ANNUAL REPORT
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NOAA GRANT NA57FX0367

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ABSTRACT

In response to a continuing and severe decline in the number of harbor seals in the Gulf of Alaska, the National Marine Fisheries Service provided annual grants of $500,000 to the Alaska Department of Fish and Game to investigate the causes of the decline and to monitor current trends in the population. Results obtained in the area of decline were compared to results obtained in southeastern Alaska (SE) where seals have remained abundant.

Aerial surveys of trend sites in the Kodiak and Ketchikan areas suggest seal numbers are increasing in both areas. Seals numbers along the Ketchikan route increased at an annual rate of approximately 8 percent since 1983. While in the Kodiak area numbers were stable or possibly increasing. Aerial surveys of seals along the Sitka trend route indicate a stable population since 1983.

Satellite-linked time depth recorders (SDRs) were attached to 27 seals in 1993 and 1994 to monitor their movements, and haulout and diving behaviors. Based on the 27 seals, movements were highly variable by individual. Seals generally remained in the area of their capture with most traveling less than 50 kilometers. Some individuals were relocated up to 150 kilometers from their capture site, but all eventually returned to their "resident" haulout. Individual seals used open water habitats, heads of bays, river mouths, and glacial fjords suggesting harbor seals are exploiting a wide variety of habitats. An additional 21 satellite-linked time depth recorders were attached to seals in 1995; those data will be processed and reported in the 1996 contract year.

There was no statistical difference in the proportion of time seals in SE Alaska and Kodiak spent hauled out, however, there were seasonal trends in haulout patterns. Seals spent more time hauled out during summer and less time during winter. Small sample sizes and sampling biases confounded interpretation of these data.

The diving behavior of these 27 harbor seals was characterized by relatively short and shallow dives. The majority of dives were less than 4 minutes in duration and less than 50 meters in depth. Harbor seals rarely dove deeper than 150 meters, with only 1-2% of all dives being to greater depths. The distribution of dives among different depth categories varied considerably by seal and by area. Data on maximal dive depths seemed to indicate harbor seals were sometimes diving to the bottom. Seals in SE dove deeper than seals near Kodiak, reflecting the deeper bathymetry of the area. Harbor seals in both areas showed strong seasonal patterns in dive depth. The percentage of shallow dives increased markedly during the late spring and summer while deeper dives were more common during the fall and winter. Subadults in Kodiak dove deeper and more frequently than subadults in SE Alaska, although very small sample sizes preclude definite conclusions. Adult males also dove more frequently in Kodiak than in SE Alaska. Since dive frequency can be considered a potential index of foraging effort, the increased frequency in Kodiak is suggestive of greater foraging

effort and hence lower food availability. Future analyses will investigate other potential indices of foraging effort, such as the actual time spent diving (i.e., time submerged) and will associate location data with the dive data.

Seals were tested for phocine herpesvirus, phocine distemper virus, *Brucella spp.*, influenza virus, *Toxoplasma gondii*, *Chlamydia psittaci*, and caliciviruses. Seals have apparently been exposed to phocine herpesvirus, phocine distemper virus, *Brucella spp.*, *Toxoplasma gondii*, and *Chlamydia psittaci*. Most titers to these agents were low and no seals exhibiting symptoms of these diseases have been found. The significance of exposure to these disease agents in unknown. There is no evidence of exposure to influenza or caliciviruses.

Blood samples were analyzed for standard clinical chemistry and hematology values, and work continues on other hematological indicators of health. Several hematological values were significantly affected by age, sex, animal and sample handling, region, and season. Consequently, this variation must be taken into account when regional and interannual comparisons are performed. Preliminary comparisons showed that some hematological values of seals from SE Alaska differed in magnitude and patterns of seasonal change as from seals sampled within Kodiak or Prince William Sound areas. While we currently do not understand the implications of these differences, there did not appear to be widespread indications of poor health or disease from any region.

Composition counts of the seals at Tugidak Island suggest a decrease in the proportion of yearlings from approximately 15 percent of the total number of seals in the 1970s to 4-8% in 1994-1995. Based on these counts, the percentage of pups on the southwestern beach has not changed since the 1970s but pupping is approximately 8 -10 days earlier than in the 1970s. The decreased proportion of yearlings ashore may reflect reduced first-year survival rates, changes in behavior, or both.

Samples of skin for genetics studies were taken from all seals handled. A preliminary analysis grouped samples according to the three areas used by NMFS in stock assessment reports. Based on the 114 (of 351 samples available) samples from Alaska, no statistically significant genetic differentiation was found among the three areas combined. However, pair-wise comparisons among the three areas showed that the Bering Sea sample was significantly differentiated from the Gulf of Alaska. If Russian samples are included with others from the Alaskan Bering Sea, both Gulf of Alaska and SE Alaska show significant genetic differences from Bering Sea seals. There is either no geographic population structuring or the power of the statistical tests for detecting differences was too, low possibly due to small samples sizes.

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INTRODUCTION

From 1993 to 1995, the U.S. Congress allocated $500,000 annually for the Alaska Department of Fish and Game (ADF&G) to investigate the causes of a large decline in the number of harbor seals (*Phoca vitulina*) in Alaska. This money was provided to ADF&G through annual grants administered by the National Marine Fisheries Service, Alaska Region. This report documents the progress of these investigations from 1993 through 1995 and fulfills annual reporting requirements under NOAA Grant Number NA57FX0367. This study has continued in 1995-1996 and results of that research will be included in later reports.

The best documentation of the decline in harbor seals is from Tugidak Island where the number of seals decreased by approximately 90% between 1976 and 1992 (Pitcher 1990, National Marine Fisheries Service (NMFS) unpublished data). Surveys in Prince William Sound documented a 57% decline between 1984 and 1993 (Frost and Lowry 1994). Surveys around the Kodiak Archipelago in 1977-1978 documented 22,808 seals (Pitcher and Calkins 1979). In 1992, the NMFS surveyed the same area plus some additional areas where seals were found, and counted a total of 2,417 seals (Loughlin 1993). This represents an 89% decline in the number of seals counted.

Based on available data, it appears that a decline has not occurred in SE Alaska. Numbers of seals along a trend route in the Ketchikan area increased at an average annual rate of 8% from 1983-1995. Seal numbers appeared stable in the Sitka area from 1983-1995. General observations suggest an abundant seal population in SE Alaska.

Causes for the decline in harbor seal numbers in the Gulf of Alaska have not been identified (Pitcher 1990). Possible factors that may be affecting seal numbers include direct and indirect interactions with fisheries, environmental changes causing food limitation, directed human harvests, disease, predation, pollutants, and disturbance (Sease 1992, Hoover-Miller 1994). Some of the decline in Prince William Sound was due to the Exxon Valdez oil spill (Frost et al. 1994), but numbers were already declining before the spill (Pitcher 1989).

Concern over the decline in harbor seals is heightened because it has occurred simultaneously with other species of marine mammals in the Gulf of Alaska and Aleutian Islands. Steller sea lions, (*Eumetopias jubatus*) (declared a threatened species by NMFS in 1990) have declined 45 - 90 percent in the same area (National Marine Fisheries Service 1992). Fur seals (*Callorhinus ursinus*) breed on the Pribilof Islands and spend winter months in the Gulf of Alaska and off the west coast of North America. They feed on fish that are similarly important in the diets of sea lions and harbor seals. Fur seals were declared depleted by NMFS in 1988 after declining from 2.1 million animals in 1949-51 to 877,000 in 1983. Likewise, some species of fish-eating seabirds from the Pribilof Islands have declined 50 percent from 1975 to 1989 (Springer 1993). This project was designed to investigate the harbor seal decline by comparing population characteristics in the Gulf of Alaska and SE Alaska.

Components of this investigation include aerial surveys to monitor current population trends; satellite tagging to determine seal movements and dive patterns, and by inference the areas and depths used by seals for feeding; viral and bacterial studies to assess disease prevalence; physiological studies to monitor health and body condition; population demographics at Tugidak Island to continue long-term monitoring of this site; and stock-separation studies.

The overall objectives of this study were to:

1) Monitor the trend in harbor seal numbers in selected areas.
2) Investigate factors that may be affecting harbor seals in those areas.
3) Provide information to NMFS that can be used for designing a conservation and management program for harbor seals.

Specific Objectives of this study were to:

Objective 1. Determine and monitor the number and trend in number of harbor seals at selected sites in SE Alaska and the Kodiak Archipelago.

Objective 2. Describe the distribution and use of harbor seal haulouts in SE Alaska and Ketchikan areas and the Kodiak Archipelago during the pupping and molting periods, including temporal and spatial patterns of haulout use.

Objective 3. Describe the areas and depths used for feeding by harbor seals in SE Alaska and the Kodiak Archipelago.

Objective 4. Determine the health status and the prevalence of infectious diseases in harbor seals from SE Alaska and the Kodiak Archipelago.

Objective 5. Provide support to studies by other investigators to examine nutritional status, energetic requirements, and food habits of harbor seals.

Objective 6. Determine the reproductive rate, age and sex composition, and level of human disturbance at Tugidak Island during pupping and molting periods and compare results to similar data collected in the 1970s.

Objective 7. Determine stock structure of harbor seals in Alaska.

To address each of these objectives a variety of people, agencies, and academic institutions conducted cooperative studies. Each of these objectives is addressed in separate chapters of this report which have been prepared by the individual investigators.

ACKNOWLEDGMENTS

This study has been a joint effort of many individuals, agencies and academic institutions. The efforts of the following individuals were vital in accomplishing this project:

From the Alaska Department of Fish and Game, Rob DeLong (satellite data software development), Bruce Dinneford (field assistance), Kathy Frost (satellite data analysis), Lloyd Lowry (project oversight and satellite data analysis), Dennis McAllister (field assistance and technical assistance), Grey Pendleton (statistical analysis), Ken Pitcher (data analysis and reporting), Una Swain (dive data analysis, field assistance and administrative assistance), and Dave VandenBosch (logistics and equipment preparation); from Wildlife Pathology International, Terry Spraker and Denise Bradley (field assistance, pathology, and bacteriology); from the NMFS, National Marine Mammal Laboratory, George Antonelis (field assistance and aerial surveys), Thomas Loughlin (project oversight), and Robert Small (aerial survey data analysis); from the University of Alaska, Brian Fadely (field assistance and physiology), Lauri Jemison (Tugidak Island studies), and Kate Wynne (field assistance and aerial surveys); and from the NMFS Southwest Fisheries Science Center, Greg O'Corry-Crowe and Robin Westlake (genetics). Vessel support was provided by the crews of the ADF&G research vessel Pandalus, the NOAA Vessel John N. Cobb, and Joe McLung of the U.S. Fish and Wildlife Service vessel Surfbird.

CHAPTER ONE

OBJECTIVE 1

Determine and monitor the number and trend in number of harbor seals at selected sites in the Ketchikan area and the Kodiak Archipelago.

HARBOR SEAL POPULATION TRENDS IN SOUTHEAST ALASKA AND THE GULF OF ALASKA

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INTRODUCTION

In the Gulf of Alaska and Prince William Sound regions of Alaska, harbor seal (*Phoca vitulina*) numbers declined substantially over the past 20 years (Pitcher 1990, Hoover-Miller 1994, Frost et. al. 1996). A sympatric species of pinniped, the Steller sea lion (*Eumetopias jubatus*) also declined greatly in the Gulf of Alaska and Aleutian Islands during this period and is classified as "threatened" under the Endangered Species Act (NMFS 1995). In Southeast Alaska (SE) harbor seal numbers appeared to be increasing or stable in recent years and are thought to be relatively abundant (Lewis 1995).

Because of concerns about the declining populations, an expanded program of harbor seal population monitoring was begun in 1993 to determine current status and trend. Two geographic areas were chosen; the Kodiak area in the Gulf of Alaska where numbers were thought to be declining and SE where numbers were thought to be increasing or stable. We also continued collection of data from Tugidak Island near Kodiak Island where a major decline of harbor seals in Alaska was first documented (Pitcher 1990). Trend data were collected concurrently with studies of growth, condition, diseases, pollutants, movements, diving behavior, habitat use, food habits and genetic relationships in an attempt to gain insight into cause(s) of the decline.

