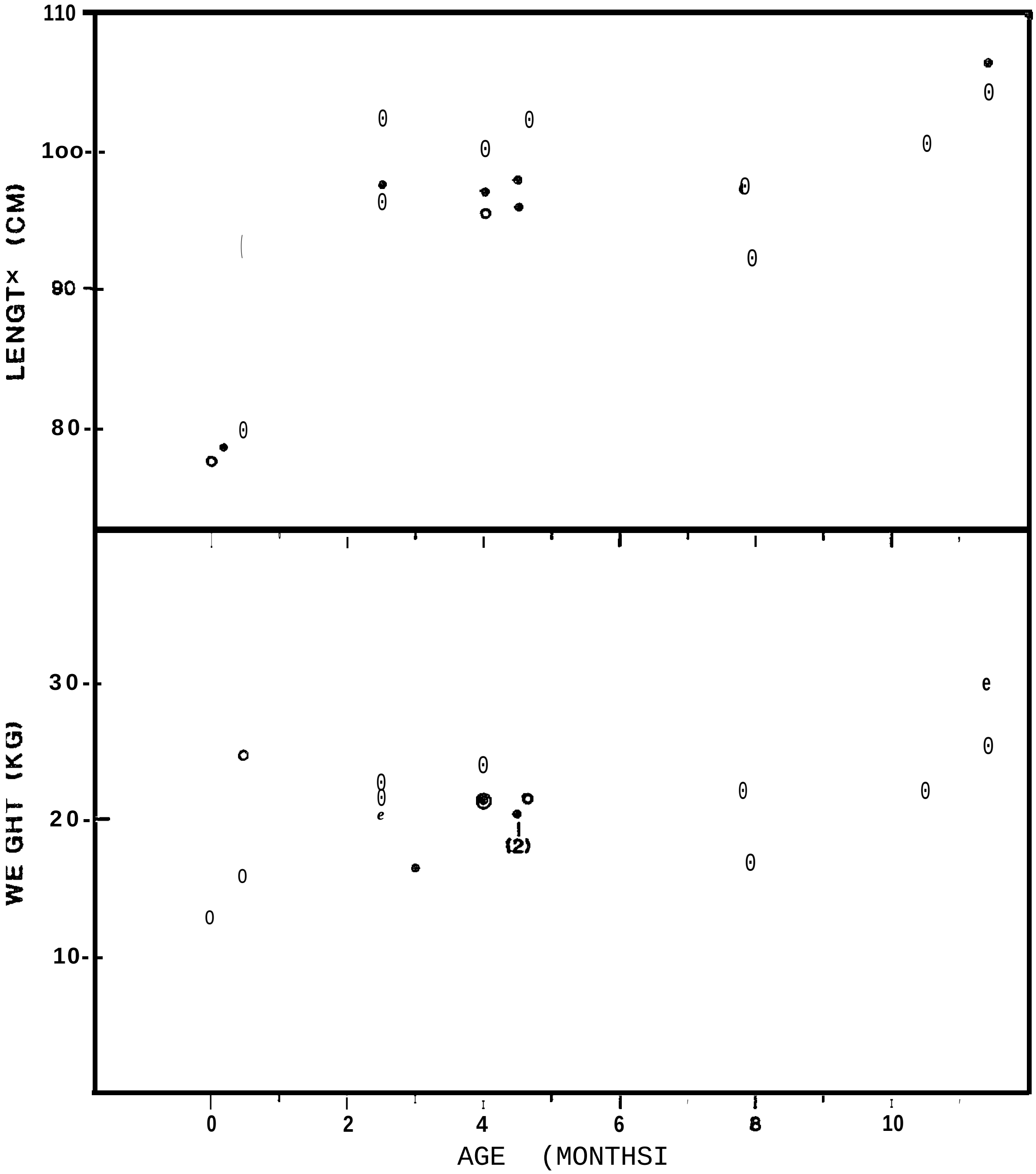

FIGURE 6. FIRST YEAR BODY GROWTH IN STANDARD LENGTH AND WEIGHT FOR 20 HARBOR SEALS COLLECTED IN THE KODIAK ISLAND AREA, •, MALE; ○, FEMALE.

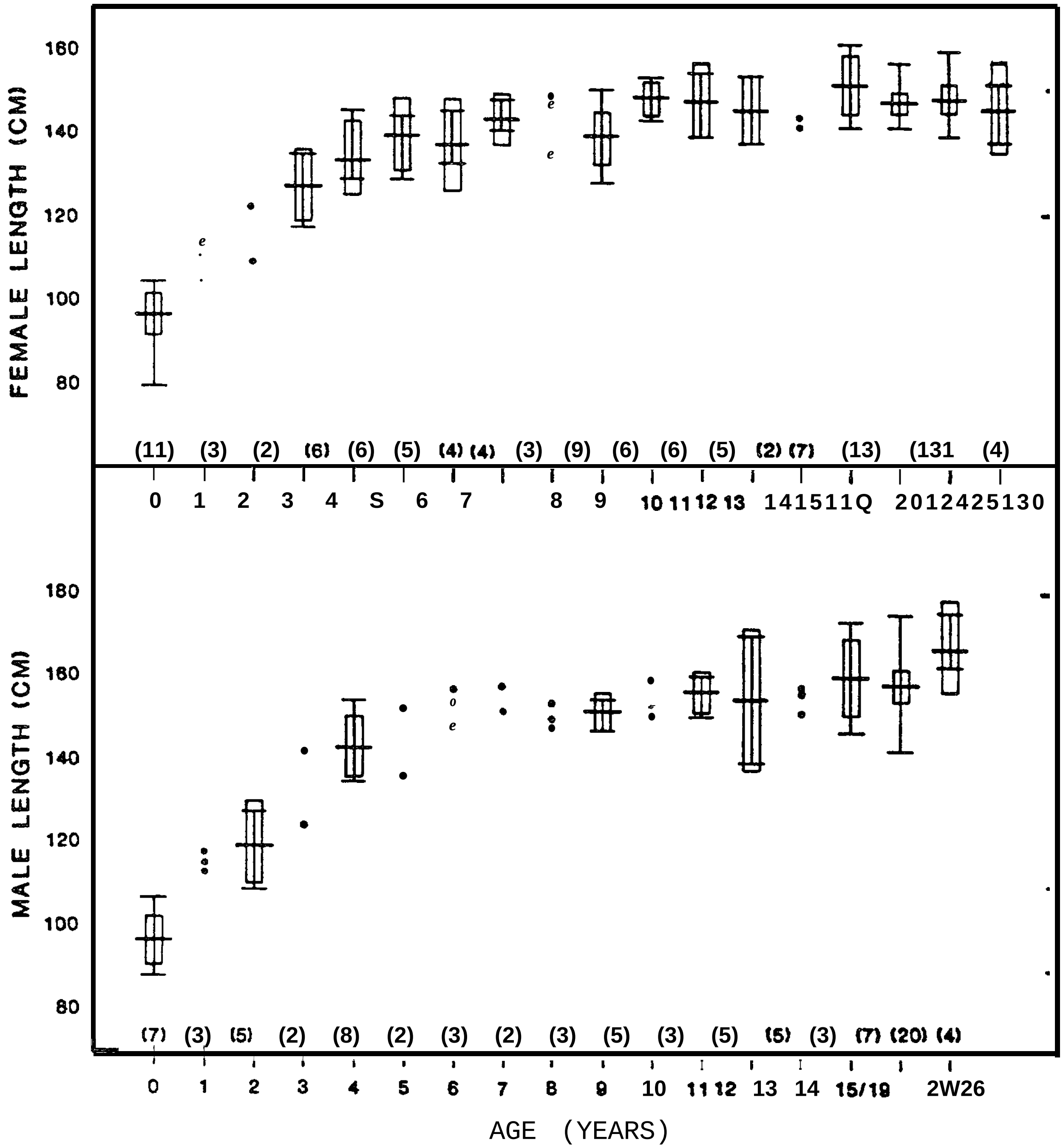

FIGuRE 7, STANDARD LENGTHS OF MALE AND FEMALE HARBOR SEALS FROM THE KODIAK AREA BY AGE CLASS. VERTICAL LINE, RANGE; BOX, 95% CONFIDENCE INTERVAL; HORIZONTAL LINE IN BOX, MEAN; NUMBER IN PARENTHESIS, SAMPLE SIZE; •, INDIVIDUAL LENGTHS OF SAMPLE SIZE < 4.

Table 10. Comparison of standard lengths of adult harbor seals (7 years old and older) collected in various localities in the Gulf of Alaska. Data points are means with 95% confidence limits.

Area	Sample MM	Size FF	Standard Length (cm) MM	FF
Icy and Yakutat Bays	*	8	*	138.2 ± 4.4
Prince William Sound	30	20	154.4 ± 2.8	144.0 ± 2.5
Kenai coast	17	19	156.0 ± 2.0	146.4 ± 2.7
Lower Cook Inlet	8	9	148.9 ± 5.5	138.9 ± 2.6
Kodiak area	57	71	157.1 ± 2.1	145.8 ± 1.5
Alaska Peninsula	*	7	*	147.9 ± 5.8
TOTAL	112	134	155.4 ± 1.4	144.8 ± 1.1

* N < 4

Table 11. Summary of statistical comparisons between male and female standard lengths and weights. Results are from t-tests. Tests indicating significant differences ($P < 0.05$) are underlined.

Area	Statistical Significance Standard Length	Statistical Significance Weight
Prince William Sound	<u>$p < 0.001$</u>	$P > 0.10$
Kenai coast	<u>$p < 0.001$</u>	$P > 0.10$
Lower Cook Inlet	<u>$p < 0.001$</u>	$P > 0.05$
Kodiak	<u>$P < 0.001$</u>	<u>$P < 0.01$</u>
All areas combined	<u>$P < 0.001$</u>	<u>$P < 0.001$</u>

Mean weights were also significantly greater ($P<0.01$) for adult male harbor seals (10 years old and older) than those for females; at 84.6 ± 2.1 kg and 76.5 ± 3.0 kg, respectively. However, the heaviest seal weighed during this study was a pregnant female at 127.5 kg. Significant differences in weights between sexes did not persist for most geographic areas (Tables 11 and 12) because of the large variance and small sample sizes.