METHODS

Harbor seal trend count surveys were conducted in the Ketchikan and Sitka areas of SE (Figures 1 and 2). These survey routes, which were established in 1983 (Calkins and Pitcher 1984), were surveyed again in 1984 (Pitcher 1986). The Ketchikan route was surveyed again in 1988 (Pitcher 1989) and 1993 (Loughlin 1994). We then

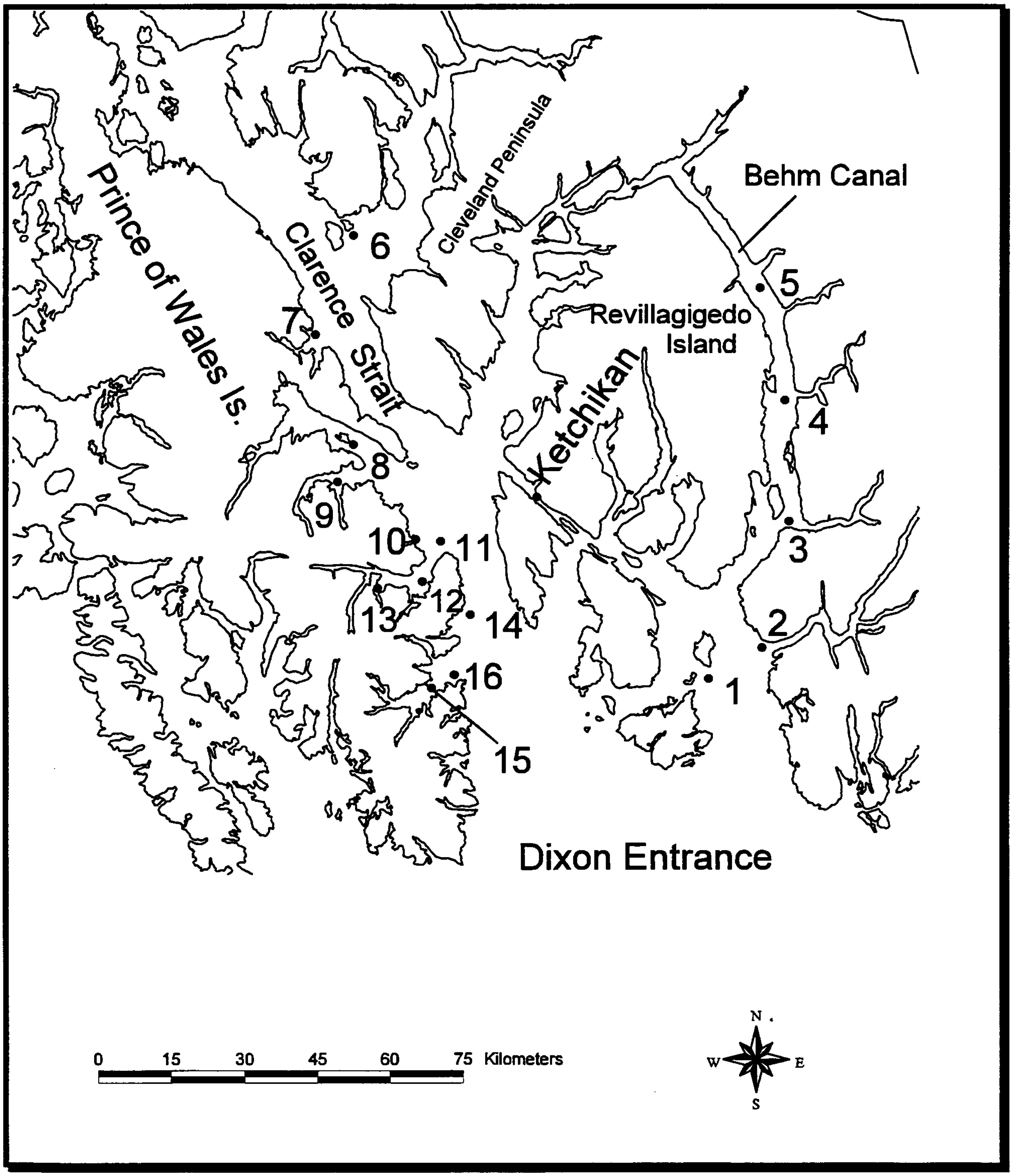

Figure 1. Ketchikan trend count aerial survey route.

1. Whale Rk.	2. White Reef	3. Carp I.	4. New Eddystone
5. Channel I.	6. Eagle I.	7. Tolstoi I.	8. Daisy I.
9. McKenzie I.	10. Clover Bay	11. Skin I.	12. Lancaster C.
13. E. Dora Bay	14. Wedge I.	15. Moria Sound	16. Whiterock I.

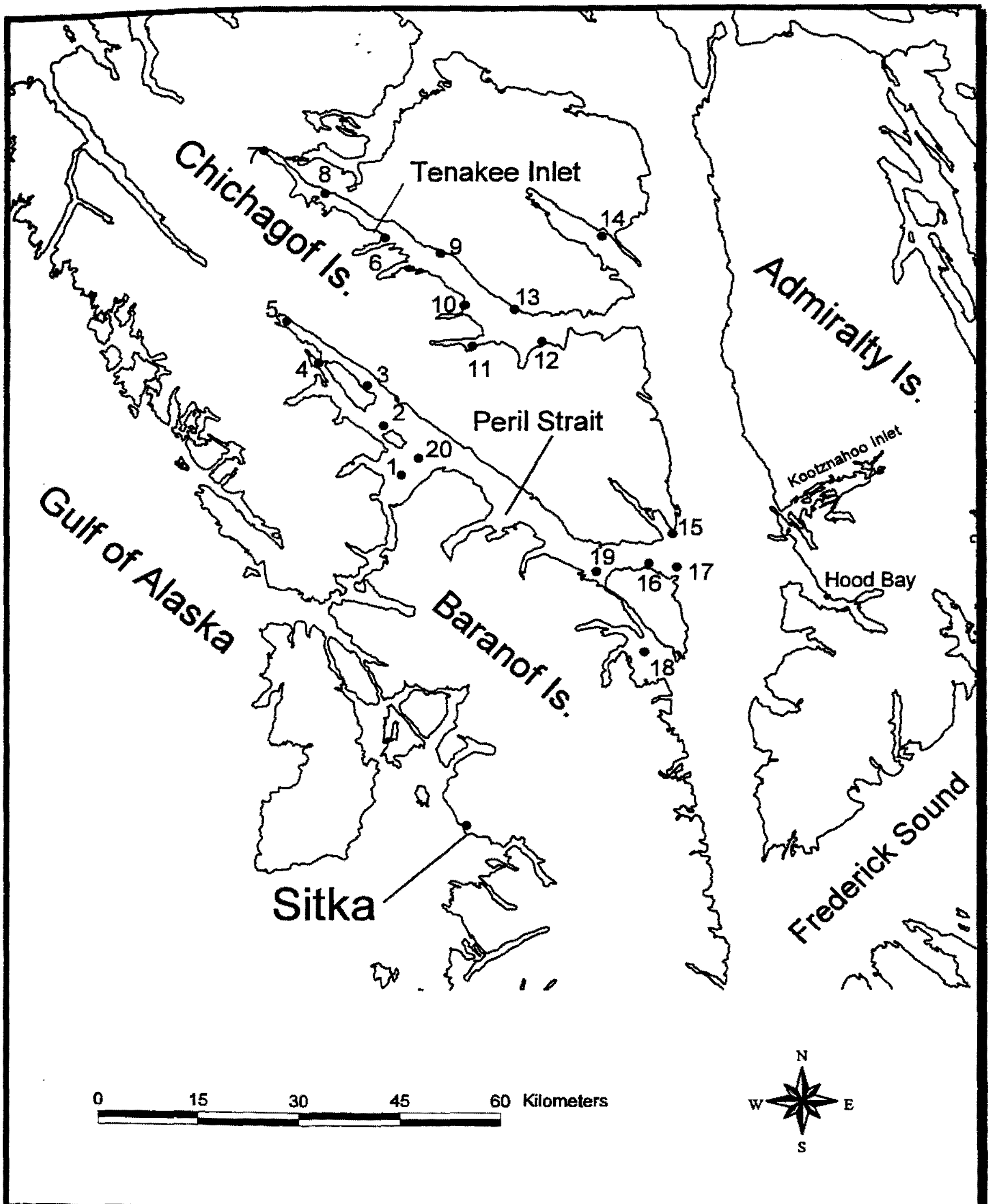

Figure 2. Sitka trend count aerial survey route.

1. Hogatt Reef	2. Vixen I.	3. Moser I. N.	4. Southarm
5. Northarm	6. Long Bay	7. Hd. of Tenakee	8. Grassy I.
9. Mid. Is. Shoal	10. Saltry B.	11. Crab Bay	12. Strawberry
13. Tenakee	14. Appletree	15. Pt. Hayes	16. Traders
17. Midway Reef	18. Plover	19. Pt. Moses	20. Krugloi I.

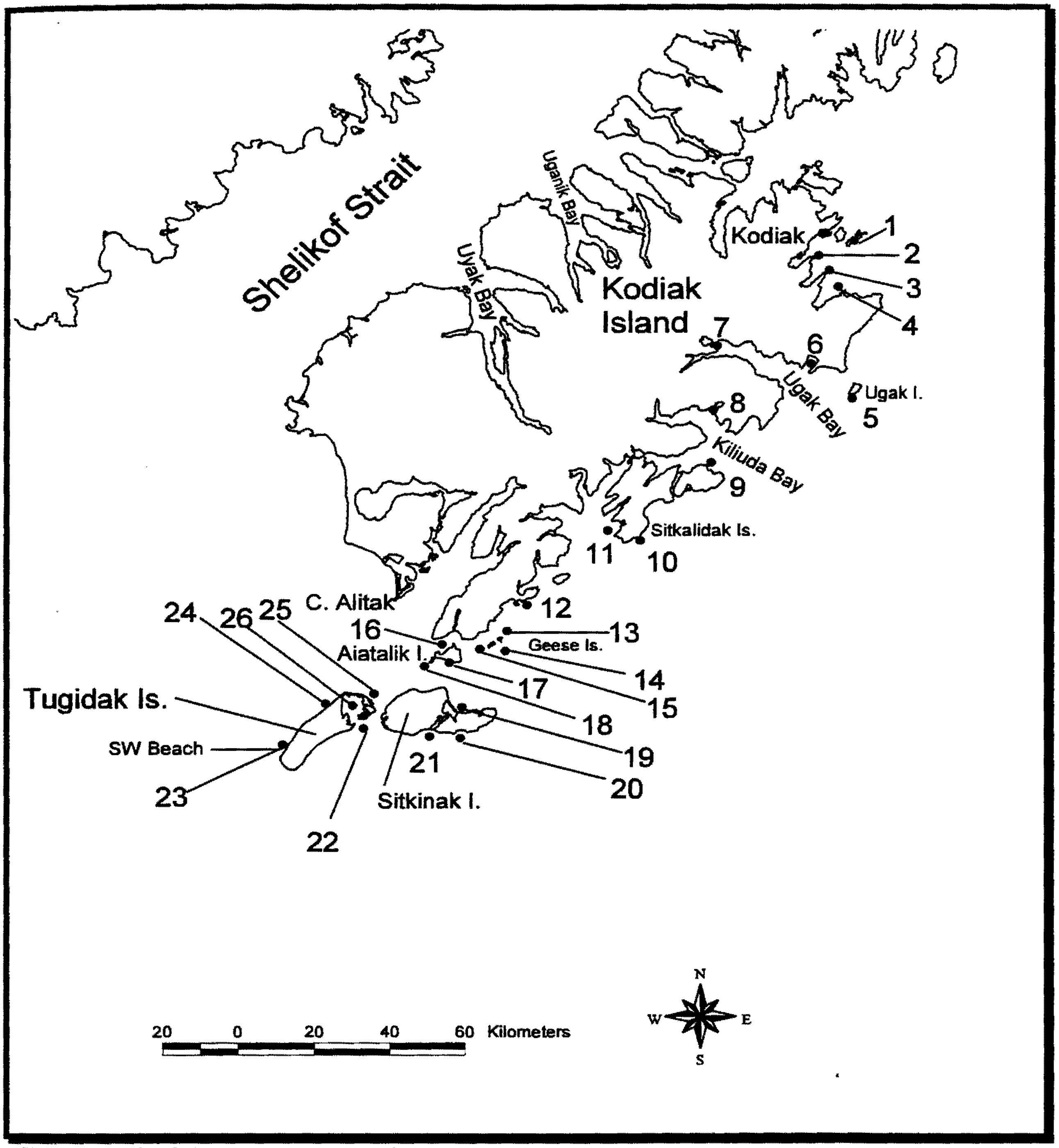

Figure 3. Kodiak trend count aerial survey route.

1. Long I.	2. Cliff Pt.	3. Broad Pt.	4. Kalsin Bay
5. Ugak I	6. W. Pasagshak	7. U. Ugak Bay	8. Shearwater Bay
9. Barnabas Rks.	10. Black Pt.	11. Rolling Bay	12. O. Kaguyak
13. Geese I. N.	14. Geese I. SE.	15. Geese I SW	16. Aiaktalik Ledges
17. Aiaktalik I.	18. Sunstrom I.	19. Sitkinak L. N.	20. Sitkinak SE
21. Sitkinak L S.	22. Tugidak Bars	23. SW Tugidak	24. Tugidak N.
25. Tugidak NNE	26. Tugidak Lagoon (In)		

conducted surveys in 1994 and 1995. Loughlin (1994) surveyed the Sitka route in 1993 and we surveyed it in 1995. A trend count route, established in the Kodiak Island area (Figure 3) in 1992 (Loughlin 1993), was also flown in 1993, 1994, and 1995.