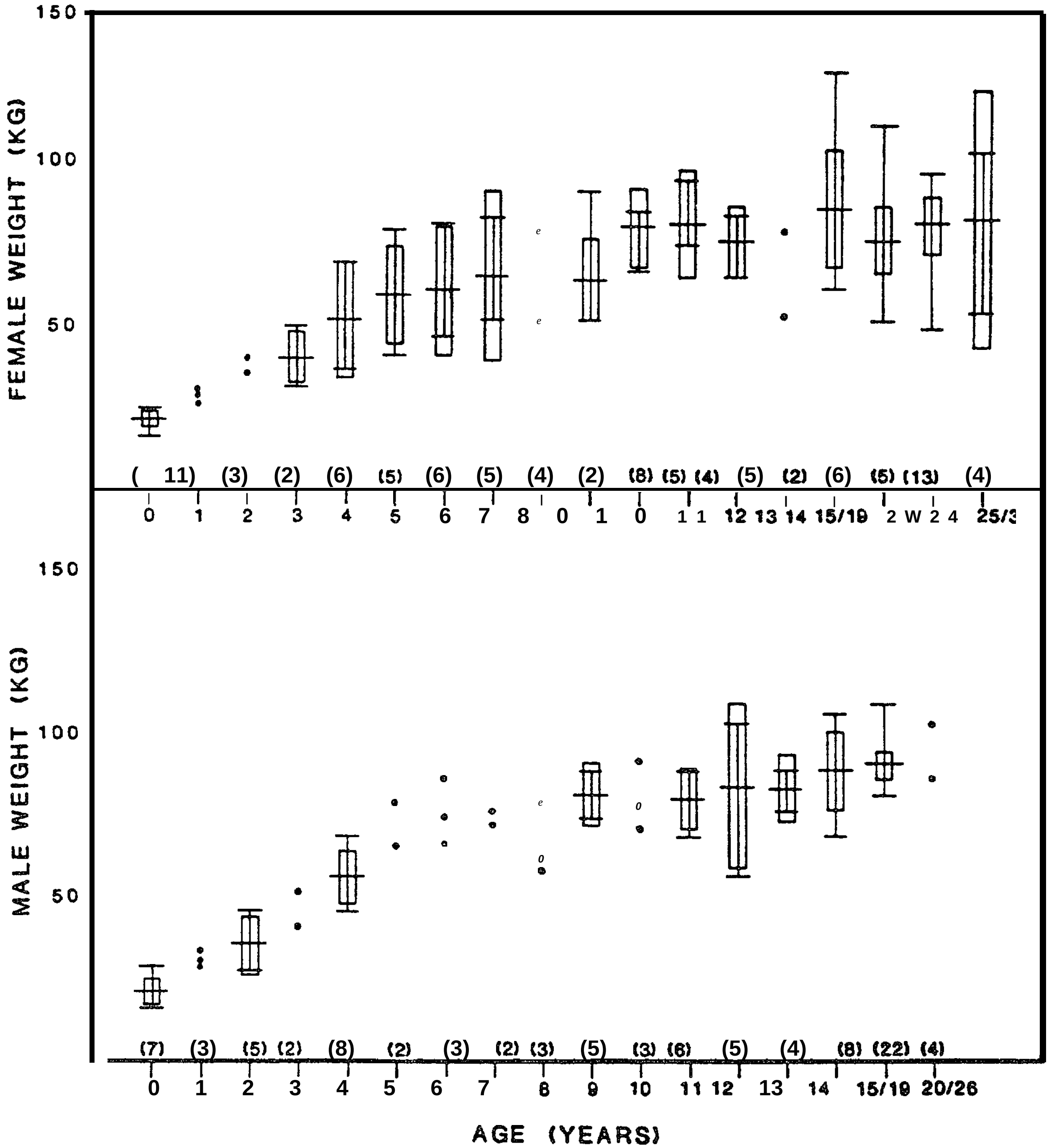

FIGURE $. WEIGHTS OF MALE AND FEMALE HARBOR SEALS FROM THE KODIAK AREA BY AGE CLASS. VERTICAL LINE, RANGE; BOX, 95% CONFIDENCE INTERVAL; HORIZONTAL LINE IN BOX. MEAN: NUMBER IN PARENTHESIS, SAMPLE SIZE; • , INDIVIDUAL WEIGHTS OF SAMPLE SIZE < 4.

Table 12. Comparison of weights of adult harbor seals (10 years old and older) collected in various localities in the Gulf of Alaska. Data points are means with 95% confidence limits.

Area	Sample Size MM	Sample Size FF	Weight (kg) MM	Weight (kg) FF
Icy and Yakutat Bays	*	6	*	64.4 ± 19.2
Prince William Sound	9	8	78.2 ± 7.4	72.9 ± 12.5
Kenai coast	12	11	80.4 ± 6.1	80.5 ± 5.6
Lower Cook Inlet	6	8	83.6 ± 10.8	69.4 ± 10.8
Kodiak area	50	54	87.2 ± 3.1	79.8 ± 4.0
Alaska Peninsula	*	6	*	64.9 ± 14.8
TOTAL	77	93	84.6 ± 2.1	76.5 ± 3.0

* $N < 4$

Geographic comparisons of adult body size showed some distinct differences (Figure 9). Standard lengths (Table ‘10) of adult males showed significant differences among some areas ($P<0.05$). Males from Kodiak, Kenai and Prince William Sound were similar in size and did not differ significantly ($P>0.10$). Males from lower Cook Inlet were significantly shorter than males from Kodiak and Kenai ($P<0.05$). Females from Prince William Sound, Kenai, Kodiak and the Alaska Peninsula were of similar size while those from Icy and Yakutat Bays and lower Cook Inlet were considerably smaller ($P<0.01$).

Weights (Table 12) of adult males were significantly different ($P<0.05$) among some areas. Kodiak males were the heaviest and Prince William Sound animals were the lightest. The only significant differences were between these extremes. Weights of adult females were also significantly different ($P<0.05$) among areas. The lightest animals were from Icy and Yakutat Bays and the heaviest were from Kodiak and Kenai.

Length appears to be a much better measure of physical size than weight. Fatness, and consequently weight varies seasonally but length changes only with skeletal growth. Individual variation is much greater with weight than with length, making statistical comparisons of weight less precise.

PHYSICAL CONDITION

Blubber thickness was measured for each collected animal. The amount of blubber was assumed to be an indicator of physical condition. In order to compare populations over time and between areas it was necessary to consider the effects of sex, age and season on blubber thickness. To eliminate confounding effects of attaining nutritional independence and sexual maturity, analyses were restricted to animals $\geq$7 years old which formed the largest segment of our sample. Blubber thickness for males and females was examined separately because females were significantly

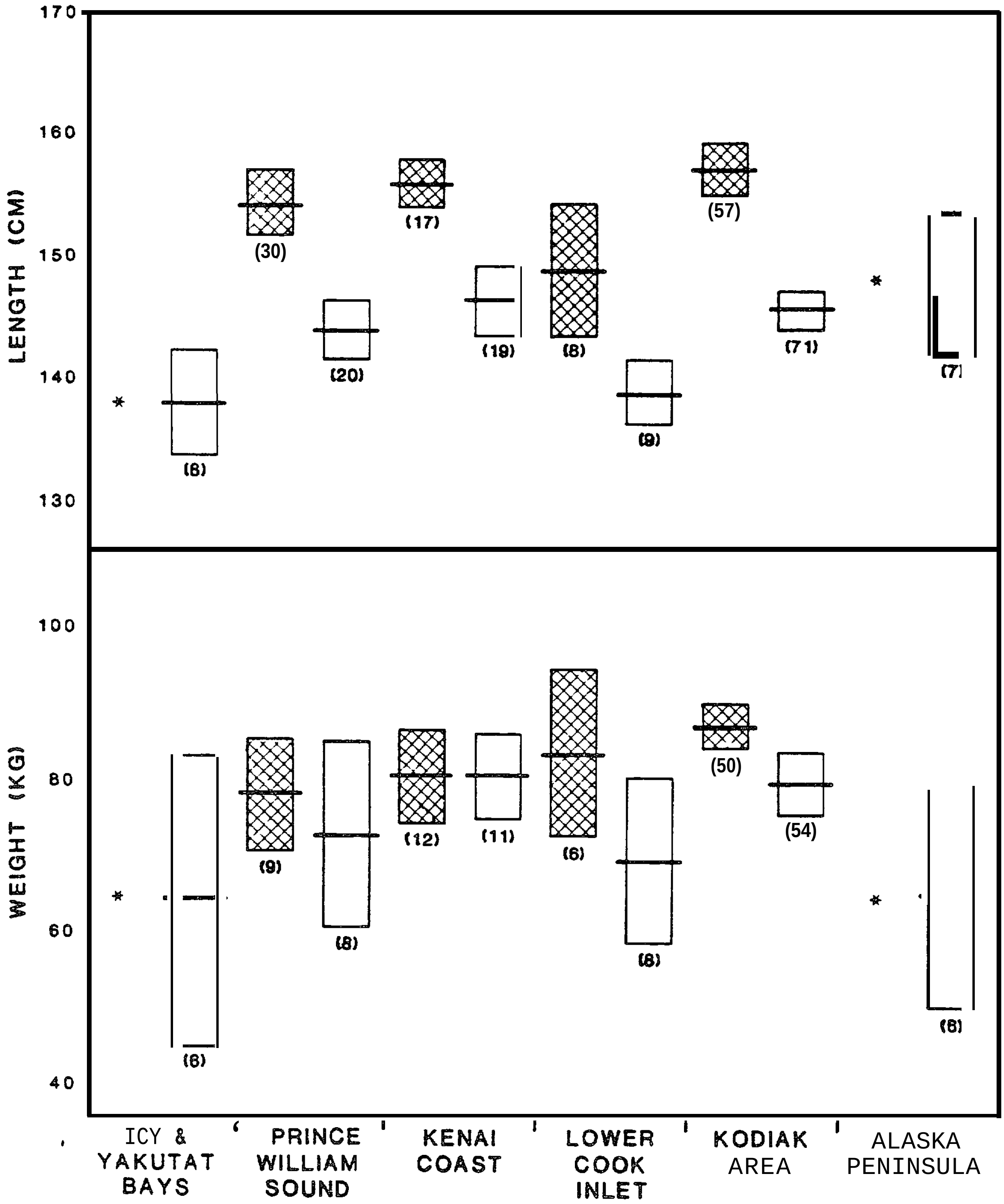

FIGURE 9. MEAN WEIGHTS AND STANDARD LENGTHS OF ADULT HARBOR SEALS COLLECTED FROM VARIOUS LOCALITIES IN THE GULF OF ALASKA, [crosshatched box], MALE; [open box], FEMALE; BOX, 95% CONFIDENCE INTERVAL: HORIZONTAL LINE, MEAN: NUMBER IN PARENTHESIS, SAMPLE SIZE; * , SAMPLE SIZE < 4.