These trend routes were surveyed with single engine, float equipped aircraft during the molting period in August and September. Surveys were flown during a four hour window around low tide. Seals at each haulout site were photographed with 35mm motor-driven cameras. Seal numbers were counted from color slide images projected on paper screens. We attempted to obtain at least 5 replicate surveys each year. Count data from these trend sites are summarized in Appendices I-III.

At the southwestern Tugidak Island haulout (Figure 3) counts of seals were made from 30-m bluffs during the molting period (late August and early September) in 1994 and 1995. The counts were conducted within one hour of daytime low tide. Counts from 1990 (Pitcher 1991) and 1992 (NMFS unpublished data) as well as data presented by Pitcher (1990) were also used in this analysis. These count data are summarized in Appendix IV.

A new trend count route was established in the Gulf of Alaska, along the south side of the Alaska Peninsula, the Semidi Islands and Chirikof Island, in August 1995 and is reported in Appendix V.

Analytical Methods

Variation in counts of animals used for estimating population trends comes from both changes in population numbers and from factors that affect the counting process (i.e., not all animals in the population at a point in time are counted). To estimate population trends in the presence of counting process variation, assumptions are required about the form of the process. Rather than assume that a constant proportion of the seals was seen on every survey, we modeled the counting process as a function of environmental covariates. We estimated trends using overdispersed multinomial models (Link and Sauer, in press). With this method, the counts (Y_{ij}, i indicates site and j indicates replicate) are assumed to be overdispersed Poisson random variables with means (m_i) where

$$\ln(m_i) = h(i) * g(\underline{x}) * f(t)$$

and h(i), a site effect, is treated as a multiplicative nuisance parameter, $g(\underline{x})$ is a loglinear function of the environmental covariables ($\underline{x}$) that are unrelated to population change and f(t) is the smoothed population trajectory with t indicating year. Conditioning on the total number of seals counted at each site, the counts can be described with a Dirichlet compound multinomial distribution. From this distribution, quasi-likelihood estimates of trend and covariate effects were produced using a Newton-Raphson algorithm with iterative reweighting (W. A. Link, unpublished). The advantages of this approach are that counts are adjusted for the effects of the environmental covariates simultaneously with the estimation of the population trajectory and trend and that variability not accounted for by the covariates can differ among sites.

Covariables used in the analyses include relative date, time of day, time relative to low tide, and tide height at the low tide nearest in time to the survey, which were the covariables used by Frost et al. (1995). Quadratic terms and two-way interactions were also included for some covariates. Models with both linear and quadratic population trajectories were tested. The combination of covariates and degree of polynomial used in the model to produce the trend estimates were determined using Akaike's Information Criteria (AIC) (Burnham and Anderson 1992) from models with all combinations of covariates.

Because population trajectories were not linear, trend was defined as the geometric mean rate of change over the interval of the counts. Standard errors were based on an approximated information matrix and were used to produce 95% confidence intervals. Adjusted mean counts were produced following the residual method of Sauer and Geissler (1990). Using the selected model for an area, predicted values were produced for each count in the data set. Residuals were then calculated as the observed count minus the predicted count. The residuals were then averaged for each year for an area. These mean residuals were then added to the value on the estimated trend line for the appropriate years to produce the adjusted mean count.

Recent harbor seal count data from the Kodiak area were analyzed both with and without the 1992 count data. The 1992 counts were much lower than subsequent counts and may not have been representative.

For the Tugidak Island data, linear regression of the natural logs of mean annual counts by year was used to determine if trends in seal numbers existed and to estimate the observed mean annual rate of change (Caughley and Birch 1971, Caughley 1977). Estimated slopes of regressions for time periods were compared by using analysis of covariance with partial sums of squares (SAS type III). Tests of individual slopes (H: slope=0) were performed with t-tests.

RESULTS

Counts of harbor seals on the Ketchikan trend count route from 1983-1995 showed a positive trend ($z=12.194$, $p<0.0001$) (Table 1, Figure 4) with an average annual rate of population change of 8.0%. Six of the 9 covariates tested, including both interaction terms, were included in the selected model for the Ketchikan route, as was the quadratic trend term (Table 2). This complex model could be the result of accomodating the low average count in 1993.

Table 1. Harbor seal population trends in southeast Alaska and the Gulf of Alaska.

Area	Trend (%/yr)	95% Confidence Limits	P(HO:=0)
Ketchikan	8.0	6.7 - 9.2	<0.0001
Sitka	-1.5	-3.2 - 0.4	0.123
Kodiak 1992-1995	22.7	17.7 - 27.2	0.001
Kodiak 1993-1995	4.8	-1.4 - 11.0	0.129
SW Tugidak 1976-1982	-25.8	-32.9 - -18.8	<0.001
SW Tugidak 1982-1995	-7.9	-10.3 - -5.5	<0.001
Remainder Tugidak 1992-1995	21.5	4.8 - 38.2	0.031
Remainder Tugidak 1993-1995	15.3	-29.9 - 61.0	0.145

The trend in numbers of harbor seals counted on the Sitka route from 1983-1995 was not different from 0 ($z=-1.543$, $p=0.123$ (Table 1, Figure 5) with an average annual rate of population change of -1.5%. The only covariates available for the Sitka route were linear and quadratic terms for relative date of the counts as time was not recorded in 1983. Of these, the quadratic trend model with the quadratic date effect was selected based on AIC (Table 2).

Data from the Kodiak trend count route indicate either a stable or increasing population (Table 1, Figure 6). When the full data series (1992-1995) is examined there is a significant increasing trend ($z=8.864$, $p<0.001$) with an estimated annual rate of population change of 22.7%. However, if only 1993-1995 data are analyzed the trend was not different from 0 ($z=1.519$, $p=0.129$) and the estimated rate of population change was 4.8%. The covariates used in these analyses also differed (Table 2.)

In the analyses for each of these routes, the covariate for relative date of the survey, either linear or quadratic, was included in the selected model. In Kodiak, the negative linear coefficient indicates that predicted maximum counts would be on or before the date of the earliest count. At Ketchikan, the negative quadratic term indicates that the predicted maximum count would be within the range of dates of the existing counts. It is not clear how to interpret the positive quadratic term from the Sitka data set. However this data analysis had no other covariates and this result could be an artifact of an unmodeled factor. All of the other covariates were included in at least 1 selected model. The relationship between the covariates and the counts should become clearer with additional years of data.

Table 2. Environmental covariates[1] selected for harbor seal trend models.

Area	Time period	Covariate	Coefficient
Ketchikan[2]	1983-1995	2	-0.36
		4	-0.16
		6	-0.93
		7	0.12
		8	-0.97
		9	-0.07
Kodiak	1992-1995	1	-0.05
		3	0.07
		8	-0.09
Kodiak	1993-1995	1	-0.13
		5	0.08
		6	0.13
		9	-0.02
Sitka[2,3]	1983-1995	2	0.20

[1]Covariates used in the models: 1) date of survey relative to the mean survey date of counts on that route, 2) relative survey date squared (to investigate quadratic patterns in the effect of survey date), 3) time-of-day of survey relative to the mean time-of-day for all surveys, 4) relative time-of-day squared, 5) tide height at the low tide closest in time to the survey, 6) survey time relative to the time of the closest low tide, 7) survey time in relation to sunrise, 8) time-of-day/tide height interaction, 9) time relative to low tide/tide height interaction.

[2]Quadratic trend models selected for this route.

[3]Only covariates 1 and 2 were available for the Sitka route.

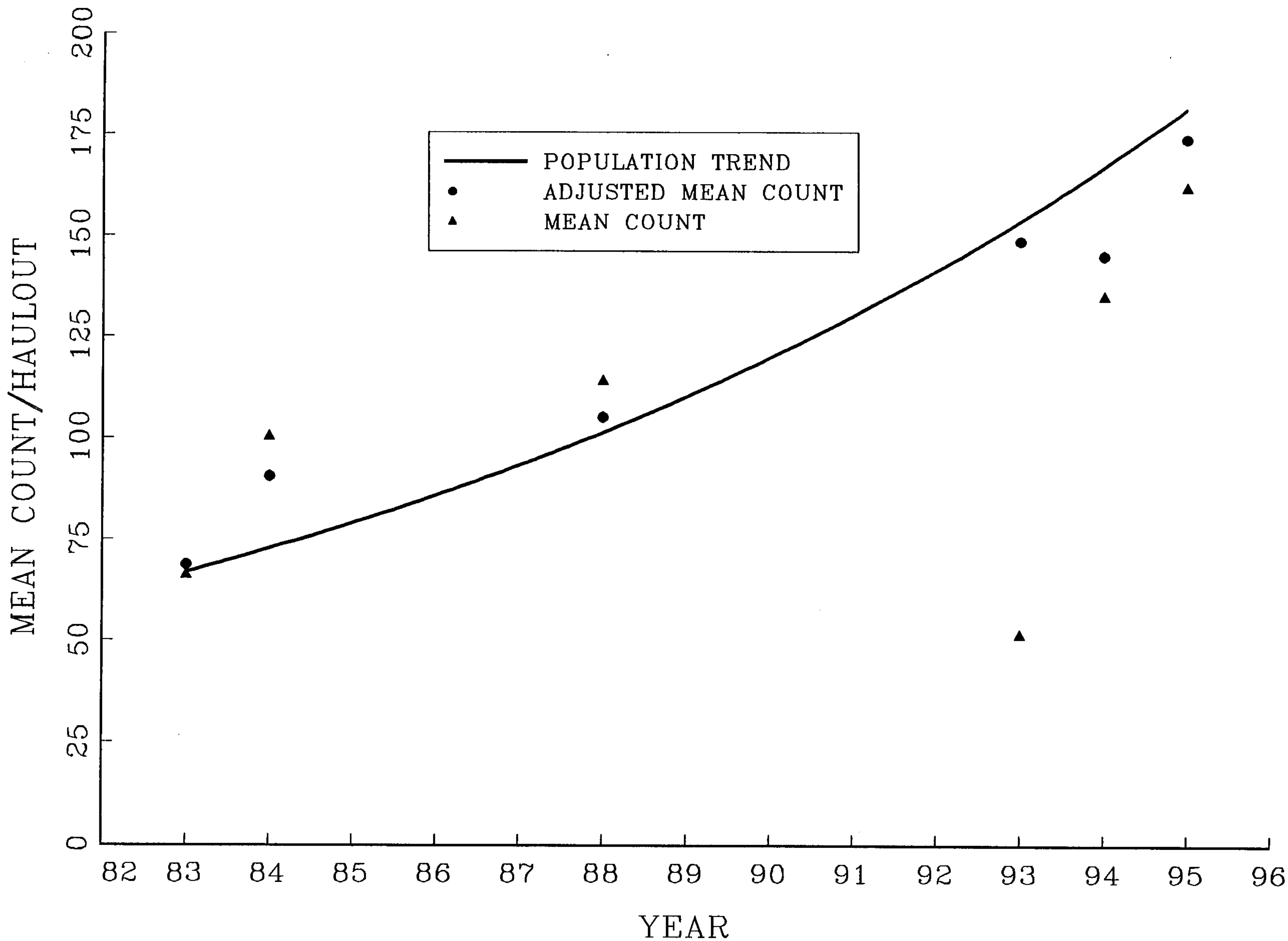

Figure 4. Harbor seal population trend for the Ketchikan area trend count survey route.