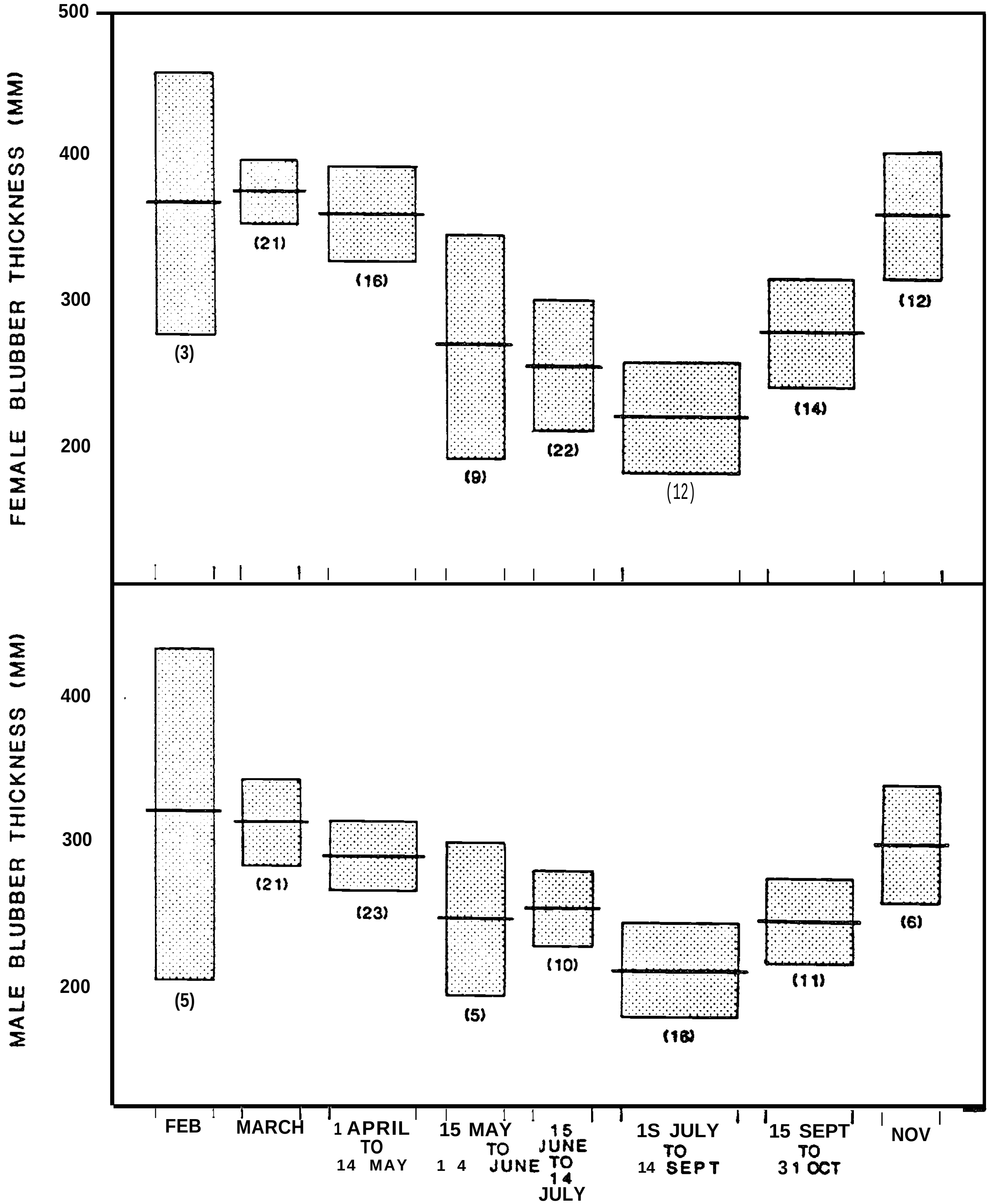

FIGuRE 10. SEASONAL PATTERNS OF BLUBBER THICKNESS OF ADULT (≥ 7 YEARS) HARBOR SEALS COLLECTED IN THE GULF OF ALASKA, EXCLUDING ANIMALS TAKEN IN THE KODIAK AREA IN 1977. HORIZONTAL LINE. MEAN; BOX, 95% CONFIDENCE INTERVAL; NUMBER IN PARENTHESIS, SAMPLE SIZE.

Early molt (anagen): Characterized by heavy pigmentation throughout the follicle. New guard hair shafts have grown beyond the skin surface, but do not extend beyond the underfur layer. Both old and new guard hairs present in many follicles.

Late molt (anagen): Pigment throughout the follicle, however, less dense than during early molt. New guard hairs nearly as long as old guard hairs. Rapid shedding of old guard hairs.

Ending molt (catagen): Follicles with light, but even distribution of pigment. No old guard hairs remaining.

The period of active molt began about 2 June and extended into early October (Table 14). The highest proportion of molting animals was found in late July (Figure 11). Sample sizes were too small and the sampling schedule inadequate to analyze timing of the molt by sex and age class and by geographic area. The one animal classified as being in end molt during the 20 June-2 July period was a pup less than 1 month old and obviously was completing the lanugo molt. The only animal found to be actively molting during October was a 15 year old male.

Table 14. Progression of the molt in 325 harbor seals of all ages and both sexes collected in the Gulf of Alaska.

Time Period	Stage of Molt: Resting #	Resting %	Beginning #	Beginning %	Early #	Early %	Late #	Late %	End #	End %
7-11 Feb.	4	100	0	0	0	0	0	0	0	0
18-26 March	46	100	0	0	0	0	0	0	0	0
7 Apr.-10 May	75	100	0	0	0	0	0	0	0	0
20 May-1 June	69	100	0	0	0	0	0	0	0	0
20 June-2 July	37	73	11	22	2	4	0	0	1	2
29-30 July	1	14	5	71	0	0	0	0	1	14
27 Aug.-9 Sept.	18	82	2	9	0	0	1	5	1	5
6-14 Oct.	16	94	0	0	0	0	1	6	0	0
4-10 Nov.	29	100	0	0	0	0	0	0	0	0

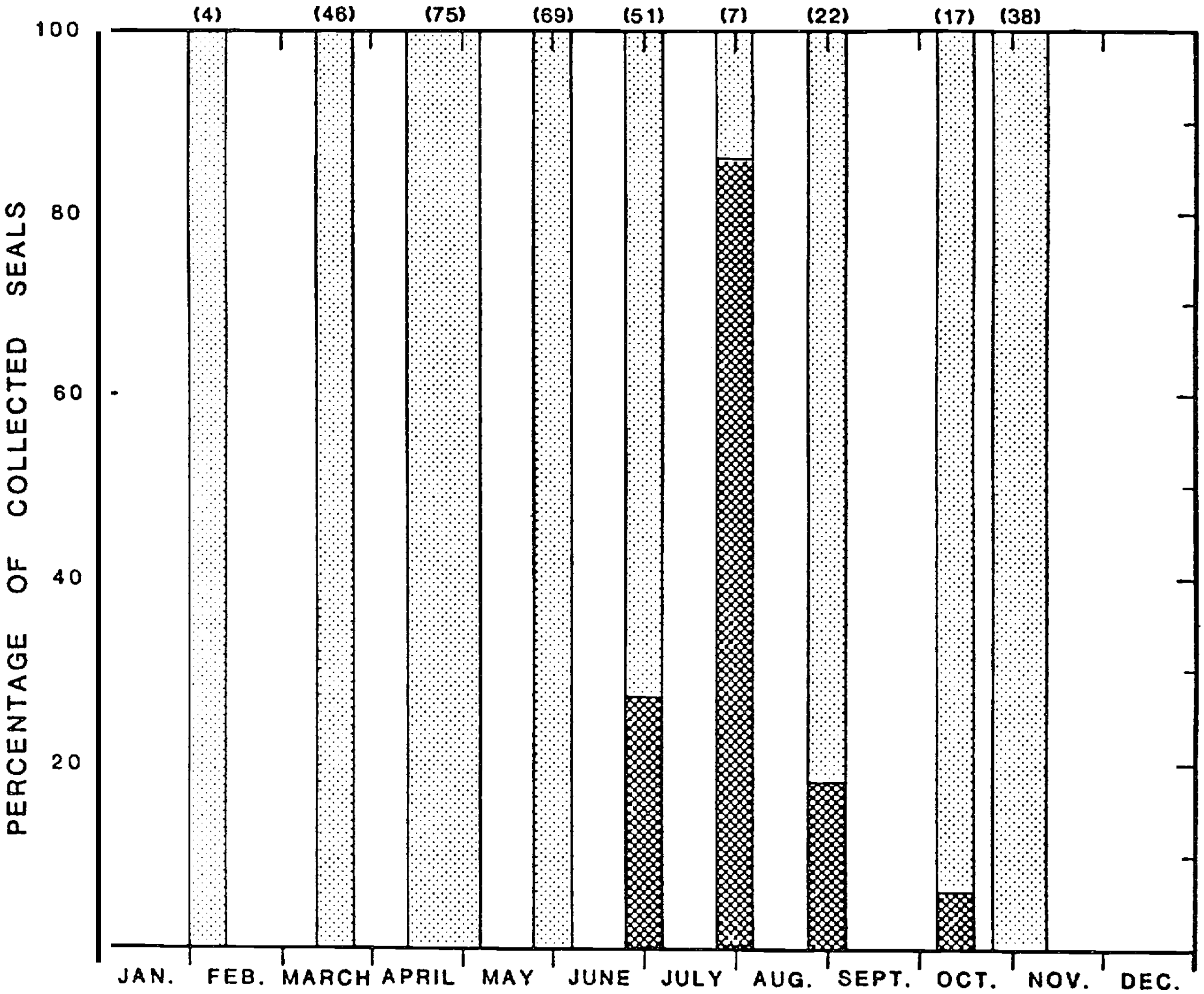

FIGURE 11. PROPORTIONS OF MOLTING HARBOR SEALS BY COLLECTING PERIOD IN THE GULF OF ALASKA. ALL AGES AND BOTH SEXES COMBINED. ▩, MOLTING STAGE: ☐, RESTING STAGE: NUMBER IN PARENTHESIS, SAMPLE SIZE.

POPULATION CHARACTERISTICS

Sex Ratio

Sex ratios for various age categories of seals collected during this study are presented in Table 15. The only age category which had a significant deviation ($P<0.05$) from an even sex ratio was the oldest group (21-31 years) where 25 of 32 seals (78%) were females. These data agree closely with those of Bigg (1969); females comprised 53% of the postnatal seals anti few males over 20 years were collected.

Table 15. Sex ratios of various age classes of harbor seals collected in the Gulf of Alaska

Age Classes	MM: FF Sex Ratio	Chi square	(P)
Fetal	41 : 51	0.55	>0.10
0 - 5 years	132 : 130	0.01	>0.90
5 - 10 years	63 : 86	1.79	>0.10
11 - 20 years	68 : 63	0.10	>0.10
21 - 31 years	7 : 25	5.50	<().()5
o - 31 years	270 : 304	1.01	>0.10

Age Structure of the Sample

It appears that our sample did not accurately reflect age structure of the population below about 4 years of age (Figure 12). Young seals were particularly vulnerable to collecting and were therefore deliberately selected against. The oldest female was 31 years old and the oldest male was 26 years.

Mortality

KL_x series life tables (Caughley 1966) were constructed to examine mortality patterna. Because it appeared that animals were not fully represented in our sample until 4 years of age we deleted age classes 1-3 years in the analyses. Initial pup production was estimated from age specific pregnancy rates and age frequency distribution. Age frequencies were smoothed using probit regression (Caughley 1977). Assumptions basic to these life table analyses are that the initial size of each age class is equal and that age specific mortality and reproductive rates have remained constant over the range of age classes present. Neither assumption can be conclusively demonstrated, nevertheless we felt they were approximated and that it was valid to proceed. When frequency values for an age class dropped below five, life table calculations were stopped.

Mortality rates for both sexes were high from birth to 4 years; estimated at 74.2% ‘for females and 79.2% for males (Tables 16 and 17). The mean annual mortality rate for females between 4 and 19 years was 11.4% and for males between 4 and 17 years, 12.7%. Mortality rates for both sexes reached minimal levels between about 8 and 13 years and then appeared to increase slightly. By combining sexes, the life table was extended to 23 years (Table 18) and an increase in mortality rate was apparent after 18 years. Although not shown by the life tables there is evidence that males in the older age classes have a considerably higher mortality rate than females. In a sample of 32 seals, between 21 and 31 years of age, only seven were males.

Table 16. Life table for male harbor seals collected in the Gulf of Alaska.

Age	Frequency*	Survival	Mortality	Mortality rate
0	89. 30**	1.000	0.792	0.792
4 years	18.60	0.208	0.022	0.106
5	16.57	0.186	0.019	0.102
6	14.89	0.167	0.016	0.096
7	13.47	0.151	0.014	0.093
8	12.24	0.137	0.012	0.088
9	11.14	0.125	0.011	0.088
10	10.16	0.114	0.010	0.088
11	9.27	0.104	0.009	0.087
12	8.45	0.095	0.009	0.095
13	7.70	0. 086	0.008	0.093
14	7.00	0.078	0.007	0.090
15	6.35	0.071	0.007	0.099
16	5.74	0.064	0.006	0.094
17	5.16	0.058		
>17	26.13			

* Age frequencies ≥ 4 years smoothed by probit curve.

** Estimated value based on age frequencies and age specific fecundity rates.

Bigg (1969) estimated average annual mortality of harbor seals between 5 years and the end of life at 29% for males and 15% for females. Values in the literature for adult mortality in other phocid seals are 14% for bearded seals, *Erignathus barbatus*, (Benjaminsen 1975); 8-10% for harp seals, *Pagophilus groenlandicus*, (Sergeant 1976); and Weddell seals, *Leptonychotes weddelli*, 15-20% for females and perhaps as high as 50% for males (Siniff et al. 1977).

Table 17. Life table for female harbor seals collected in the Gulf of Alaska.

Age	Frequency*	Survival	Mortality	Mortality rate
0	89.30**	1.000	0.742	0.742
4 years	23.04	0.258	0.028	0.109
5	20.55	0.230	0.023	0.100
6	18.50	0.207	0.019	0.092
7	16.76	0.188	0.017	0.090
8	15.24	0.171	0.015	0.088
9	13.90	0.156	0.014	0.090
10	12.70	0.142	0.012	0.085
11	11.60	0.130	0.011	0.085
12	10.60	0.119	0.011	0.092
13	9.68	0.108	0.009	0.083
14	8.83	0.099	0.009	0.091
15	8.03	0.090	0.008	0.089
16	7.28	0.082	0.008	0.098
17	6.58	0.074	0.008	0.108
18	5.91	0.066	0.007	0.106
19	5.28	0.059		
>19	23.80			

* Age frequencies ≥ 4 years smoothed by probit curve.
** Estimated value based on age frequencies and age specific fecundity rates.

FOOD HABITS

Stomachs from 357 seals were examined. for food during this study. Food was present in 172 stomachs. Data previously collected on harbor seal food habits from Prince William Sound (Pitcher 1977) were also included in these analyses to expand coverage of geographic variations.

All Areas and Seasons Combined

Analysis of prey utilization with all areas and all seasons combined (Table 19) showed that fishes comprised 73.8%, cephalopods 22.2% and decapod crustaceans 4.1% of the occurrences of prey items. Cephalopods included both octopus (*Octopus* sp.) and squids of the family Gonatidae. Decapod crustaceans were primarily shrimps with one occurrence of a crab. A minimum of 27 species of fishes were eaten belonging to 13 families. Major prey items were ranked (Table 20) using a modified Index of Relative Importance. The top three prey taken by harbor seals in the Gulf of Alaska were walleye pollock (*Theragra chalocogramma*), octopus and capelin (*Mallotus villosus*).

Area Comparisons of Prey Utilization

Table 21(A-F) is a presentation of prey utilization by harbor seals according to area of collection. In all areas except Kodiak and Prince William Sound, sample sizes were small and the collections did not have

Table 18. Life table for harbor seals, both sexes combined, collected in the Gulf of Alaska.

Age	Frequency*	Survival	Mortality	Mortality rate
0	178.60**	1.000	0.767	0.767
4, years	41.65	0.233	0.025	0.107
5	37.12	0.208	0.021	0.101
6	33.40	0.187	0.018	0.096
7	30.23	0.169	0.015	0.089
8	27.48	0.154	0.014	0.091
9	25.05	0.140	0.012	0.086
10	22,86	0.128	0.011	0.086
11	20.87	0.117	0.010	0.085
12	19.06	0.107	0.010	0.093
13	17.38	0.097	0.008	0.082
14	15.83	0.089	0.008	0,090
15	14.38	0.081	0.008	0.099
16	13.02	0.073	0.007	0.096
17	11.74	0.066	0.007	0.106
18	10.53	0.059	0.006	0.102
19	9.38	0.053	0.007	0.132
20	8.30	0.046	0.005	0.109
21	7.26	0.041	0.006	0.146
22	6.27	0.035	0.005	0.143
23	5.32	0.030		

* Age frequencies ≥ 4 years smoothed by probit curve.
** Estimated value based on age frequencies and age specific fecundity rates.

complete seasonal coverage, therefore, caution must be applied when making comparisons. Either walleye pollock or octopus was the top ranked food item in all areas. Walleye pollock was the top ranked item in the three eastern areas i.e., Northeastern Gulf of Alaska, Prince William Sound and Kenai coast. In the three western areas i.e., Lower Cook Inlet, Kodiak Island and Alaska Peninsula, octopus had the highest ranking. In lower Cook Inlet, invertebrates (i.e. octopus and shrimps) made up over 60% of both occurrences and volumes.

In two areas, Kodiak Island and Prince William Sound, where larger samples and fairly complete seasonal coverage were obtained we statistically compared occurrences of some major prey species between these areas (Table 22). In Prince Willian Sound more pollock ($P<0.001$) were eaten while in Kodiak higher utilization of capelin ($P<0.05$) occurred. octopus and Pacific cod (*Gadus macrocephalus*) were not utilized at significantly different rates ($P>0.05$). While samples were too small for statistical testing, it appeared that a higher proportion of squids and herring were eaten in Prince William Sound and more Pacific sandlances (*Ammodytes hexapterus*), flatfishes and sculpins were preyed upon in the Kodiak area (Table 22).

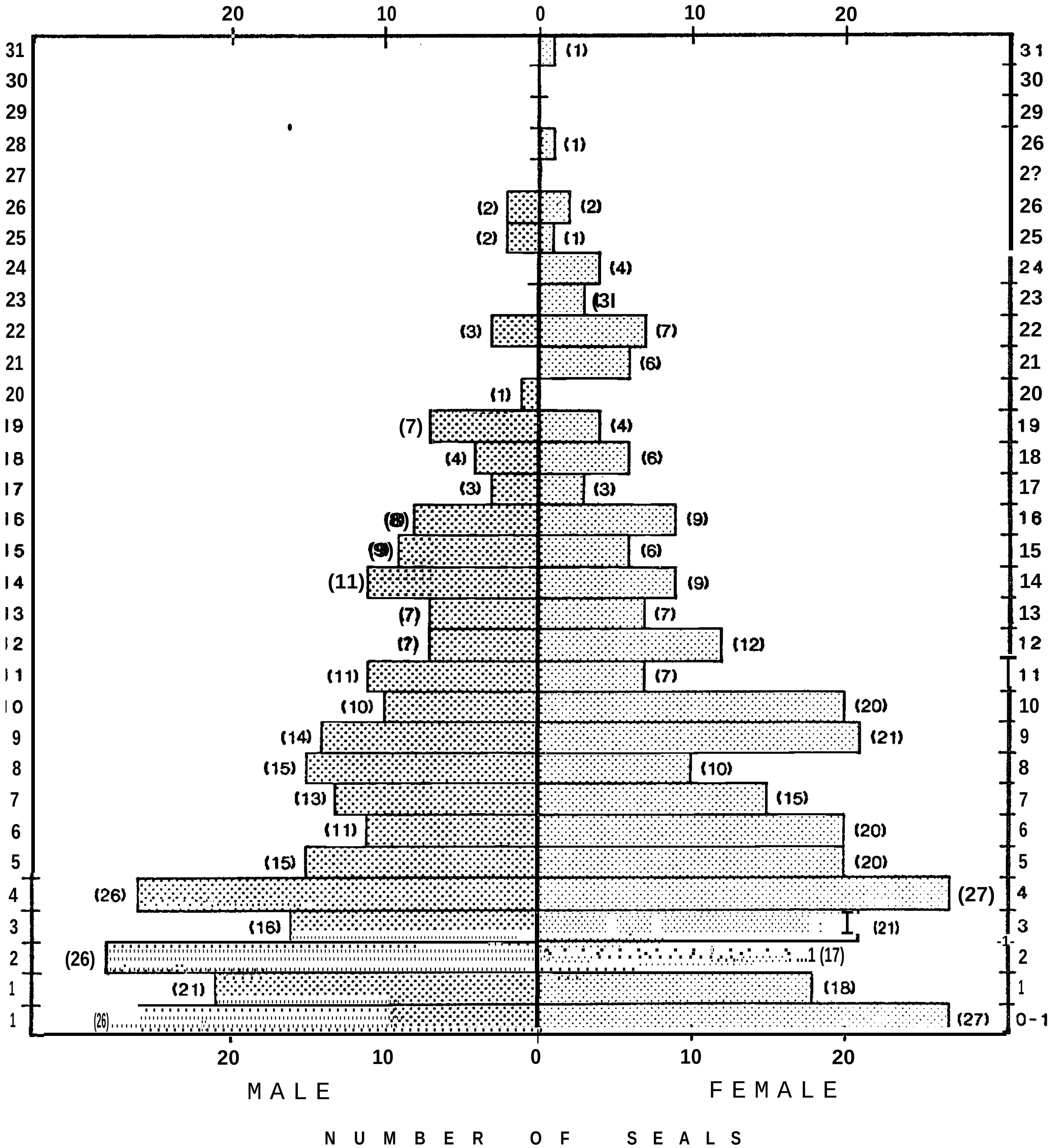

FIGURE 12. SEX AND AGE COMPOSITION OF 574 HARBOR SEALS COLLECTED IN THE GULF OF ALASKA. NUMBER IN PARENTHESIS. NUMBER OF SEALS IN AGE CLASS.

Table 19. Summary of composition of stomach contents from 255 harbor seals collected in the Gulf of Alaska, all areas and all seasons combined.