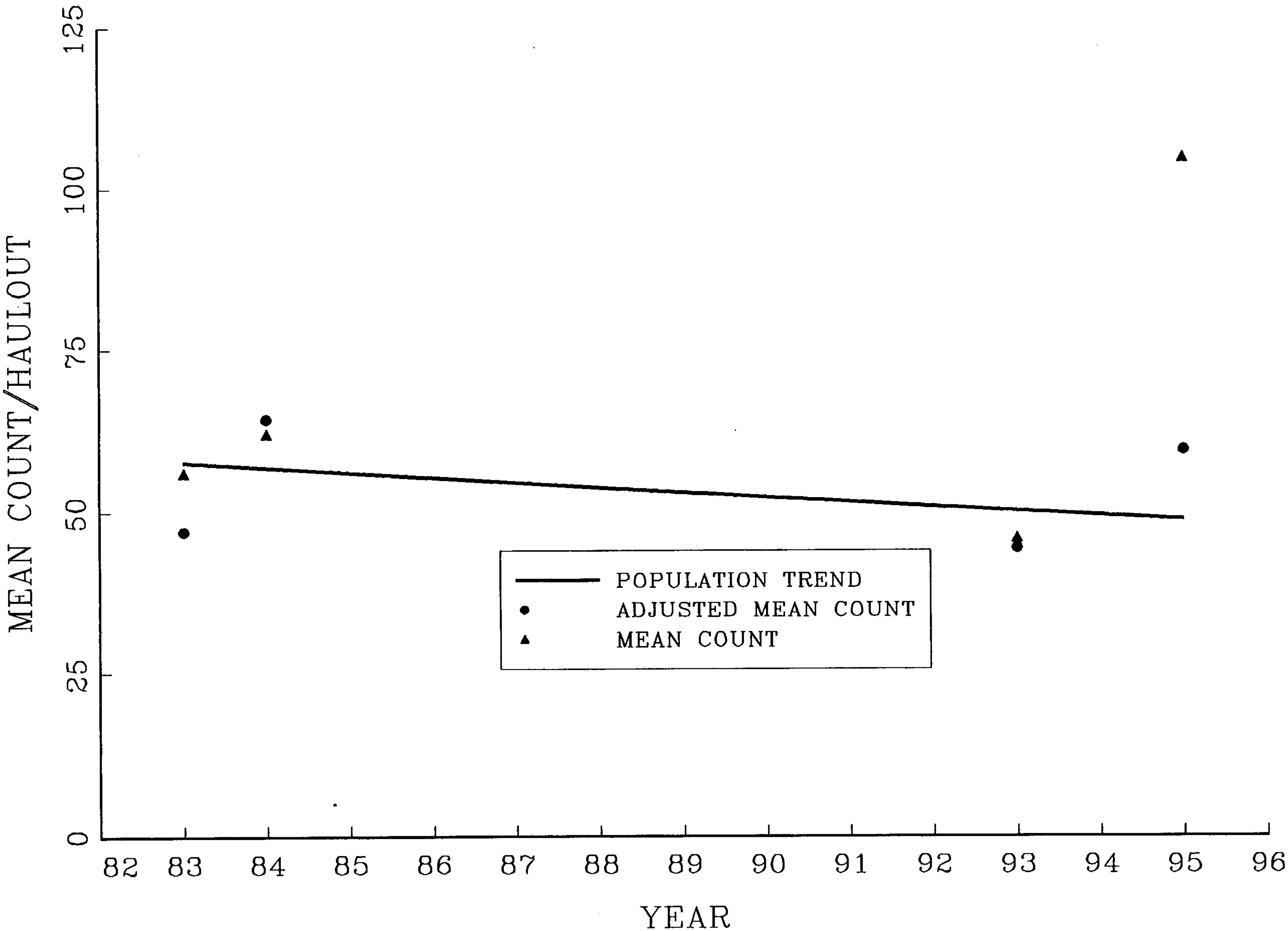

Figure 5. Harbor seal population trend for the Sitka area trend count survey route.

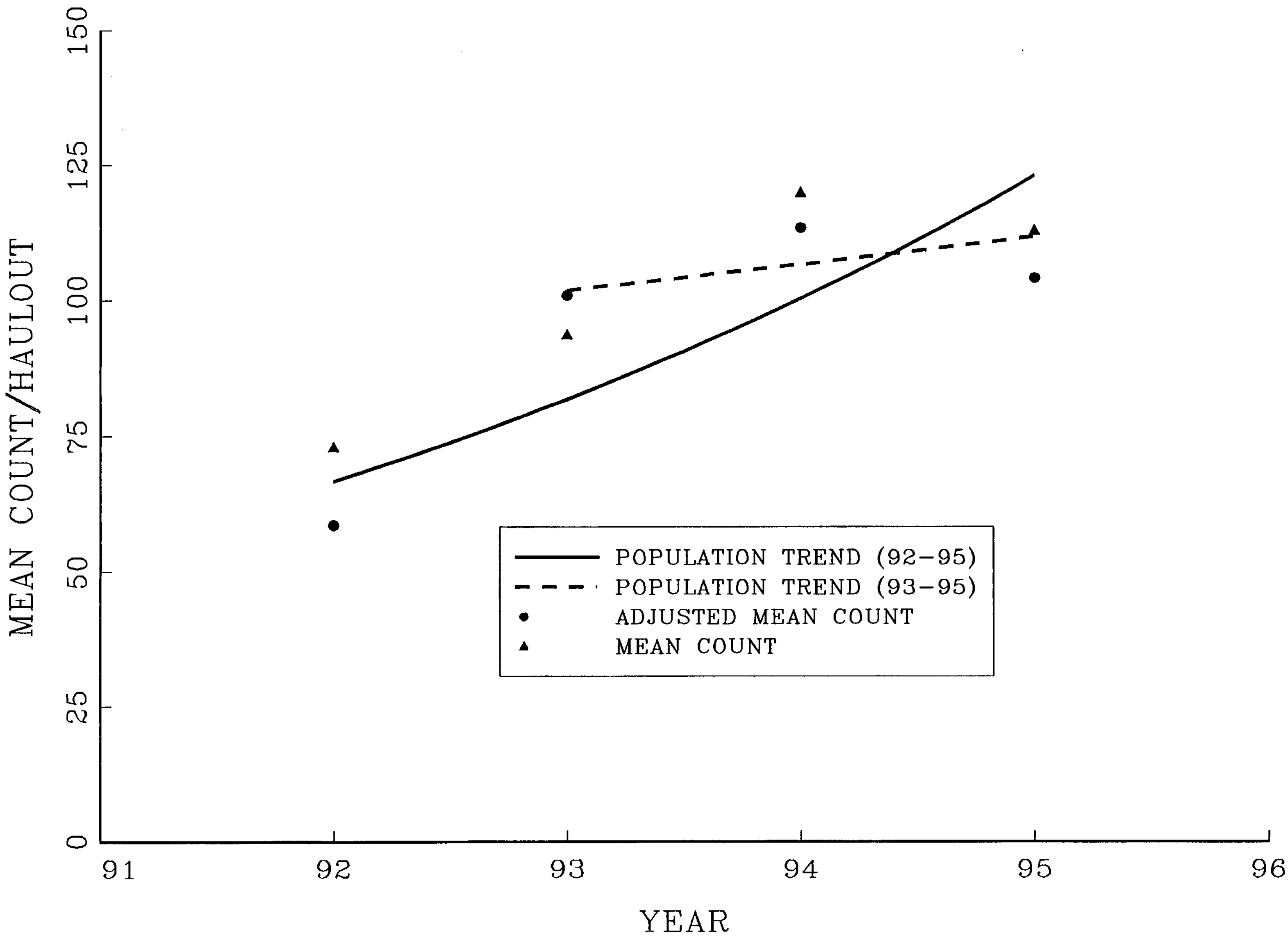

Figure 6. Harbor seal population trends for the Kodiak Island area trend count survey route.

Harbor seal numbers on the southwest beach of Tugidak Island showed significant declining trends from 1976-1982 ($p<0.001$) and 1982-1995 ($p<0.001$) (Table 1, Figure 7). The rate of decline moderated from 1976-1982 (-25.8%/yr) to 1982-1995 (-7.9%/yr) ($p=0.001$).

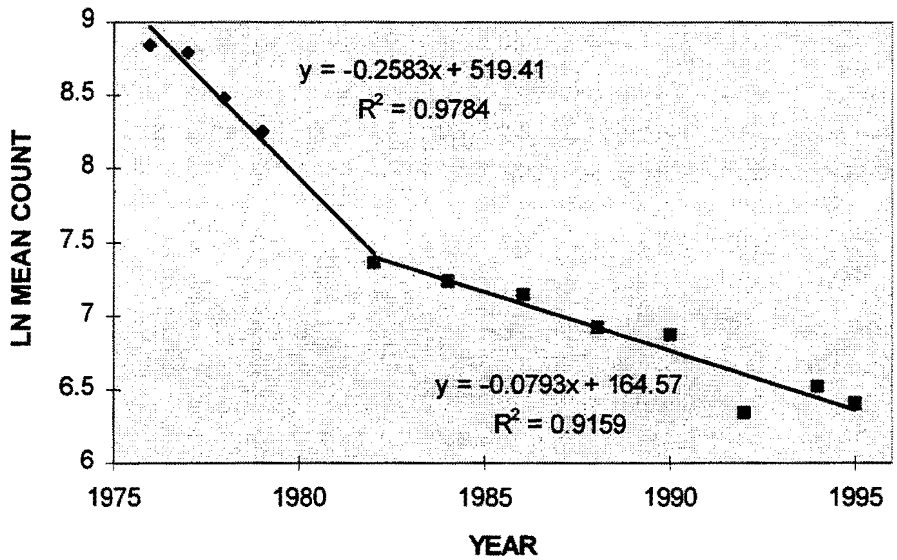

Figure 7. Linear regressions describing changes in numbers of harbor seals during the molting period on Tugidak Island, Gulf of Alaska 1976-1995.

DISCUSSION

Based on the results of this study in the Ketchikan and Sitka areas and counts made in Glacier Bay in northern SE (Mathews 1995) it appears that harbor seal numbers have been increasing or stable throughout SE over the past 13 years. We found an average annual rate of increase of about 8% for the Ketchikan area while harbor seals numbers around Sitka were stable. The Glacier Bay counts indicated that numbers increased from 1975-1984 and have been stable since that time. Human take of harbor seals, except for Alaskan Native subsistence harvest, has been prohibited in the U.S. since 1972 so population numbers may have been increasing before our first surveys in 1983. Numbers of harbor seals in British Columbia, just south of SE, have increased at an annual rate of about 12.5% since 1973 when they were legally protected (Olesiuk et. al. 1990).

Data from the Kodiak Island area trend count route indicate that the population may be increasing although the 1992 counts did not fit the trend line well. The 48% increase in numbers counted between 1992 and 1993 is far above what is biologically possible by recruitment from a closed harbor seal population. Even smoothed over 4 years (1992-

1995) an average annual rate of change of 22.7% is extremely high. The 4.8% annual increase estimated between 1993 and 1995 appears a more realistic estimate although the trend was not significant (p=0.129).

Harbor seal numbers on the southwest Tugidak Island beach, as measured by low tide counts during the molting period have continued to decrease. While there was a strong declining trend from 1982-1994 (-7.9%/yr, p=0.001), the rate of decrease was substantially lower than that of the late 1970s and early 1980s. The trend appears flat from 1990-1995 (F=1.903, p=0.302). Numbers on southwest Tugidak, during the pupping season, appear to have increased over the past three years (Jemison unpublished data). Harbor seals numbers at sites on the remainder of Tugidak Island may be increasing (rate of change for 1992-1995=21.5%, p=0.031 and for 1993-95=15.3%, p=0.145).

There were no systematic surveys of harbor seals in the greater Kodiak area prior to 1992. We assumed that harbor seal numbers had declined substantially since the 1970s because of the observed decline on the southwestern beach of Tugidak and general observations of field biologists in the area. We attempted to evaluate this assumption by comparing maximum counts of seals on major haulouts made incidentally during field work in the 1970s (Pitcher and Calkins 1979) with maximum counts made during molt period surveys conducted between 1992 and 1995 (Table 3). There appeared to be a high correlation between maximum and mean counts obtained during surveys (R^2=0.959 between mean and maximum counts from southwest Tugidak Island 1976-1995). These comparisons support the assumption that a major area-wide decline has occurred as maximum counts at individual haulout sites declined between 35% and 79%. The average percent decline for all comparisons was 66%. This comparison probably minimized the degree of decline as counts in the 1990s were made during the molting period when maximum numbers are normally hauled-out (Pitcher and Calkins 1979, Thompson and Harwood 1990) and previous counts were made between May and October. Also many more counts were made during the 1990s, increasing the probability that a higher count would be obtained at each site. The 1990 surveys were flown when tidal conditions were optimal for maximum numbers of seals to be hauled out which was not always the case during the 1970s as the counts were from incidental observations.

In Prince William Sound, based on trend counts during the molt, harbor seal numbers have declined by 65% between 1984 and 1995 and by 19% since 1989 (Frost et. al. 1996). An ongoing decline was exacerbated by the *Exxon Valdez* oil spill in 1989. Results of the 1995 surveys suggested a possible deviation from the recent declining trend, however it will require several years of additional data to determine if a significant change in population trajectory has occurred.

Table 3. Comparisons of maximum counts of harbor seals from major harbor seal haulouts in the Kodiak Island area during the 1970s and 1990s.

Haulout Site	Maximum Count 1970s	Maximum Count 1990s	% Change
Geese Islands	670	316	-53%
Kalsin Bay	200	123	-38%
Sitkinak Lagoon	450	292	-35%
SE Sitkinak	1000	251	-75%
Ugak Island	1600	335	-79%
Total	3920	1317	-66%

Harbor seals in Aialik Bay, within Kenai Fjords National Park, have been declining in abundance since the early 1980s (Hoover-Miller 1994).

In summary, it appears that harbor seals are relatively abundant and have been increasing or stable throughout SE. In much of the Gulf of Alaska large declines have been documented since 1976. In some areas of the Gulf, the declines have definitely slowed and possibly stopped or reversed.

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Appendix I. Harbor seal survey data from the Ketchikan area trend count route.