Prey	Occurrences No.	Occurrences % ± 95% C.L.(%)	Volume cc	Volume %
Cephalopod	97	22.2 +4.0	20,433	21.7
octopus Sp. (octopus)	77	17.753.7	18,753	19.9
Gonatidae (squids)	20	4.6 ± 2.1	1,680	1.8
Decapoda	18	4.1 + 2.0	3,800	4.0
Shrimps	17	3.9 ± 1.9	3,400	3.6
Crabs	1	0.2 ± 0.6	400	0.4
Raj idae				
Raja spp. (skates)	3	0.7 ± 0.9	2,780	3.0
Clupea harengus (herring)	29	6.7 ± 2.5	6,560	7.0
Salmonidae				
Oncorhynchus spp. (salmon)	8	1.8 ± 1.4	4,037	4.3
Osmeridae	53	12.2 + 3.2	15,359	16.3
Mallotus villosus (capelin)	40	9.2 ± 2.8	10,687	11.3
Thaleicthys pacificus (eulachon)	8	1.8 ± 1.4	4,162	4.4
Hypomesus pretiosus (surf smelt)	4	0.9 ± 1.0	460	0.5
Unid. osmeridae (smelts)	1	0.2 ± 0.5	50	0.1
Gadidae	134	30.7 + 4.4	26,603	28.2
Eleginus gracilis (saffron cod)	5	1.1 ± 1.1	395	0.4
Gadus macrocephalus (Pacific cod)	28	6.4 ± 2.4	3,240	3.4
Micrgradus proximus (Pacific tomcod)	7	1.6 ± 1.3	1,030	1.1
Theragra chalcogramma (walleye pollock)	94	21.6 ± 4.0	21,938	23.3
Zoarcidae				
Lycodes spp. (eelpouts)	6	1.4 ± 1.2	60	0.1
Scorpaenidae				
Sebastes spp. (rockfishes)	4	0.9 ± 1.0	810	0.9
Hexagrammidae				
Hexagrammos spp. (greenings)	2	0.5 ± 0.7	400	0.4

Table 20. Rankings of major prey of harbor seals collected in the Gulf of Alaska. Modified Index of Relative Importance = percentage of occurrences X percentage of volumes. Only those prey with modified I.R.I. ≥ 2 are included.

Prey	Modified I.R.I.	Percent of Occurrences	Percent of Volume
Walleye pollock	503	21.6	23.3
octopus	352	17.7	19.9
Capelin	104	9.2	11.3
Herring	47	6.7	7.0
Pacific cod	22	6.4	3.4
Flatfishes	15	5.3	2.8
Shrimps	14	3.9	3.6
Squids	8	4.6	1.8
Eulachon	8	1.8	4.4
Salmon	8	1.8	4.3
Pacific sandfish	7	2.3	3.2
Sculpins	5	2.3	2.0
Skates	2	0.7	3.0
Pacific sandlance	2	4.4	0.5
Pacific tomcod	2	1.6	1.7

Table 21. A-F. Major prey of harbor seals from six geographic areas in the Gulf of Alaska. Prey are ranked by order of modified Index of Relative Importance. Only prey with modified I.R.I. values ≥ 2 are included.

A. Northeastern Gulf of Alaska; Yakutat Bay to Middleton Island. Total stomachs with contents=17, total occurrences=39, total volumes=2,420 cc.

Prey	Modified I.R.I.	Percent of Occurrences with 95% C.L.	Percent of Volume
Walleye pollock	640	28.2 ± 15.4	22.7
Surf smelt	196	10.3 ± 10.8	19.0
Capelin	143	23.1 ± 14.5	6.2
Shrimps	131	2.6 ± 6.3	50.4

Continued

Table 21. Continued.

E. Alaska Peninsula. Puale Bay, Shumagin Islands and Sanak Island. Total stomach with contents=6, total occurrences=9, total volumes=8,185 cc.

Prey	Modified I.R.I.	Percent of Occurrences with 95% C.L.	Percent of Volume
octopus	929	33.3 ± 41.8	27.9
Walleye pollock	824	22.2 ± 37.5	37.1
Pacific sandfish	342	11.1 ± 29.7	30.8
Pacific cod	40	22.2 ± 37.5	1.8
Sculpins	26	11.1 ± 29.7	2.3

F. Kodiak Island; The Barren Islands to Chirikof Island. Total stomachs with contents=102, total occurrences=192, total volumes=42,685 cc.

Prey	Modified I.R.I.	Percent of Occurrences with 95% C.L.	Percent of Volume
octopus	631	21.4 ± 6.1	29.5
Capelin	323	10.9 ± 4.7	21.3
Walleye pollock	70	12.0 ± 4.9	5.8
Flatfishes	63	10.9 ± 4.7	5.8
Pacific cod	55	8.3 ± 4.2	6.6
Pacific sandlance	9	8.3 ± 4.2	1.1
Herring	9	2.1 ± 2.3	4.2
Shrimps	8	3.6 ± 2.9	2.2
Salmon	6	2.1 ± 2.3	2.9
Sculpins	3	4.2 ± 3.1	0.7
Eulachon	2	0.5 ± 1.3	4.6

Table 23. Seasonal variations in occurrences of principal prey (N ≥ 4) of harbor seals. Winter (W)=1 February-9 May, Summer (S)= 10 May-30 September and Fall (F)=1 October - 30 November.

Kodiak Island Area

Prey	(W) Occurrences Number	(W) Percentage ± 95% C.L.	(S) Occurrences Number	(S) Percentage ± 95% C.L.	(F) Occurrences Number	(F) Percentage ± 95% C.L.
octopus	17	30.4 ± 12.9	13	17.6 ± 9.4	11	17.7 ± 10.3
Salmon	0	0.0	4	5.4 ± 5.8	0	0.0
Capelin	3	5.4 ± 6.8	15	20.3 ± 9.8	3	4.8 ± 6.1
Pacific cod	6	10.7 ± 9.0	5	6.8 ± 6,4	5	8.1 ± 7.6
Walleye pollock	8	14.3 ± 10.1	9	12.2 ± 8.1	6	9.7 ± 8.2
Pacific sandlance	0	0.0	3	4.1 ± 5.2	13	21.0 ± 10.9
Total Occurrences	56		74		62	

Prince William Sound

Prey	(W) Occurrences Number	(W) Percentage ± 95% C.L.	(S) Occurrences Number	(S) Percentage ± 95% C.L.	(F) Occurrences Number	(F) Percentage ± 95% C.L.
octopus	10	14.1 ± 8.8	2	15.4 ± 27.1	5	13.2 ± 12.1
Squids	9	12.7 ± 8.4	2	15.4 ± 27.1	5	13.2 ± 12.1
Herring	14	19.7 ± 10.0	2	15.4 ± 27.1	2	5.3 ± 8.4
Salmon	0	0.0	4	30.8 ± 33.5	0	0.0
Capelin	4	5.6 ± 6.1	1	7.7 ± 21.0	0	0.0
Walleye pollock	20	28.2 ± 11.2	1	7.7 ± 21.0	15	39.5 ± 16.9
Total Occurrences	71		13		38	

Prey of Harbor Seal Pups

Prey items were found in the stomachs of 13 harbor seals between the ages of 2.5 and 11 months (Table 24). Small fishes were the primary food. The sample size was too small, as shown by the large confidence limits, to make many valid statistical comparisons with animals of older age classes. Nevertheless, chi-square analysis of occurrence of prey eaten by pups and prey eaten by all other age classes showed one significant ($P<0.01$) difference. A higher proportion of capelin (35.7% compared to 9.2%) was eaten by pups than by all other age classes combined. Specialized feeding on shrimps by newly-weaned harbor seal pups has been reported by Havinga (1933), Fisher (1952) and Bigg (1973) but was not reflected in our data.

Table 24. Prey of harbor seal pups, 0-12 months of age, collected in the Gulf of Alaska.

Prey	Occurrences	
	Number	Percentage ± 95% C.L.
Shrimps	1	7.1 ± 19.4
Capelin	5	35.7 ± 32.1
Pacific tomcod	1	7.1 ± 19.4
Walleye pollock	5	35.7 ± 32.1
Pacific sandlance	1	7.1 ± 19.4
Unidentified fish	1	7.1 ± 19.4
TOTAL	14	99.8

Discussion

Other studies of harbor seal food habits in the eastern North Pacific reflected diets with similar compositions to that found in this study. In Washington, principal prey were members of the families Gadidae, Pleuronectidae, Clupeidae, Cottidae, Batrachoididae and Embiotocidae (Scheffer and Sperry 1931 and Calambokidis et al. 1978). In British Columbia, Spalding (1964) observed that stomachs of harbor seals collected mainly during the summer and fall contained primarily octopus, squids, herring and salmon. Imler and Sarber (1947), working in Southeastern Alaska, found that Gadidae, herring, Pleuronectidae, salmon and shrimps were major food items. Prey reported for harbor seals in the Aleutian Islands included octopus, walleye pollock, rock greenling, *Hexagrammos lagocephalus*, and Atka mackerel, *Pleurogrammus monopterygius*, (Wilke 1957; Kenyon 1965).

The high ranking of walleye pollock (Table 15) may have been a direct reflection of their abundance. Pereyra and Ronholt (1976) found that pollock were the dominant fish species in the Gulf of Alaska, comprising 45% of total fish stocks. They also found that pollock had increased proportionately from 5% of the fish stocks in 1961 to a 1973-75 level of 45%.

The major differences in prey utilization between Prince William Sound and the Kodiak area may be the result of differing habitats. Water depths and bottom topography are considerably different in these areas. Kodiak waters have a large, shallow shelf area, particularity east and south of the Island, while Prince William Sound generally has a precipitous coast with depths reaching 740 meters. These features may influence prey composition, abundance and availability to harbor seals.

Seasonal variations in utilization of certain prey appeared to be explained by seasonal availability of the prey. Salmon were taken only during the summer periods in both Prince William Sound and the Kodiak area. In both areas, salmon are available in nearshore waters only during this period. Capelin were utilized to a greater extent during summer in the Kodiak area which probably reflects nearshore distribution associated with reproductive activities. Also in the Kodiak area, sandlance were utilized to a much greater extent during the fall period. No reason for this is known.

RADIO-TELEMETRY STUDIES

Radio–tracking studies of harbor seals were conducted in the Tugidak Island area between 8 May and 9 September 1978. Objectives of this research were to determine the range of individual movements, extent of haulout area fidelity and haulout patterns. Thirty-five harbor seals (Table 25) were captured on the large haulout area on southwest Tugidak Island and radio transmitters were attached by means of a bracelet around a hind flipper. Signals from the transmitters could be received only when the seals were hauled out. Twenty-one seals were captured between 8 May and 2 June. Capture operations were then suspended until 3 July in order to avoid disturbance during pupping. Fourteen additional seals were equipped with transmitters during 3-9 July. Two backup marking techniques were used to detect radio loss and failure. These included individually recognizable color combinations of Temple cattle ear tags placed in the hind flippers and color combinations of plastic flagging attached to the radio transmitters.

Total numbers of seals and radio-tagged seals ashore on the southwest hauling area were monitored visually and with a radio receiver from 30 m bluffs abutting the beach. Nearly every day from 1-30 June and l-August-5 September. Counts and radio checks were timed to coincide with daylight low tides, a period when maximum numbers were usually hauled out. Visual searches were conducted to locate radio-tagged individuals and the results were compared with the radio checks to detect transmitter failures.

Table 25. Sex and age composition of 35 radio-tagged harbor seals captured on the southwestern hauling area of Tugidak Island.

Sex and Age Classification	Number of Seals
Mature females	24
Immature females	5
Mature males	5
Immature males	1
Total	35

A total of 27 aerial radio-tracking surveys were flown to locate animals which had moved from their site of capture and were hauled out at other areas. A Bell 206 helicopter and a Bellanca Scout fixed-wing aircraft were used for the surveys. Coverage by these surveys included most of the shoreline and all of the known major hauling areas in the Kodiak Island group. The coast between Wide Bay and Amalik Bay on the Alaska Peninsula was surveyed one time, however, weather conditions prevented thorough coverage.

Movements

Eight seals were located a total of 17 times at hauling areas other than the site of capture (Figure 13). The longest movement was by a mature female, TR-18, which moved to Ugak Island, a minimum distance of 194 km. This seal was captured on 17 May, then was found hauled out on Tugidak again on 1 June. Nine days later she was found on Ugak Island. She was located three additional times, all on Ugak. The final contact was on 9 September during the last survey. TR-18 was pregnant when captured and probably had not given birth before moving to Ugak as she was not accompanied by a pup when last observed on Tugidak.

TR-5, another pregnant female, was captured on 11 May. She was not located again until 30 June when a radio tracking survey was flown around Chirikof Island, 74 km southwest of Tugidak Island. TR-5 was next relocated back on Tugidak Island on 3 August. The radio had failed so it was impossible to determine if she was hauled out any place except Tugidak where visual observations were made. She was seen periodically on Tugidak the remainder of the study period.

Another pregnant female, TR-4, was captured on 10 May. She was observed three times through 27 May on Tugidak and then was located with a pup on a sand bar just north of Sitkinak Island on 10 and 11 June. This represented a minimum movement of 56 km. From 1-5 September she was back on Tugidak. On 9 September she was found at the same hauling area north of Sitkinak where she had been on 10 and 11 June.

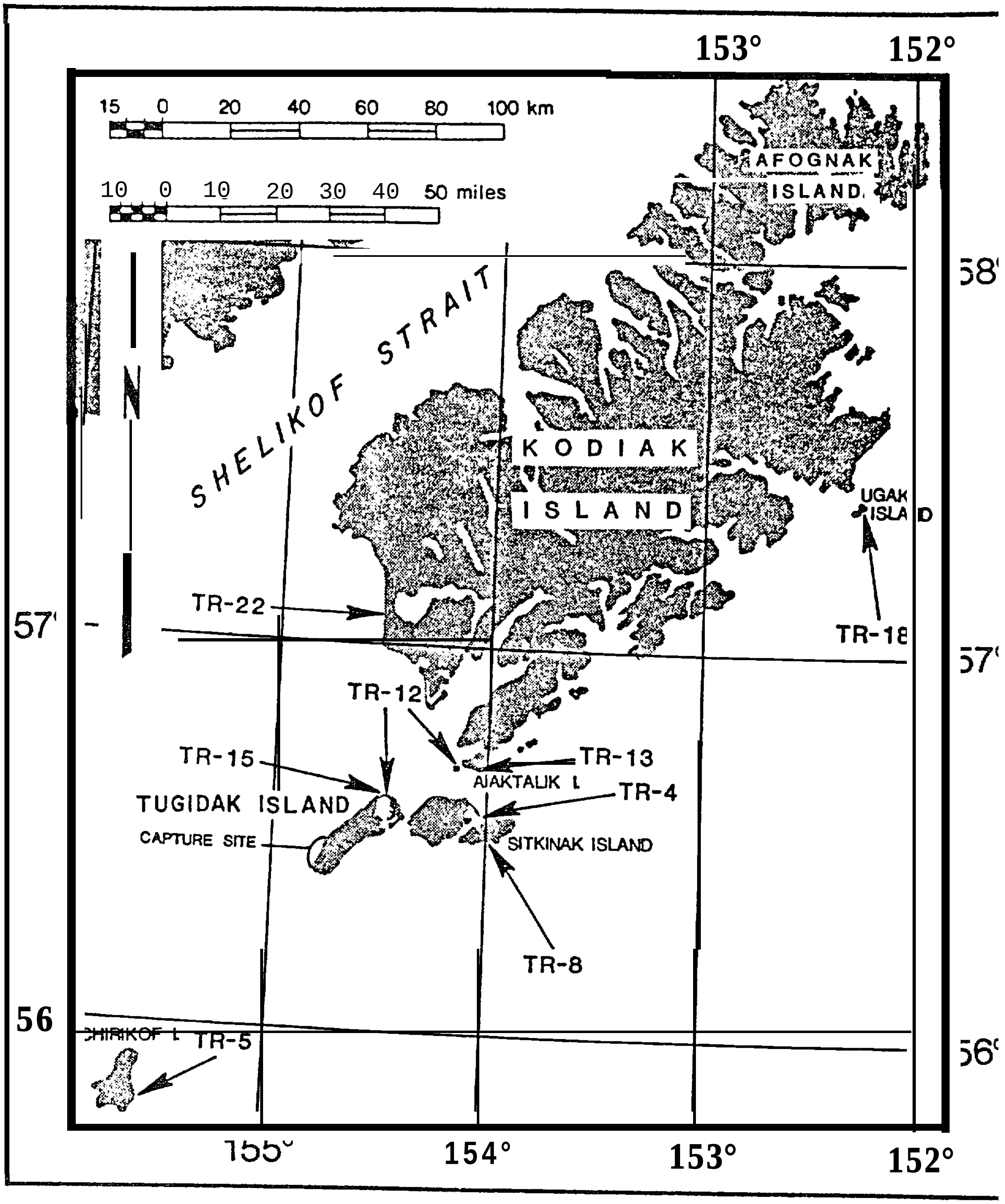

FIGURE 13. LOCATIONS OF RADIO TAGGED HARBOR SEALS FOUND AT HAULING AREAS OTHER THAN THEIR SITE OF CAPTURE ON SOUTHWEST TUGIDAK ISLAND,

TR-8, a pregnant female, was captured on 11 May then seen on Tugidak on 12 May and on 2 June, without a pup on either occasion. No contacts were made until 24-27 August on Tugidak. On 9 September she was found on southeastern Sitkinak, 56 km away.

Another pregnant female, TR-12 was captured on 12 May. She was observed again on southwest Tugidak on 16 and 21 May. On 8 June she was found on northern Tugidak, 26 km distant. On 1, 2 and 24 July she was located on Sundstrom Island an additional 24 km to the northeast.

TR-22, captured on 3 July, was accompanied by a pup. On 28 August she was located on the west coast of Kodiak, 74 km from southwest Tugidak. Her hind flipper was badly abraded at the transmitter attachment site so the radio was removed.

An immature male, TR-13, was captured on 13 May. He hauled out on southwest Tugidak on 21, 22, 24, 25 and 26 May and then was next located on Aiaktalik Island about 54 km away on 10 June. Three days later, TR-13 was back on Tugidak and was observed there frequently throughout the summer.

TR-15, an adult male, was captured on 8 May. He was located a total of nine times, all but one time on southwest Tugidak. On 30 June he was hauled out on the southwestern hauling area and the next day was found on northern Tugidak a minimum movement of 26 km.

Although only eight seals were found at hauling areas other than the capture site it was probable that additional movements occurred. Many of the other seals didn't haulout on southwest Tugidak for extended periods of time and only occasional surveys of other hauling areas were flown. Seals which were not hauled out at the time of the surveys would not have been detected. Five of the eight animals found on other hauling areas were in the northern Tugidak, Sitkinak, Aiaktalik Islands areas (Figure 13) which are the nearest major hauling areas to southwestern Tugidak. Other than this, no obvious pattern of movement was apparent.

One animal, TR-18, moved from Tugidak and appeared to use another hauling area for the remainder of the study period. Two seals, TR-4 and 13, appeared to alternate between two hauling areas. TR-5 made a major move and then returned and appeared to stay at Tugidak. TR-12 was located at three different hauling areas. Three seals, TR-8, 15 and 22, were found only one time at a hauling area other than Tugidak. We could not discern any correlation between sex or age of the animals and degree of movement, however, samples of all groups except adult females were small (Table 25).

Hauling Area Fidelity

Twenty-three of 35 (66%) of the radio-tagged harbor seals were found only at the hauling area where they were captured. Four seals were never relocated after their capture. They either died, moved beyond the range of the surveys or were not hauled out during aerial surveys. Also, if the radios failed or were lost they would not have been located during aerial surveys. Of the eight animals which were located at hauling areas other than Tugidak, three were found on the same hauling area more than one time. It is obvious from these observations that while fidelity to a single hauling area was not complete there was a strong tendency to use one or in some instances two hauling areas repeatedly.

Haulout Patterns

Haulout patterns of individual radio-tagged seals are presented in Figure 14. It was impossible to quantify with complete confidence frequency of haulout because some individuals used more than one hauling area and it was impossible to monitor more than the primary site regularly. Two extended periods with near daily monitoring were used to examine hauling patterns. These were 3–30 June and 1 August-5 September. Animals were arbitrarily classified as "residents" by excluding those found hauled out at other locations and those absent for extended periods. Estimates of the proportion of days hauled out were based on these animals and were undoubtedly biased upward because animals which might have been "residents" but hauled out infrequently were deleted from the analysis. During the June period "resident" seals hauled out on an average of 49.6% of the days (Table 26) and during the August-September period they hauled out on 41.3% of the days (Table 27).

Haulout patterns varied tremendously between individuals (Figure 14). Several animals (TR-7, 14, 15, 19 and 34) hauled out frequently throughout the study period without extended absences. Other seals (TR-3, 6, 10, 11, 21 and 27) had extended absences from Tugidak, were never located at other hauling areas and appeared to haulout infrequently. Some animals (TR-5, 16, 34 and 35) hauled out in somewhat regular patterns while other (TR-6, 14, 15 and 17) appeared more haphazard in their hauling habits.

Table 26. Proportion of days which "resident" radio-tagged harbor seals hauled out on southwest Tugidak Island from 1-30 June 1978.

Animal	Proportion of Days	Animal	Proportion of Days
TR-2	11/25	TR- 17	9/25
TR- 7	16/25	TR- 19	20/25
TR-14	16/25	TR- 20	4/25
TR-16	11/25		