SITE #	SITE NAME	DATE	# SEALS
1	Whale Rock (1)	8/7/83	24
1	Whale Rock (1)	8/8/83	41
1	Whale Rock (1)	8/9/83	56
1	Whale Rock (1)	8/10/83	35
1	Whale Rock (1)	8/11/83	30
1	Whale Rock (1)	8/12/83	24
1	Whale Rock (1)	8/13/83	37
1	Whale Rock (1)	8/14/83	20
1	Whale Rock (1)	8/16/83	9
2	White Reef (2)	8/7/83	139
2	White Reef (2)	8/8/83	141
2	White Reef (2)	8/9/83	133
2	White Reef (2)	8/10/83	119
2	White Reef (2)	8/11/83	118
2	White Reef (2)	8/12/83	92
2	White Reef (2)	8/13/83	130
2	White Reef (2)	8/14/83	184
2	White Reef (2)	8/16/83	213
3	Carp I (3)	8/7/83	17
3	Carp I (3)	8/8/83	5
3	Carp I (3)	8/9/83	0
3	Carp I (3)	8/10/83	0
3	Carp I (3)	8/11/83	7
3	Carp I (3)	8/12/83	8
3	Carp I (3)	8/13/83	23
3	Carp I (3)	8/14/83	15
3	Carp I (3)	8/16/83	10
4	N Eddystone Rk (4)	8/7/83	91
4	N Eddystone Rk (4)	8/8/83	108
4	N Eddystone Rk (4)	8/9/83	48
4	N Eddystone Rk (4)	8/10/83	24
4	N Eddystone Rk (4)	8/11/83	94
4	N Eddystone Rk (4)	8/12/83	110
4	N Eddystone Rk (4)	8/13/83	85
4	N Eddystone Rk (4)	8/14/83	160
4	N Eddystone Rk (4)	8/16/83	213
5	Channel Is (5)	8/7/83	179
5	Channel Is (5)	8/8/83	231
5	Channel Is (5)	8/9/83	147
5	Channel Is (5)	8/10/83	136
5	Channel Is (5)	8/11/83	177
5	Channel Is (5)	8/12/83	230
5	Channel Is (5)	8/13/83	154
5	Channel Is (5)	8/14/83	103
5	Channel Is (5)	8/16/83	341
6	Eagle I (6)	8/7/83	94
6	Eagle I (6)	8/8/83	64
6	Eagle I (6)	8/9/83	62
6	Eagle I (6)	8/10/83	134

SITE #	SITE NAME	DATE	# SEALS
6	Eagle I (6)	8/11/83	93
6	Eagle I (6)	8/12/83	57
6	Eagle I (6)	8/13/83	117
6	Eagle I (6)	8/14/83	188
6	Eagle I (6)	8/16/83	155
7	Tolstoi I (7)	8/6/83	11
7	Tolstoi I (7)	8/8/83	9
7	Tolstoi I (7)	8/9/83	20
7	Tolstoi I (7)	8/10/83	22
7	Tolstoi I (7)	8/11/83	35
7	Tolstoi I (7)	8/12/83	8
7	Tolstoi I (7)	8/13/83	17
7	Tolstoi I (7)	8/14/83	14
7	Tolstoi I (7)	8/16/83	0
8	Daisy I (8)	8/6/83	78
8	Daisy I (8)	8/8/83	47
8	Daisy I (8)	8/9/83	61
8	Daisy I (8)	8/10/83	148
8	Daisy I (8)	8/11/83	72
8	Daisy I (8)	8/12/83	127
8	Daisy I (8)	8/13/83	86
8	Daisy I (8)	8/14/83	45
8	Daisy I (8)	8/16/83	109
9	McKenzie I (9)	8/6/83	100
9	McKenzie I (9)	8/8/83	194
9	McKenzie I (9)	8/9/83	71
9	McKenzie I (9)	8/10/83	107
9	McKenzie I (9)	8/11/83	143
9	McKenzie I (9)	8/12/83	121
9	McKenzie I (9)	8/13/83	78
9	McKenzie I (9)	8/14/83	108
9	McKenzie I (9)	8/16/83	148
10	Clover Bay (10)	8/6/83	39
10	Clover Bay (10)	8/8/83	16
10	Clover Bay (10)	8/9/83	39
10	Clover Bay (10)	8/10/83	16
10	Clover Bay (10)	8/11/83	51
10	Clover Bay (10)	8/12/83	41
10	Clover Bay (10)	8/13/83	35
10	Clover Bay (10)	8/14/83	72
10	Clover Bay (10)	8/16/83	56
11	Skin I (11)	8/6/83	24
11	Skin I (11)	8/8/83	0
11	Skin I (11)	8/9/83	10
11	Skin I (11)	8/10/83	11
11	Skin I (11)	8/11/83	52
11	Skin I (11)	8/12/83	10
11	Skin I (11)	8/13/83	18
11	Skin I (11)	8/14/83	10

SITE #	SITE NAME	DATE	# SEALS
11	Skin I (11)	8/13/83	18
11	Skin I (11)	8/14/83	10
11	Skin I (11)	8/16/83	3
12	Lancaster C (12	8/6/83	5
12	Lancaster C (12	8/8/83	0
12	Lancaster C (12	8/9/83	4
12	Lancaster C (12	8/10/83	0
12	Lancaster C (12	8/11/83	4
12	Lancaster C (12	8/12/83	6
12	Lancaster C (12	8/13/83	8
12	Lancaster C (12	8/14/83	7
12	Lancaster C (12	8/16/83	6
13	E Dora Bay (13)	8/6/83	23
13	E Dora Bay (13)	8/8/83	46
13	E Dora Bay (13)	8/9/83	0
13	E Dora Bay (13)	8/10/83	121
13	E Dora Bay (13)	8/11/83	24
13	E Dora Bay (13)	8/12/83	50
13	E Dora Bay (13)	8/13/83	75
13	E Dora Bay (13)	8/14/83	44
13	E Dora Bay (13)	8/16/83	44
14	Wedge I (14)	8/6/83	18
14	Wedge I (14)	8/8/83	57
14	Wedge I (14)	8/9/83	49
14	Wedge I (14)	8/10/83	44
14	Wedge I (14)	8/11/83	64
14	Wedge I (14)	8/12/83	78
14	Wedge I (14)	8/13/83	53
14	Wedge I (14)	8/14/83	155
14	Wedge I (14)	8/16/83	158
15	Moria Sound (15	8/6/83	12
15	Moria Sound (15	8/8/83	44
15	Moria Sound (15	8/9/83	90
15	Moria Sound (15	8/10/83	29
15	Moria Sound (15	8/11/83	66
15	Moria Sound (15	8/12/83	31
15	Moria Sound (15	8/13/83	19
15	Moria Sound (15	8/14/83	57
15	Moria Sound (15	8/16/83	11
16	Whiterock I (16	8/6/83	19
16	Whiterock I (16	8/8/83	19
16	Whiterock I (16	8/9/83	37
16	Whiterock I (16	8/10/83	86
16	Whiterock I (16	8/11/83	59
16	Whiterock I (16	8/12/83	31
16	Whiterock I (16	8/13/83	5
16	Whiterock I (16	8/14/83	17
16	Whiterock I (16	8/16/83	53
1	Whale Rock (1)	8/6/84	139
1	Whale Rock (1)	8/10/84	46
1	Whale Rock (1)	8/11/84	127
1	Whale Rock (1)	8/12/84	131
1	Whale Rock (1)	8/14/84	109
1	Whale Rock (1)	8/15/84	74
1	Whale Rock (1)	8/16/84	80
1	Whale Rock (1)	8/17/84	62
1	Whale Rock (1)	8/18/84	34
2	White Reef (2)	8/6/84	125
2	White Reef (2)	8/10/84	154
2	White Reef (2)	8/11/84	147
2	White Reef (2)	8/12/84	234
2	White Reef (2)	8/14/84	264
2	White Reef (2)	8/15/84	241
2	White Reef (2)	8/16/84	257
2	White Reef (2)	8/17/84	259
2	White Reef (2)	8/18/84	237
3	Carp I (3)	8/6/84	0
3	Carp I (3)	8/10/84	0
3	Carp I (3)	8/11/84	0
3	Carp I (3)	8/12/84	0
3	Carp I (3)	8/14/84	0
3	Carp I (3)	8/15/84	0
3	Carp I (3)	8/17/84	0
3	Carp I (3)	8/18/84	0
4	N Eddystone Rk (4)	8/6/84	21
4	N Eddystone Rk (4)	8/10/84	142
4	N Eddystone Rk (4)	8/11/84	97
4	N Eddystone Rk (4)	8/12/84	110
4	N Eddystone Rk (4)	8/14/84	127
4	N Eddystone Rk (4)	8/15/84	75
4	N Eddystone Rk (4)	8/16/84	101
4	N Eddystone Rk (4)	8/18/84	65
5	Channel Is (5)	8/6/84	136
5	Channel Is (5)	8/10/84	148
5	Channel Is (5)	8/11/84	180
5	Channel Is (5)	8/12/84	305
5	Channel Is (5)	8/14/84	318
5	Channel Is (5)	8/15/84	491
5	Channel Is (5)	8/16/84	507
5	Channel Is (5)	8/18/84	541
6	Eagle I (6)	8/6/84	85
6	Eagle I (6)	8/10/84	90
6	Eagle I (6)	8/11/84	105
6	Eagle I (6)	8/12/84	107
6	Eagle I (6)	8/14/84	212
6	Eagle I (6)	8/15/84	213
6	Eagle I (6)	8/16/84	195
7	Tolstoi I (7)	8/6/84	6
7	Tolstoi I (7)	8/10/84	1
7	Tolstoi I (7)	8/11/84	0
7	Tolstoi I (7)	8/12/84	5
7	Tolstoi I (7)	8/14/84	35

SITE #	SITE NAME	DATE	# SEALS
7	Tolstoi I (7)	8/15/84	23
7	Tolstoi I (7)	8/16/84	12
8	Daisy I (8)	8/6/84	85
8	Daisy I (8)	8/10/84	48
8	Daisy I (8)	8/11/84	47
8	Daisy I (8)	8/12/84	140
8	Daisy I (8)	8/14/84	97
8	Daisy I (8)	8/16/84	196
8	Daisy I (8)	8/17/84	106
9	McKenzie I (9)	8/6/84	165
9	McKenzie I (9)	8/10/84	103
9	McKenzie I (9)	8/11/84	95
9	McKenzie I (9)	8/12/84	129
9	McKenzie I (9)	8/14/84	214
9	McKenzie I (9)	8/15/84	213
9	McKenzie I (9)	8/16/84	245
9	McKenzie I (9)	8/17/84	233
10	Clover Bay (10)	8/6/84	12
10	Clover Bay (10)	8/10/84	0
10	Clover Bay (10)	8/11/84	29
10	Clover Bay (10)	8/12/84	49
10	Clover Bay (10)	8/14/84	72
10	Clover Bay (10)	8/15/84	74
10	Clover Bay (10)	8/16/84	62
10	Clover Bay (10)	8/17/84	78
11	Skin I (11)	8/6/84	0
11	Skin I (11)	8/10/84	43
11	Skin I (11)	8/11/84	33
11	Skin I (11)	8/12/84	51
11	Skin I (11)	8/14/84	51
11	Skin I (11)	8/15/84	69
11	Skin I (11)	8/16/84	36
11	Skin I (11)	8/17/84	40
12	Lancaster C (12	8/10/84	0
12	Lancaster C (12	8/11/84	6
12	Lancaster C (12	8/12/84	5
12	Lancaster C (12	8/14/84	20
12	Lancaster C (12	8/15/84	0
12	Lancaster C (12	8/16/84	15
13	E Dora Bay (13)	8/10/84	54
13	E Dora Bay (13)	8/11/84	54
13	E Dora Bay (13)	8/12/84	31
13	E Dora Bay (13)	8/14/84	97
13	E Dora Bay (13)	8/15/84	74
13	E Dora Bay (13)	8/16/84	116
14	Wedge I (14)	8/6/84	19
14	Wedge I (14)	8/10/84	87
14	Wedge I (14)	8/11/84	48
14	Wedge I (14)	8/12/84	172
14	Wedge I (14)	8/14/84	163
14	Wedge I (14)	8/15/84	136

SITE #	SITE NAME	DATE	# SEALS
14	Wedge I (14)	8/16/84	32
14	Wedge I (14)	8/17/84	100
15	Moria Sound (15	8/10/84	38
15	Moria Sound (15	8/11/84	0
15	Moria Sound (15	8/12/84	12
15	Moria Sound (15	8/14/84	135
15	Moria Sound (15	8/15/84	111
15	Moria Sound (15	8/16/84	115
15	Moria Sound (15	8/17/84	77
16	Whiterock I (16	8/6/84	42
16	Whiterock I (16	8/10/84	69
16	Whiterock I (16	8/11/84	8
16	Whiterock I (16	8/12/84	73
16	Whiterock I (16	8/14/84	84
16	Whiterock I (16	8/15/84	106
16	Whiterock I (16	8/16/84	99
16	Whiterock I (16	8/17/84	59
1	Whale Rock (1)	8/6/88	115
1	Whale Rock (1)	8/10/88	141
1	Whale Rock (1)	8/11/88	24
1	Whale Rock (1)	8/14/88	85
1	Whale Rock (1)	8/15/88	78
1	Whale Rock (1)	8/16/88	88
2	White Reef (2)	8/6/88	214
2	White Reef (2)	8/10/88	220
2	White Reef (2)	8/11/88	213
2	White Reef (2)	8/14/88	297
2	White Reef (2)	8/15/88	361
2	White Reef (2)	8/16/88	337
3	Carp I (3)	8/6/88	0
3	Carp I (3)	8/10/88	0
3	Carp I (3)	8/11/88	0
3	Carp I (3)	8/12/88	0
3	Carp I (3)	8/14/88	0
3	Carp I (3)	8/15/88	0
3	Carp I (3)	8/16/88	0
4	N Eddystone Rk (4)	8/6/88	71
4	N Eddystone Rk (4)	8/10/88	56
4	N Eddystone Rk (4)	8/11/88	44
4	N Eddystone Rk (4)	8/12/88	55
4	N Eddystone Rk (4)	8/14/88	98
4	N Eddystone Rk (4)	8/15/88	172
4	N Eddystone Rk (4)	8/16/88	147
5	Channel Is (5)	8/6/88	394
5	Channel Is (5)	8/10/88	292
5	Channel Is (5)	8/11/88	162
5	Channel Is (5)	8/12/88	253
5	Channel Is (5)	8/14/88	218
5	Channel Is (5)	8/15/88	337
5	Channel Is (5)	8/16/88	414
6	Eagle I (6)	8/6/88	149

SITE #	SITE NAME	DATE	# SEALS
6	Eagle I (6)	8/10/88	155
6	Eagle I (6)	8/11/88	235
6	Eagle I (6)	8/12/88	250
6	Eagle I (6)	8/14/88	270
6	Eagle I (6)	8/15/88	331
6	Eagle I (6)	8/16/88	270
7	Tolstoi I (7)	8/6/88	15
7	Tolstoi I (7)	8/10/88	46
7	Tolstoi I (7)	8/12/88	59
7	Tolstoi I (7)	8/14/88	59
7	Tolstoi I (7)	8/15/88	72
7	Tolstoi I (7)	8/16/88	60
8	Daisy I (8)	8/6/88	137
8	Daisy I (8)	8/10/88	129
8	Daisy I (8)	8/12/88	136
8	Daisy I (8)	8/14/88	195
8	Daisy I (8)	8/15/88	188
8	Daisy I (8)	8/16/88	265
9	McKenzie I (9)	8/6/88	217
9	McKenzie I (9)	8/10/88	173
9	McKenzie I (9)	8/12/88	145
9	McKenzie I (9)	8/14/88	97
9	McKenzie I (9)	8/15/88	156
9	McKenzie I (9)	8/16/88	168
10	Clover Bay (10)	8/6/88	22
10	Clover Bay (10)	8/9/88	41
10	Clover Bay (10)	8/10/88	52
10	Clover Bay (10)	8/12/88	43
10	Clover Bay (10)	8/14/88	17
10	Clover Bay (10)	8/15/88	3
10	Clover Bay (10)	8/16/88	8
11	Skin I (11)	8/6/88	0
11	Skin I (11)	8/9/88	7
11	Skin I (11)	8/10/88	10
11	Skin I (11)	8/12/88	10
11	Skin I (11)	8/14/88	17
11	Skin I (11)	8/15/88	15
11	Skin I (11)	8/16/88	12
12	Lancaster C (12	8/6/88	8
12	Lancaster C (12	8/10/88	11
12	Lancaster C (12	8/12/88	17
12	Lancaster C (12	8/15/88	17
12	Lancaster C (12	8/16/88	4
13	E Dora Bay (13)	8/6/88	92
13	E Dora Bay (13)	8/9/88	76
13	E Dora Bay (13)	8/10/88	73
13	E Dora Bay (13)	8/12/88	55
13	E Dora Bay (13)	8/14/88	93
13	E Dora Bay (13)	8/15/88	87
13	E Dora Bay (13)	8/16/88	116
14	Wedge I (14)	8/6/88	163

SITE #	SITE NAME	DATE	# SEALS
14	Wedge I (14)	8/9/88	133
14	Wedge I (14)	8/10/88	110
14	Wedge I (14)	8/12/88	105
14	Wedge I (14)	8/15/88	97
14	Wedge I (14)	8/16/88	123
15	Moria Sound (15	8/6/88	107
15	Moria Sound (15	8/9/88	89
15	Moria Sound (15	8/10/88	82
15	Moria Sound (15	8/11/88	74
15	Moria Sound (15	8/12/88	122
15	Moria Sound (15	8/15/88	122
15	Moria Sound (15	8/16/88	129
16	Whiterock I (16	8/6/88	83
16	Whiterock I (16	8/9/88	92
16	Whiterock I (16	8/10/88	56
16	Whiterock I (16	8/11/88	67
16	Whiterock I (16	8/12/88	123
16	Whiterock I (16	8/15/88	75
16	Whiterock I (16	8/16/88	130
1	Whale Rock (1)	9/15/93	5
1	Whale Rock (1)	9/16/93	34
1	Whale Rock (1)	9/17/93	30
1	Whale Rock (1)	9/18/93	24
1	Whale Rock (1)	9/19/93	28
1	Whale Rock (1)	9/20/93	25
2	White Reef (2)	9/15/93	281
2	White Reef (2)	9/16/93	278
2	White Reef (2)	9/17/93	121
2	White Reef (2)	9/18/93	301
2	White Reef (2)	9/19/93	324
2	White Reef (2)	9/20/93	268
3	Carp I (3)	9/15/93	0
3	Carp I (3)	9/16/93	10
3	Carp I (3)	9/17/93	9
3	Carp I (3)	9/18/93	18
3	Carp I (3)	9/19/93	13
3	Carp I (3)	9/20/93	14
4	N Eddystone Rk (4)	9/15/93	58
4	N Eddystone Rk (4)	9/16/93	70
4	N Eddystone Rk (4)	9/17/93	62
4	N Eddystone Rk (4)	9/18/93	68
4	N Eddystone Rk (4)	9/19/93	66
4	N Eddystone Rk (4)	9/20/93	58
5	Channel Is (5)	9/15/93	18
5	Channel Is (5)	9/16/93	32
5	Channel Is (5)	9/17/93	19
5	Channel Is (5)	9/18/93	26
5	Channel Is (5)	9/19/93	108
5	Channel Is (5)	9/20/93	26
6	Eagle I (6)	9/13/93	207
6	Eagle I (6)	9/14/93	75

SITE #	SITE NAME	DATE	# SEALS
6	Eagle I (6)	9/15/93	110
6	Eagle I (6)	9/16/93	228
6	Eagle I (6)	9/17/93	196
7	Tolstoi I (7)	9/15/93	4
7	Tolstoi I (7)	9/16/93	17
7	Tolstoi I (7)	9/17/93	22
7	Tolstoi I (7)	9/18/93	35
7	Tolstoi I (7)	9/19/93	26
7	Tolstoi I (7)	9/20/93	33
8	Daisy I (8)	9/15/93	12
8	Daisy I (8)	9/16/93	19
8	Daisy I (8)	9/17/93	15
8	Daisy I (8)	9/18/93	7
8	Daisy I (8)	9/19/93	13
8	Daisy I (8)	9/20/93	0
9	McKenzie I (9)	9/15/93	0
9	McKenzie I (9)	9/16/93	13
9	McKenzie I (9)	9/17/93	13
9	McKenzie I (9)	9/18/93	0
9	McKenzie I (9)	9/19/93	10
9	McKenzie I (9)	9/20/93	1
10	Clover Bay (10)	9/15/93	1
10	Clover Bay (10)	9/16/93	0
10	Clover Bay (10)	9/17/93	0
10	Clover Bay (10)	9/18/93	17
10	Clover Bay (10)	9/19/93	35
10	Clover Bay (10)	9/20/93	42
11	Skin I (11)	9/15/93	3
11	Skin I (11)	9/16/93	3
11	Skin I (11)	9/17/93	10
11	Skin I (11)	9/18/93	4
11	Skin I (11)	9/20/93	10
12	Lancaster C (12	9/15/93	0
12	Lancaster C (12	9/16/93	16
12	Lancaster C (12	9/17/93	25
12	Lancaster C (12	9/18/93	8
12	Lancaster C (12	9/19/93	53
12	Lancaster C (12	9/20/93	22
13	E Dora Bay (13)	9/15/93	0
13	E Dora Bay (13)	9/16/93	26
13	E Dora Bay (13)	9/17/93	31
13	E Dora Bay (13)	9/18/93	27
13	E Dora Bay (13)	9/19/93	33
13	E Dora Bay (13)	9/20/93	23
14	Wedge I (14)	9/15/93	50
14	Wedge I (14)	9/16/93	60
14	Wedge I (14)	9/17/93	67
14	Wedge I (14)	9/18/93	61
14	Wedge I (14)	9/19/93	89
14	Wedge I (14)	9/20/93	57
15	Moria Sound (15	9/15/93	74

SITE #	SITE NAME	DATE	# SEALS
15	Moria Sound (15	9/16/93	132
15	Moria Sound (15	9/17/93	97
15	Moria Sound (15	9/18/93	49
15	Moria Sound (15	9/19/93	49
15	Moria Sound (15	9/20/93	60
16	Whiterock I (16	9/15/93	10
16	Whiterock I (16	9/16/93	28
16	Whiterock I (16	9/17/93	23
16	Whiterock I (16	9/18/93	27
16	Whiterock I (16	9/19/93	30
16	Whiterock I (16	9/20/93	37
1	Whale R	8/22/94	59
1	Whale R	8/23/94	58
1	Whale R	8/24/94	71
1	Whale R	9/6/94	16
1	Whale R	9/7/94	40
2	White R	8/22/94	410
2	White R	8/23/94	506
2	White R	8/24/94	628
2	White R	9/6/94	130
2	White R	9/7/94	384
3	Carp I	8/22/94	0
3	Carp I	8/23/94	0
3	Carp I	8/24/94	0
3	Carp I	9/6/94	0
3	Carp I	9/7/94	0
4	New Eddy	8/22/94	287
4	New Eddy	8/23/94	260
4	New Eddy	8/24/94	469
4	New Eddy	9/6/94	96
4	New Eddy	9/7/94	102
5	Channel I	8/22/94	233
5	Channel I	8/23/94	247
5	Channel I	8/24/94	339
5	Channel I	9/6/94	76
5	Channel I	9/7/94	115
6	Eagle I	8/22/94	543
6	Eagle I	8/23/94	531
6	Eagle I	8/24/94	593
6	Eagle I	9/6/94	257
7	Tolstoi I	8/22/94	79
7	Tolstoi I	8/23/94	78
7	Tolstoi I	8/24/94	87
7	Tolstoi I	9/6/94	52
7	Tolstoi I	9/7/94	55
8	Daisy I	8/22/94	85
8	Daisy I	8/23/94	96
8	Daisy I	8/24/94	84
8	Daisy I	9/6/94	13
8	Daisy I	9/7/94	25
9	McKenzie I	8/22/94	256

SITE #	SITE NAME	DATE	# SEALS
9	McKenzie I	8/23/94	189
9	McKenzie I	8/24/94	133
9	McKenzie I	9/6/94	41
9	McKenzie I	9/7/94	58
10	Clover B	8/22/94	72
10	Clover B	8/23/94	59
10	Clover B	8/24/94	74
10	Clover B	9/6/94	44
10	Clover B	9/7/94	37
11	Skin I	8/22/94	0
11	Skin I	8/23/94	0
11	Skin I	8/24/94	0
11	Skin I	9/6/94	6
11	Skin I	9/7/94	18
12	Lancaster I	8/22/94	21
12	Lancaster I	8/23/94	45
12	Lancaster I	8/24/94	41
12	Lancaster I	9/6/94	13
12	Lancaster I	9/7/94	35
13	E. Dora Bay	8/22/94	63
13	E. Dora Bay	8/23/94	106
13	E. Dora Bay	8/24/94	57
13	E. Dora Bay	9/6/94	37
13	E. Dora Bay	9/7/94	38
14	Wedge I	8/22/94	264
14	Wedge I	8/23/94	215
14	Wedge I	8/24/94	241
14	Wedge I	9/6/94	82
14	Wedge I	9/7/94	110
15	Moria S	8/22/94	241
15	Moria S	8/23/94	274
15	Moria S	8/24/94	91
15	Moria S	9/6/94	80
15	Moria S	9/7/94	74
16	Wh. Rock I	8/22/94	136
16	Wh. Rock I	8/23/94	70
16	Wh. Rock I	8/24/94	24
16	Wh. Rock I	9/6/94	68
16	Wh. Rock I	9/7/94	140
1	Whale R	8/23/95	14
1	Whale R	8/24/95	110
1	Whale R	8/25/95	40
1	Whale R	8/26/95	46
1	Whale R	8/27/95	98
1	Whale R	8/28/95	69
2	White R	8/23/95	374
2	White R	8/24/95	464
2	White R	8/25/95	530
2	White R	8/26/95	570
2	White R	8/27/95	645
2	White R	8/28/95	562