$\bar{x}$ number of days = 12.4 (49.6%)
Standard deviation = 5.3

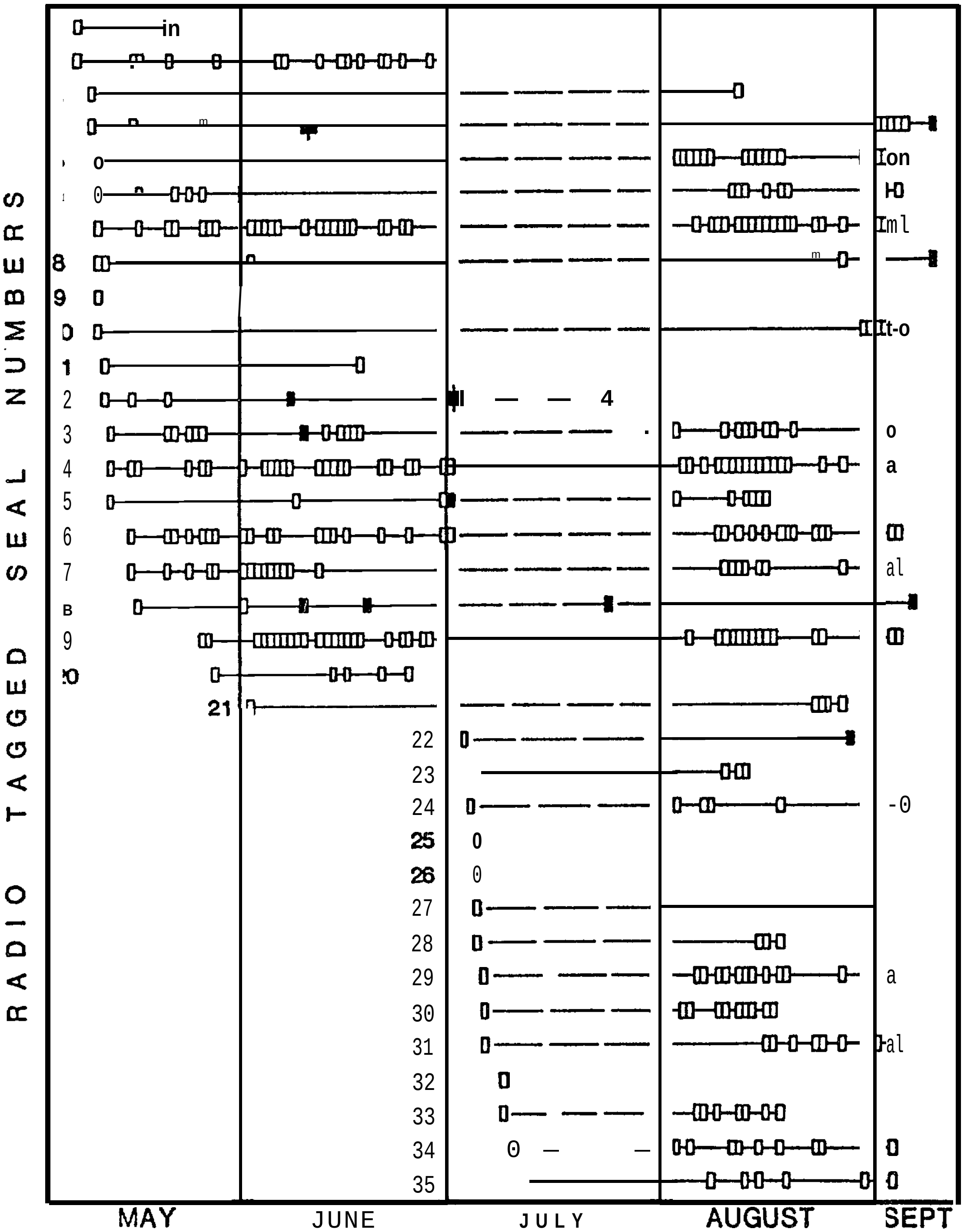

FIGURE 14. HAULOUT PATTERNS OF RADIO TAGGED HARBOR SEALS ON SOUTHWEST TUGIDAK ISLAND SHOWING THE PRESENCE OR ABSENCE OF EACH INDIVIDUAL DURING DAILY RADIO CHECKS. OPEN BOX, PRESENT; DARK BOX. FOUND ON OTHER HAULING AREA; FROM B MAY TO 2 JUNE CAPTURE OPERATION CAUSED DISTURBANCE; 25 VALID RADIO CHECKS BETWEEN 1 AND 30 JUNE; NO ON SITE RADIO CHECKS 2-31 JULY; 31 VALID RADIO CHECKS BETWEEN 1 AUGUST AND 5 SEPTEMBER

Table 27. Proportion of days which "resident" radio tagged harbor seals hauled out on southwest Tugidak Island from 1 August through 5 September 1978.

Animal	Proportion of Days	Animal	Proportion of Days
TR- 5	19/31	TR-17	9/31
TR- 6	9/31	TR-19	15/31
TR- 7	22/31	TR-24	5/31
TR- 13	10/31	TR-29	13/31
TR-14	19/31	TR- 34	10/ 31
TR-16	15/31	TR-35	7/31

$\bar{x}$ number of days = 12.8 (41.3%)
Standard deviation = 5.3

Movement Rates

Limited data were collected on movement rates by dividing the minimum distances between locations where an animal was found by the number of days elapsed between sightings. The rates were minimums in all instances because the actual route traveled was unknown and the time taken to travel was probably less than observed in most cases. Minimum movement rates for four animals were 24 ion/day, 19 Ian/day, 27 km/day and 26 km/ day ,

Discussion

Harbor seals have generally been considered sedentary animals with perhaps limited seasonal movements (Havinga 1933; Scheffer and Slipp 1944; Fisher 1952). Previous studies which have documented movements of harbor seals have involved young animals which were tagged at their birthplaces (Vania et al. 1969; Bonner and Witthames 1974). These studies documented dispersal of juveniles up to 250 km from large pupping areas. Mansfield (1967) and Knudtson (1974) both mentioned wandering or dispersal of young animals and referred to them as "rangers." Boulva (1971) felt that the Sable Island harbor seal colony was isolated from the mainland because of distance (165 km).

In Puget Sound it was suggested that both long distance movements and year around site loyalty occurred (Calambodkis et al. 1978). The results of our work appear to agree with this as considerable individual variation was obvious. Knudtson (1974) and Reijnders (1976) reported observations of the same animals returning repeatedly to the same hauling area. Their results are similar to our findings of considerable hauling area fidelity by some individuals.

INDEX COUNT SITES

Because of difficulties associated with censusing an ubiquitous marine mammal such as the harbor seal it appeared more feasible to monitor population status utilizing index count sites and following trends rather than by attempting total enumerations. To accomplish this a major hauling site was selected in each of the three lease areas in the Gulf of Alaska. These included Channel Island (60 14 35 N; 147 22 00 W) in the northeastern Gulf of Alaska, Elizabeth Island (59 08 20 N; 151 48 10 W) in lower Cook Inlet and southwest Tugidak Island (56 27 04 N; 154 46 35 W) in the Kodiak lease area. Data where available from Tugidak Island from previous years. We selected the period from 20 August through 10 September to conduct the counts because previous observations indicated that maximum numbers of seals hauled out then. Daily counts were made of seals hauled out during daytime low tides. Regression analyses indicated that stage of tide was the major explainable variable associated with numbers of seals hauled out (r^2 = 0.18 at Elizabeth Island and r^2 = 0.08 at Charnel Island). Maximum counts were usually obtained at low tide (Figure 15). Counts were made from the ground with the aid of binoculars and spotting scopes. Counts of large groups of seals on Tugidak Island were made from polaroid prints. Counts were made at Channel Island from 25 August to 10 September 1978, at Elizabeth Island from 21 August to 10 September 1978 and at Tugidak Island from 1-30 June 1976 and 1978 and 20 August to 5 September 1976 and 1978.

Data from Channel Island and Elizabeth Island are summarized in Tables 28 and 29. These are the first counts made at these locations and will serve as a baseline for future comparisons. On Tugidak Island, data were collected for June and August-September of both 1976 and 1978 (Tables 30 and 31). The mean count for June 1978 was 54% of the average June count for 1976. The average August-Septenber count for 1978 was 70% of the 1976 average. These reductions were both highly significant ($P<0.01$). The reason for the apparent decline is not evident. However, considerable disturbance was documented and could be a factor.

Table 28. Channel Island harbor seal count data, 25 August-10 September 1978.

Number of Seals	Number of Seals	Number of Seals
258	559	118
251	498	254
178	453	520
138	141	358
183	237	477
209	280	122
296	180	

$\bar{x}$ with 95% confidence limits = 285.5 $\pm$ 68.4
Range = 118 - 559
Standard Deviation = 142.7

Table 29. Elizabeth Island harbor seal count data, 21 August-10 September 1978.

Number of Seals	Number of Seals	Number of Seals
282	99	262
88	110	472
220	114	264
184	539	279
250	619	59
123	336	294
241	41	291
237	269	615

$\bar{x}$ with 95% confidence limit 262.0 ± 69.8
Range = 41 - 619
Standard Deviation = 161.7

Table 30. Summary of 1-30 June 1976 and 1978 harbor seal counts on Tugidak Island.

1976		1978	
Number of Seals	Number of Seals	Number of Seals	Number of Seals
2819	2278	731	1460
2574	1974	981	1773
1824	2785	715	851
1304	3566	1332	1148
1039	2525	1725	909
1335		1439	893
		812	1637
		892	1348
		714	939
		1078	927
		1965	765
		2086	853
		1570	

	1976	1978
$\bar{x}$ with 95% Confidence Limits	2183.9 ± 517.4	1181.7 ± 176.2
Range	1039 - 3566	714 - 2086
Standard Deviation	770.2	419.0

Table 31. Summary of 20 August-5 September 1976 and 1978 harbor seal counts on Tugidak Island.

1976		1978	
Number of Seals	Number of Seals	Number of Seals	Number of Seals
8716	6437	2532	5599
2800	9042	2587	5758
7645	9300	3983	5257
3700	7785	4814	6817
6735	6904	5966	4576
6781	7182	5372	4805

	1976	1978
$\bar{x}$ with 95% Confidence Limits	6918.9 ± 1301.8	4838.8 ± 854.7
Range	2800 - 9300	2532 - 6817
Standard Deviation	1962.5	1288.5

EFFECTS OF DISTURBANCE

Observations on Tugidak Island during the summers of 1976 and 1978 provided information on disturbance events and some insight into their possible effects on the population. All observations were of hauled out animals. A disturbance event was classified as any event which caused hauled out seals to rush into the water. Information on disturbance was descriptive rather than quantitative and interpretation of the effects is speculative.

Disturbances generally could be categorized as either major or minor based on the reaction of the seals. Major disturbances sent all the seals into the water and were often followed by a long period before they rehauled. Minor disturbances sent only a portion of the seals into the water and they returned rapidly to the haulout. Naturally occurring disturbances included earth slides and actions of birds and other seals. Earth slides caused both major and minor disturbances depending on their proximity and magnitude. Gulls (Laridae), ravens (Corvus *corax*) and bald eagles (*Haliaeetus leucocephalus*) all caused disturbances of varying intensities, usually when the birds were foraging for placentas, fetal membranes or feces. Agonistic behavior of seals and actions associated with parturition sometimes caused surrounding animals to go into the water. Occasionally, for no apparent reason, a single animal dashed into the water alarming other animals which followed.

Human related disturbances observed on Tugidak included: aircraft overflights, and disturbances caused by all terrain vehicles, hikers, domestic animals and research activities. Although boat traffic was not a disturbing factor on Tugidak, it was in many locations. Seals on Tugidak seemed to be particularly sensitive to aircraft. During aerial radio tracking surveys we noted that seals on Tugidak went into the water when a small, fixed-wing airplane passed over at 2,000 feet while in other areas they remained undisturbed when the aircraft was only 1,000 feet or less in altitude. Helicopters were particularly disturbing: probably because they usually flew at low altitudes and were loud. Occasionally, a large jet flying at high altitude (probably >30,000 feet) would cause animals to go into the water although the noise level was low. Certain research activities, particularly capturing hauled out seals to attach radio transmitters, were major disruptive factors. These were timed to avoid sensitive periods such as pupping and molting and were one time occurrences rather than continuing activities. The other disturbing activities including all terrain vehicle use, hikers and domestic animals were comparatively limited and at present are not serious.