SITE #	SITE NAME	DATE	# SEALS
3	Carp I	8/23/95	0
3	Carp I	8/24/95	0
3	Carp I	8/25/95	0
3	Carp I	8/26/95	0
3	Carp I	8/27/95	0
3	Carp I	8/28/95	0
4	N Eddystone Rk (4)	8/23/95	151
4	N Eddystone Rk (4)	8/24/95	287
4	N Eddystone Rk (4)	8/25/95	182
4	N Eddystone Rk (4)	8/26/95	298
4	N Eddystone Rk (4)	8/27/95	367
4	N Eddystone Rk (4)	8/28/95	257
5	Channel I	8/23/95	251
5	Channel I	8/24/95	189
5	Channel I	8/25/95	227
5	Channel I	8/26/95	306
5	Channel I	8/27/95	333
5	Channel I	8/28/95	312
6	Eagle I	8/23/95	525
6	Eagle I	8/24/95	408
6	Eagle I	8/25/95	399
6	Eagle I	8/26/95	497
6	Eagle I	8/27/95	419
6	Eagle I	8/28/95	482
7	Tostoi I	8/23/95	79
7	Tostoi I	8/24/95	83
7	Tostoi I	8/25/95	69
7	Tostoi I	8/26/95	95
7	Tostoi I	8/27/95	81
7	Tostoi I	8/28/95	85
8	Daisy I	8/23/95	67
8	Daisy I	8/24/95	105
8	Daisy I	8/25/95	113
8	Daisy I	8/26/95	114
8	Daisy I	8/27/95	103
8	Daisy I	8/28/95	133
9	McKenzie I	8/23/95	93
9	McKenzie I	8/24/95	119
9	McKenzie I	8/25/95	136
9	McKenzie I	8/26/95	79
9	McKenzie I	8/27/95	136
9	McKenzie I	8/28/95	142
10	Clover Bay	8/23/95	26
10	Clover Bay	8/24/95	83
10	Clover Bay	8/25/95	90
10	Clover Bay	8/26/95	76
10	Clover Bay	8/27/95	67
10	Clover Bay	8/28/95	71
11	Skin I	8/23/95	0
11	Skin I	8/24/95	0
11	Skin I	8/25/95	15

SITE #	SITE NAME	DATE	# SEALS
11	Skin I	8/26/95	0
11	Skin I	8/27/95	0
11	Skin I	8/28/95	0
12	Lancaster	8/23/95	0
12	Lancaster	8/24/95	31
12	Lancaster	8/25/95	27
12	Lancaster	8/26/95	48
12	Lancaster	8/27/95	77
12	Lancaster	8/28/95	45
13	E. Dora Bay	8/23/95	32
13	E. Dora Bay	8/24/95	116
13	E. Dora Bay	8/25/95	86
13	E. Dora Bay	8/26/95	96
13	E. Dora Bay	8/27/95	98
13	E. Dora Bay	8/28/95	113
14	Wedge I	8/24/95	214

SITE #	SITE NAME	DATE	# SEALS
14	Wedge I	8/25/95	184
14	Wedge I	8/26/95	139
14	Wedge I	8/27/95	267
14	Wedge I	8/28/95	313
15	Moria Sound	8/23/95	141
15	Moria Sound	8/24/95	190
15	Moria Sound	8/25/95	157
15	Moria Sound	8/26/95	235
15	Moria Sound	8/27/95	205
15	Moria Sound	8/28/95	324
16	Wh. Rock I	8/23/95	87
16	Wh. Rock I	8/24/95	90
16	Wh. Rock I	8/25/95	67
16	Wh. Rock I	8/26/95	81
16	Wh. Rock I	8/27/95	123
16	Wh. Rock I	8/28/95	143

Appendix II. Harbor seal survey data from the Sitka area trend count route.

SITE #	SITE NAME	DATE	# SEALS
1	Hoggatt	9/3/83	291
1	Hoggatt	9/4/83	31
1	Hoggatt	9/6/83	87
1	Hoggatt	9/7/83	168
1	Hoggatt	9/8/83	235
1	Hoggatt	9/9/83	149
1	Hoggatt	9/10/83	173
1	Hoggatt	9/11/83	224
2	Vixen	9/3/83	109
2	Vixen	9/4/83	97
2	Vixen	9/5/83	94
2	Vixen	9/6/83	88
2	Vixen	9/7/83	31
2	Vixen	9/8/83	51
2	Vixen	9/9/83	44
2	Vixen	9/10/83	39
2	Vixen	9/11/83	77
3	Moser I N	9/3/83	17
3	Moser I N	9/4/83	0
3	Moser I N	9/5/83	17
3	Moser I N	9/6/83	14
3	Moser I N	9/7/83	18
3	Moser I N	9/8/83	19
3	Moser I N	9/9/83	26
3	Moser I N	9/10/83	19
3	Moser I N	9/11/83	3
4	Southarm	9/5/83	24
4	Southarm	9/6/83	42
4	Southarm	9/7/83	56
4	Southarm	9/8/83	52
4	Southarm	9/9/83	57
4	Southarm	9/10/83	68
4	Southarm	9/11/83	39
5	Northarm	9/5/83	37
5	Northarm	9/6/83	49
5	Northarm	9/7/83	44
5	Northarm	9/8/83	39
5	Northarm	9/9/83	39
5	Northarm	9/10/83	36
5	Northarm	9/11/83	14
6	Long Bay	9/4/83	125
6	Long Bay	9/5/83	133
6	Long Bay	9/6/83	117
6	Long Bay	9/7/83	113
6	Long Bay	9/8/83	128
6	Long Bay	9/9/83	103
6	Long Bay	9/10/83	134
6	Long Bay	9/11/83	121

SITE #	SITE NAME	DATE	# SEALS
7	Head of Tenakee	9/4/83	49
7	Head of Tenakee	9/5/83	57
7	Head of Tenakee	9/6/83	82
7	Head of Tenakee	9/7/83	100
7	Head of Tenakee	9/8/83	91
7	Head of Tenakee	9/9/83	79
8	Grassy	9/3/83	41
8	Grassy	9/4/83	92
8	Grassy	9/5/83	119
8	Grassy	9/6/83	94
8	Grassy	9/7/83	54
8	Grassy	9/8/83	1
8	Grassy	9/9/83	1
8	Grassy	9/10/83	0
8	Grassy	9/11/83	0
9	Mid I. S.	9/3/83	2
9	Mid I. S.	9/4/83	27
9	Mid I. S.	9/5/83	24
9	Mid I. S.	9/6/83	17
9	Mid I. S.	9/7/83	12
9	Mid I. S.	9/8/83	24
9	Mid I. S.	9/9/83	34
9	Mid I. S.	9/10/83	26
9	Mid I. S.	9/11/83	64
10	Saltry Bay	9/3/83	0
10	Saltry Bay	9/4/83	0
10	Saltry Bay	9/5/83	0
10	Saltry Bay	9/6/83	10
10	Saltry Bay	9/7/83	11
10	Saltry Bay	9/8/83	21
10	Saltry Bay	9/9/83	16
10	Saltry Bay	9/10/83	21
10	Saltry Bay	9/11/83	26
11	Crab Bay	9/3/83	108
11	Crab Bay	9/5/83	113
11	Crab Bay	9/6/83	124
11	Crab Bay	9/7/83	59
11	Crab Bay	9/9/83	88
11	Crab Bay	9/11/83	108
12	Strawberry Rk	9/3/83	1
12	Strawberry Rk	9/4/83	31
12	Strawberry Rk	9/5/83	49
12	Strawberry Rk	9/6/83	44
12	Strawberry Rk	9/7/83	33
12	Strawberry Rk	9/8/83	61
12	Strawberry Rk	9/9/83	69
12	Strawberry Rk	9/10/83	37
12	Strawberry Rk	9/11/83	66

SITE #	SITE NAME	DATE	# SEALS
13	Tenakee Rk	9/3/83	0
13	Tenakee Rk	9/4/83	0
13	Tenakee Rk	9/5/83	67
13	Tenakee Rk	9/6/83	15
13	Tenakee Rk	9/7/83	43
13	Tenakee Rk	9/9/83	64
13	Tenakee Rk	9/10/83	75
13	Tenakee Rk	9/11/83	78
14	Appletree	9/3/83	208
14	Appletree	9/4/83	117
14	Appletree	9/5/83	171
14	Appletree	9/6/83	114
14	Appletree	9/9/83	104
14	Appletree	9/10/83	189
14	Appletree	9/11/83	154
15	Pt Hayes	9/3/83	56
15	Pt Hayes	9/4/83	19
15	Pt Hayes	9/5/83	7
15	Pt Hayes	9/6/83	33
15	Pt Hayes	9/7/83	28
15	Pt Hayes	9/8/83	49
15	Pt Hayes	9/9/83	67
15	Pt Hayes	9/10/83	71
15	Pt Hayes	9/11/83	44
16	Traders	9/3/83	0
16	Traders	9/4/83	0
16	Traders	9/5/83	0
16	Traders	9/6/83	0
16	Traders	9/7/83	27
16	Traders	9/8/83	29
16	Traders	9/9/83	24
16	Traders	9/10/83	18
16	Traders	9/11/83	14
17	Midway	9/3/83	42
17	Midway	9/4/83	0
17	Midway	9/5/83	0
17	Midway	9/6/83	0
17	Midway	9/7/83	7
17	Midway	9/8/83	9
17	Midway	9/9/83	19
17	Midway	9/10/83	9
17	Midway	9/11/83	21
18	Plover	9/3/83	166
18	Plover	9/4/83	24
18	Plover	9/5/83	23
18	Plover	9/6/83	23
18	Plover	9/7/83	107
18	Plover	9/8/83	136
18	Plover	9/9/83	138
18	Plover	9/10/83	82
18	Plover	9/11/83	121
19	Pt. Moses	9/4/83	14
19	Pt. Moses	9/5/83	19
19	Pt. Moses	9/6/83	36
19	Pt. Moses	9/7/83	34
19	Pt. Moses	9/8/83	32
19	Pt. Moses	9/9/83	19
19	Pt. Moses	9/10/83	38
19	Pt. Moses	9/11/83	47
20	Krugloi	9/3/83	0
20	Krugloi	9/4/83	0
20	Krugloi	9/5/83	3
20	Krugloi	9/6/83	46
20	Krugloi	9/7/83	1
20	Krugloi	9/8/83	1
20	Krugloi	9/9/83	96
20	Krugloi	9/10/83	79
20	Krugloi	9/11/83	0
1	Hoggatt	8/31/84	204
1	Hoggatt	9/1/84	304
1	Hoggatt	9/4/84	204
1	Hoggatt	9/5/84	57
1	Hoggatt	9/6/84	80
1	Hoggatt	9/9/84	122
1	Hoggatt	9/10/84	98
1	Hoggatt	9/11/84	99
1	Hoggatt	9/12/84	204
1	Hoggatt	9/13/84	143
2	Vixen	8/31/84	135
2	Vixen	9/1/84	71
2	Vixen	9/4/84	202
2	Vixen	9/5/84	179
2	Vixen	9/6/84	122
2	Vixen	9/9/84	99
2	Vixen	9/10/84	119
2	Vixen	9/11/84	51
2	Vixen	9/12/84	39
2	Vixen	9/13/84	84
3	Moser I N	8/31/84	33
3	Moser I N	9/1/84	32
3	Moser I N	9/4/84	27
3	Moser I N	9/5/84	18
3	Moser I N	9/6/84	23
3	Moser I N	9/7/84	0
3	Moser I N	9/8/84	19
3	Moser I N	9/10/84	13
3	Moser I N	9/12/84	17
4	Southarm	8/31/84	7
4	Southarm	9/1/84	23
4	Southarm	9/9/84	51
4	Southarm	9/10/84	58
4	Southarm	9/11/84	67

SITE #	SITE NAME	DATE	# SEALS
4	Southarm	9/12/84	71
4	Southarm	9/13/84	76
5	Northarm	8/31/84	1
5	Northarm	9/1/84	50
5	Northarm	9/4/84	58
5	Northarm	9/5/84	58
5	Northarm	9/6/84	39
5	Northarm	9/7/84	18
5	Northarm	9/8/84	0
5	Northarm	9/9/84	0
5	Northarm	9/13/84	33
6	Long Bay	8/31/84	231
6	Long Bay	9/1/84	289
6	Long Bay	9/4/84	121
6	Long Bay	9/5/84	229
6	Long Bay	9/6/84	216
6	Long Bay	9/7/84	158
6	Long Bay	9/9/84	124
6	Long Bay	9/11/84	149
6	Long Bay	9/12/84	122
6	Long Bay	9/13/84	124
7	Head of Tenakee	9/4/84	72
7	Head of Tenakee	9/5/84	76
7	Head of Tenakee	9/6/84	61
7	Head of Tenakee	9/8/84	49
7	Head of Tenakee	9/10/84	60
7	Head of Tenakee	9/11/84	43
7	Head of Tenakee	9/12/84	86
8	Grassy	8/31/84	78
8	Grassy	9/1/84	0
8	Grassy	9/4/84	3
8	Grassy	9/5/84	0
8	Grassy	9/6/84	6
8	Grassy	9/7/84	2
8	Grassy	9/9/84	2
8	Grassy	9/10/84	0
8	Grassy	9/11/84	0
8	Grassy	9/12/84	0
8	Grassy	9/13/84	0
9	Mid I. S.	8/31/84	9
9	Mid I. S.	9/1/84	4
9	Mid I. S.	9/4/84	1
9	Mid I. S.	9/5/84	46
9	Mid I. S.	9/6/84	6
9	Mid I. S.	9/7/84	15
9	Mid I. S.	9/9/84	51
9	Mid I. S.	9/10/84	98
9	Mid I. S.	9/11/84	85
9	Mid I. S.	9/12/84	112
9	Mid I. S.	9/13/84	98
10	Saltry Bay	8/31/84	2