Although it was difficult to evaluate overall effects of disturbance on harbor seal populations it appeared that disturbance during pupping contributed to neonatal mortality. Observations indicated that the first several hours following birth were critical to formation of the mother-pup bond. During this period the pups appeared disoriented and the females initiated “nose-to-nose” contacts. Usually within an hour after birth the pup and female went into the water for a short while. The first nursing took place within about two hours. The mother-pup association continued for about 4 weeks until the pup was weaned. It appeared that if a disturbance separated the mother and pup shortly after birth, before a strong bond was formed, permanent separation often occurred resulting in the death of the pup. By way of illustration, on 22 May 1978 a radio-tagged female was seen with a new pup (probably only hours old). There was considerable “nose-to-nose” contact and a short nursing bout. The female attempted to get the pup into the water, but a moderate surf washed the pup back ashore and the female returned to the pup on the beach. A helicopter then flew directly over the hauling area at less than 200 feet altitude scaring all the seals into the water. The female went into the water followed sometime later by the pup. We did not see them reunite and eventually lost track of them. Two days later the female was seen hauled out without her pup and it appeared that permanent separation had occurred. Disturbance did not appear to adversely affect older pups which had formed strong bonds with their mothers. Two females which were accompanied by pups were captured and separated late in June 1977. The following day both pairs were seen reunited. Burton et al. (1975), studying grey seals (*Halichoerus grypus*) found that the female smelling the pup immediately after birth and at intervals thereafter allowed her to establish the identity of her pup. They concluded that the more times a cow can smell the pup soon after birth the firmer the bond becomes. Disturbance by gulls, other seals or human intrusion may lead to a failure in bond establishment and result in abandonment of the pup.

During the molt seals are thinner than at any other time (see section on physical condition). Ronald et al. (1970) and Geraci and Smith (1976) found that stress occurred in molting seals. Findings of Feltz and Fay (1966) suggested that hauling out during the molt was important in warming the skin thus promoting growth of epidermal cells. Conceivably, disturbances during the molt which cause hauled out animals to enter the water could be detrimental to their health.

Effects of disturbance on harbor seals during other seasons are largely unknown. Kenyon (1972) presented evidence that repeated human disturbance caused Hawaiian monk seals, *Monachus schauinslandi*, to desert beaches offering preferred habitat as well as increasing juvenile mortality. Loughlin (1974) felt that disturbance factors such as boat traffic lessened use by harbor seals of some portions of Humboldt Bay. Nocturnal haulout cycles (in response to daytime disturbances) were reported for harbor seals in portions of Puget Sound and San Francisco Bay (Paulbitski 1975; Calambokidis et al. 1978). Streveler (1979) speculated that three periods of the harbor seals' life cycle were particularly sensitive and that the added stresses of human disturbance might increase mortality. His observations of the impact of disturbance on the mother-pup bond were similar to ours and further emphasize the importance of minimizing disturbance during pupping and suckling. He also felt that the breeding season and the period immediately following might be critical because animals are quite thin and adult males often have numerous wounds. Streveler said that winter weather was most severe and might be stressful. However, blubber reserves are greatest during this period which may indicate that it is not a critical period.

POTENTIAL IMPACTS OF OCS ACTIVITIES

OCS activites appear to have the potential to adversely affect harbor seal populations in at least four major ways: (1) death or physical impairment resulting from exposure to and/or ingestion of oil, (2) reduction in prey availability because of oil related mortality of organisms lower on the food chain, (3) loss of habitat due to development, and (4) stress imposed by disturbance.

The effects of direct oiling of harbor seals, or phocid seals in general, are not well known. Insulation is provided by a subcutaneous fat or "blubber" layer which is unaffected by oil. Field observations of elephant seal, *Mirounga angustirostris*, pups and grey seal pups which had been oiled did not indicate there was increased mortality (LeBoeuf 1971; Davis and Anderson 1976). Geraci and Smith (1976) experimentally coated harp seal, *Phoca groenlandica*, pups and immersed ringed seals, *Phoca hispida*, in a tank of sea water with a surface layer of crude oil. No mortality or reduction in thermoregulatory ability took place but eye irritation and behavioral changes occurred. In a later experiment, three "stressed" ringed seals died within 71 minutes after contact with oil. This may indicate that seals are more vulnerable during stressful periods such as the molt.

Engelhardt et al. (1977) found that ringed seals rapidly absorbed hydrocarbons into body tissues and fluids when exposed by immersion or ingestion. They did not determine concentrations necessary to kill the animals. It appears from the limited information available that phocid seals are not nearly as vulnerable to direct contact with oil as are sea otters (*Enhydra lutris*) and northern fur seals which depend on their pelage for insulation. Nevertheless, exposure to oil may be harmful because of absorption of hydrocarbons and increased stress.

Several studies have indicated that oil pollution might affect abundance of forage species (Evans and Rice 1974; DeVries 1975; Struhsaker 1977; Craddock 1977; Patten 1977). Extensive reductions in stocks of major prey such as walleye pollock, octopus, capelin, herring and Pacific cod would certainly have detrimental impacts on harbor seal populations.

Loss of habitat resulting from development does not appear to be a major problem. The amount of development that would take place in important harbor seal habitat would probably be negligible. Lease restrictions limiting development near major hauling or feeding areas would minimize potential conflicts.

Disturbance is an impact of OCS activities which is probably as great during the preliminary or exploratory phase as during the developmental and production stages. Low flying aircraft, both fixed wing and helicopters, are primary disturbing factors. Observations on Tugidak Island showed that helicopters transporting field geologists were a key disturbing factor. Vessel traffic appears to be a minor problem as most activities are not close enough to hauling areas to be disruptive. Disturbance impacts could be minimized by restrictive time and space zoning during both exploratory and developmental activities.

RECOMMENDATIONS

Restrictions on Disturbance

All phases of OCS development should be regulated in such a manner as to avoid disturbing major concentrations of harbor seals. Particular emphasis should be placed on avoiding disturbance during the pupping and suckling period (20 May-10 July) and the molting period (15 July-1 October). Aircraft are the most severe disturbing factor because of their speed and mobility and because they are the prevalent form of transportation. Minimum limits on altitude, perhaps 2000 feet, and horizontal distance, about 2 miles, should be placed on their use near major concentrations of seals.

Restrictions on Development

Major concentrations of harbor seals, particularly hauling areas, should be avoided as sites for development of facilities. Any planned development should be evaluated with consideration of harbor seal habitat.

Trophic Considerations

Maintenance of a large harbor seal population in the Gulf of Alaska will depend largely on the perpetuation of adequate stocks of prey organisms. We found that the major prey of harbor seals were walleye pollock, octopus, capelin, herring and Pacific cod. Relatively little is known about the life histories, distribution and key habitats of these species. The literature suggests (see previous section - Potential Impacts of OCS Activities) that harbor seal prey species may be more vulnerable to oil in the marine system than the seals themselves.

Research Needs

Improvement is needed in our ability to monitor trends in harbor seal abundance. It is impractical to census large populations of harbor seals spread over a wide geographic area. The index count areas established in 1978 were initial efforts to establish "baselines" of abundance. These should be continued for two additional years to evaluate year to year variation in numbers.

Age specific information on juvenile mortality rates i.e., between birth and 4 years of age, is not available. These age classes, particularly the first year, may be most susceptible to impacts of OCS development and it would be valuable to know the range of predevelopment juvenile mortality rates.

Research should be conducted on major prey species to provide information needed to insure their protection.

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Biological studies of harbor seals in the Gulf of Alaska were conducted from 1975 through 1978 with the major objective of gathering information which could be used to regulate OCS developmental activities in such a manner to minimize adverse effects on harbor seal populations. Data were obtained through observations and counts of hauled out seals, by relocating radio tagged animals and through analysis of specimens from collected seals.

A partial catalog of major harbor seal concentrations was developed. This listing is composed primarily of haulout areas and is weak in aquatic distribution.

Pupping appeared to occur at nearly all locations where seals hauled out and took place between about 20 May and 25 June. Weaning occurred 3-5 weeks after birth. Ovulation and breeding took place shortly after weaning in mature females. Breeding was followed by a period of delayed implantation lasting about 11 weeks, followed by an active gestation period of about 36 weeks. The average age of first ovulation was estimated at 5.0 years and the average age of first pregnancy at 5.5 years. Age specific pregnancy rates were: 0-3 years, 0%; 4 years, 17%; 5 years, 63%; 6 years, 88%; 7 years, 89%; 8 years old and older, 92%. Reproductive failures were found in 10.6% of the mature females. Male harbor seals became sexually mature at from 5 to 6 years of age. All males were spermatogenically inactive between early October and early February.

Birth weights and lengths were greater for seals from the Kodiak area than for those from the Icy-Yakutat Bay areas. Seal pups grew rapidly during the nursing period then slowly for the remainder of their first year. Growth was rapid between 1 and 5 years then slowed. Skeletal growth was completed by about 7 years and maximum weight attained at about 10 years. Adult male harbor seals were both longer and heavier than females. Geographic variations in adult body size were apparent, with the larger animals found in the Kodiak, Kenai, Prince William Sound and Alaska Peninsula areas and the smaller seals occurring in Lower Cook Inlet and the Icy-Yakutat Bay areas.

Physical condition, as reflected by blubber thickness, was good and relatively stable between early November and mid-May. Poorer condition occurred during summer, probably associated with lactation, breeding and molting. During winter 1977, seals from the Kodiak area were thinner than those collected from other areas and from Kodiak the previous year.

Molting seals were encountered between late June and early October with the highest proportion occurring in late July.

Sex ratios did not deviate significantly from 50:50 except in the 20 year plus category which was predominately females. Seals were not fully represented by our sample until about four years of age because of selection against younger animals. The oldest female collected was 31 years old and the oldest male was 26 years old. Mortality from birth to 4 years of age was estimated at 74.2% for females and 79.2% for males. Mean annual mortality for females from 4 to 19 years was calculated at 11.4% and for males from 4 to 17 years, 12.7%.

Major prey of harbor seals in the Gulf of Alaska were walleye pollock, octopus, capelin, herring and Pacific cod. Some seasonal and geographic variations in prey utilization were found. Small fishes were the main food of harbor seal pups.

Movements up to 194 km by radio-tagged seals were documented, including those of an individual which crossed 74 km of open ocean. There appeared to be a strong tendency for seals to use a single, or in some instances, two hauling areas repeatedly. Minimum movement rates ranged between 19 and 27 km/day.

It appeared that disturbance during pupping caused separation of mother-pup pairs thereby increasing neonatal mortality. Molting seals may be particularly vulnerable to the stress of disturbance because of poor physical condition and a possible physiological requirement of hauling out to warm the skin during the molt.

Index count sites were established at major haulouts in each of the lease areas and included Channel Island (NEGOA), Elizabeth Island (LCI) and southwest Tugidak Island (Kodiak). Repetitive counts were obtained at each site to form a "baseline" for future comparisons.

Potential impacts of OCS development include: (1) death or impaired health resulting from exposure to and/or ingestion of oil, (2) reduction in prey availability because of oil related mortality of organisms lower on the food chain, (3) loss of habitat due to development, and (4) stress imposed by disturbance. Recommendations to minimize these impacts include: (1) limiting activities around major harbor seal concentrations particularly during pupping, suckling and molting; (2) preventing habitat usurpation by not allowing development in the vicinity of major hauling or feeding areas; (3) research on the life histories, distribution and key habitats of major prey species; (4) research into juvenile mortality rates of harbor seals; and (5) continuation of "baseline" abundance studies at the index count sites.

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