SITE #	SITE NAME	DATE	# SEALS
10	Saltry Bay	9/1/84	0
10	Saltry Bay	9/4/84	0
10	Saltry Bay	9/5/84	0
10	Saltry Bay	9/6/84	0
10	Saltry Bay	9/12/84	62
10	Saltry Bay	9/13/84	101
11	Crab Bay	8/31/84	191
11	Crab Bay	9/4/84	155
11	Crab Bay	9/5/84	147
11	Crab Bay	9/8/84	1
12	Strawberry Rk	8/31/84	21
12	Strawberry Rk	9/1/84	11
12	Strawberry Rk	9/8/84	58
12	Strawberry Rk	9/9/84	41
12	Strawberry Rk	9/11/84	48
12	Strawberry Rk	9/12/84	54
12	Strawberry Rk	9/13/84	52
13	Tenakee Rk	8/31/84	104
13	Tenakee Rk	9/1/84	116
13	Tenakee Rk	9/4/84	121
13	Tenakee Rk	9/5/84	114
13	Tenakee Rk	9/6/84	109
13	Tenakee Rk	9/7/84	92
13	Tenakee Rk	9/8/84	159
13	Tenakee Rk	9/9/84	136
13	Tenakee Rk	9/10/84	80
13	Tenakee Rk	9/11/84	88
13	Tenakee Rk	9/12/84	86
13	Tenakee Rk	9/13/84	79
14	Appletree	8/31/84	235
14	Appletree	9/1/84	257
14	Appletree	9/4/84	186
14	Appletree	9/5/84	193
14	Appletree	9/6/84	159
14	Appletree	9/7/84	118
14	Appletree	9/8/84	80
14	Appletree	9/10/84	79
14	Appletree	9/11/84	110
14	Appletree	9/12/84	58
15	Pt Hayes	8/31/84	56
15	Pt Hayes	9/1/84	0
15	Pt Hayes	9/5/84	38
15	Pt Hayes	9/6/84	17
15	Pt Hayes	9/7/84	0
15	Pt Hayes	9/8/84	42
15	Pt Hayes	9/9/84	16
15	Pt Hayes	9/11/84	63
15	Pt Hayes	9/12/84	50
15	Pt Hayes	9/13/84	72
16	Traders	8/31/84	13
16	Traders	9/1/84	0

SITE #	SITE NAME	DATE	# SEALS
16	Traders	9/4/84	0
16	Traders	9/5/84	6
16	Traders	9/6/84	7
16	Traders	9/7/84	0
16	Traders	9/8/84	19
16	Traders	9/9/84	0
16	Traders	9/10/84	1
16	Traders	9/11/84	19
16	Traders	9/12/84	18
16	Traders	9/13/84	21
17	Midway	8/31/84	59
17	Midway	9/1/84	28
17	Midway	9/4/84	47
17	Midway	9/5/84	51
17	Midway	9/6/84	67
17	Midway	9/8/84	22
17	Midway	9/9/84	17
17	Midway	9/10/84	17
17	Midway	9/11/84	45
17	Midway	9/12/84	34
17	Midway	9/13/84	54
18	Plover	8/31/84	104
18	Plover	9/4/84	36
18	Plover	9/5/84	93
18	Plover	9/6/84	117
18	Plover	9/7/84	128
18	Plover	9/8/84	43
18	Plover	9/11/84	66
18	Plover	9/13/84	67
19	Pt. Moses	8/31/84	0
19	Pt. Moses	9/1/84	1
19	Pt. Moses	9/4/84	0
19	Pt. Moses	9/5/84	0
19	Pt. Moses	9/6/84	0
19	Pt. Moses	9/7/84	0
19	Pt. Moses	9/8/84	10
19	Pt. Moses	9/9/84	0
19	Pt. Moses	9/10/84	0
19	Pt. Moses	9/11/84	0
19	Pt. Moses	9/12/84	0
19	Pt. Moses	9/13/84	0
20	Krugloi	8/31/84	0
20	Krugloi	9/1/84	0
20	Krugloi	9/4/84	12
20	Krugloi	9/5/84	13
20	Krugloi	9/6/84	0
20	Krugloi	9/9/84	32
20	Krugloi	9/10/84	14
20	Krugloi	9/11/84	0
20	Krugloi	9/12/84	0
20	Krugloi	9/13/84	1

SITE #	SITE NAME	DATE	# SEALS
1	Hoggatt I (1)	9/13/93	15
1	Hoggatt I (1)	9/14/93	0
1	Hoggatt I (1)	9/15/93	72
1	Hoggatt I (1)	9/16/93	90
1	Hoggatt I (1)	9/18/93	47
1	Hoggatt I (1)	9/19/93	76
2	Vixen I (2)	9/13/93	78
2	Vixen I (2)	9/14/93	35
2	Vixen I (2)	9/14/93	71
2	Vixen I (2)	9/15/93	0
2	Vixen I (2)	9/16/93	92
2	Vixen I (2)	9/18/93	120
2	Vixen I (2)	9/19/93	154
3	Moser I N. (3)	9/13/93	0
3	Moser I N. (3)	9/14/93	0
3	Moser I N. (3)	9/14/93	2
3	Moser I N. (3)	9/15/93	30
3	Moser I N. (3)	9/16/93	12
3	Moser I N. (3)	9/18/93	36
3	Moser I N. (3)	9/19/93	53
4	Northarm (4)	9/13/93	4
4	Northarm (4)	9/14/93	0
4	Northarm (4)	9/14/93	2
4	Northarm (4)	9/15/93	0
4	Northarm (4)	9/16/93	0
4	Northarm (4)	9/18/93	77
4	Northarm (4)	9/19/93	79
5	Southarm (5)	9/13/93	0
5	Southarm (5)	9/14/93	18
5	Southarm (5)	9/14/93	8
5	Southarm (5)	9/15/93	14
5	Southarm (5)	9/16/93	8
5	Southarm (5)	9/18/93	21
5	Southarm (5)	9/19/93	33
6	Long Bay (6)	9/13/93	40
6	Long Bay (6)	9/13/93	59
6	Long Bay (6)	9/14/93	24
6	Long Bay (6)	9/14/93	157
6	Long Bay (6)	9/15/93	134
6	Long Bay (6)	9/16/93	220
6	Long Bay (6)	9/18/93	185
6	Long Bay (6)	9/19/93	234
7	Tenakee Hd(7)	9/13/93	25
7	Tenakee Hd(7)	9/14/93	5
7	Tenakee Hd(7)	9/14/93	0
7	Tenakee Hd(7)	9/15/93	64
7	Tenakee Hd(7)	9/16/93	25
7	Tenakee Hd(7)	9/18/93	89
7	Tenakee Hd(7)	9/19/93	92
8	Grassy (8)	9/13/93	0
8	Grassy (8)	9/13/93	41

SITE #	SITE NAME	DATE	# SEALS
8	Grassy (8)	9/14/93	0
8	Grassy (8)	9/14/93	0
8	Grassy (8)	9/15/93	0
8	Grassy (8)	9/16/93	15
8	Grassy (8)	9/18/93	94
8	Grassy (8)	9/19/93	19
9	Mid I.S. (9)	9/13/93	31
9	Mid I.S. (9)	9/13/93	75
9	Mid I.S. (9)	9/14/93	30
9	Mid I.S. (9)	9/14/93	3
9	Mid I.S. (9)	9/15/93	72
9	Mid I.S. (9)	9/16/93	70
9	Mid I.S. (9)	9/18/93	28
9	Mid I.S. (9)	9/19/93	52
10	Saltery Bay(10)	9/13/93	0
10	Saltery Bay(10)	9/13/93	1
10	Saltery Bay(10)	9/14/93	0
10	Saltery Bay(10)	9/14/93	0
10	Saltery Bay(10)	9/15/93	6
10	Saltery Bay(10)	9/16/93	0
10	Saltery Bay(10)	9/18/93	60
10	Saltery Bay(10)	9/19/93	38
11	Crab Bay (11)	9/13/93	50
11	Crab Bay (11)	9/13/93	138
11	Crab Bay (11)	9/14/93	0
11	Crab Bay (11)	9/15/93	148
11	Crab Bay (11)	9/16/93	110
11	Crab Bay (11)	9/18/93	153
11	Crab Bay (11)	9/19/93	119
12	Strawberry (12)	9/13/93	6
12	Strawberry (12)	9/13/93	0
12	Strawberry (12)	9/14/93	0
12	Strawberry (12)	9/14/93	62
12	Strawberry (12)	9/15/93	62
12	Strawberry (12)	9/16/93	51
12	Strawberry (12)	9/18/93	102
12	Strawberry (12)	9/19/93	91
13	Tenakee (13)	9/13/93	49
13	Tenakee (13)	9/13/93	99
13	Tenakee (13)	9/14/93	25
13	Tenakee (13)	9/14/93	80
13	Tenakee (13)	9/15/93	117
13	Tenakee (13)	9/16/93	86
13	Tenakee (13)	9/18/93	102
13	Tenakee (13)	9/19/93	102
14	Apple Tree (14)	9/12/93	182
14	Apple Tree (14)	9/13/93	93
14	Apple Tree (14)	9/13/93	179
14	Apple Tree (14)	9/14/93	67
14	Apple Tree (14)	9/14/93	130
14	Apple Tree (14)	9/15/93	76
14	Apple Tree (14)	9/16/93	47
14	Apple Tree (14)	9/18/93	118
14	Apple Tree (14)	9/19/93	109
15	Pt. Hayes (15)	9/12/93	0
15	Pt. Hayes (15)	9/13/93	0
15	Pt. Hayes (15)	9/14/93	0
15	Pt. Hayes (15)	9/15/93	0
15	Pt. Hayes (15)	9/16/93	27
15	Pt. Hayes (15)	9/18/93	61
15	Pt. Hayes (15)	9/19/93	56
16	Traders I (16)	9/12/93	0
16	Traders I (16)	9/13/93	0
16	Traders I (16)	9/14/93	0
16	Traders I (16)	9/15/93	0
16	Traders I (16)	9/16/93	0
16	Traders I (16)	9/18/93	29
16	Traders I (16)	9/19/93	45
17	Midway Reef(17)	9/12/93	6
17	Midway Reef(17)	9/13/93	6
17	Midway Reef(17)	9/14/93	11
17	Midway Reef(17)	9/15/93	0
17	Midway Reef(17)	9/16/93	14
17	Midway Reef(17)	9/18/93	10
17	Midway Reef(17)	9/19/93	17
18	Plover Rk. (18)	9/12/93	28
18	Plover Rk. (18)	9/13/93	69
18	Plover Rk. (18)	9/14/93	52
18	Plover Rk. (18)	9/15/93	3
18	Plover Rk. (18)	9/16/93	48
18	Plover Rk. (18)	9/18/93	33
18	Plover Rk. (18)	9/19/93	51
19	Pt. Moses (19)	9/13/93	0
19	Pt. Moses (19)	9/14/93	0
19	Pt. Moses (19)	9/15/93	0
19	Pt. Moses (19)	9/16/93	0
19	Pt. Moses (19)	9/18/93	4
19	Pt. Moses (19)	9/19/93	3
20	Krugloi I (20)	9/13/93	0
20	Krugloi I (20)	9/14/93	0
20	Krugloi I (20)	9/15/93	0
20	Krugloi I (20)	9/16/93	17
20	Krugloi I (20)	9/18/93	39
20	Krugloi I (20)	9/19/93	13
1	Hoggatt	8/23/95	673
1	Hoggatt	8/25/95	201
1	Hoggatt	8/26/95	293
1	Hoggatt	8/28/95	210
1	Hoggatt	8/30/95	357
2	Vixen	8/23/95	28
2	Vixen	8/25/95	84
2	Vixen	8/26/95	104

SITE #	SITE NAME	DATE	# SEALS
2	Vixen	8/28/95	223
2	Vixen	8/30/95	234
3	Moser I N	8/23/95	71
3	Moser I N	8/25/95	39
3	Moser I N	8/26/95	22
3	Moser I N	8/28/95	18
3	Moser I N	8/30/95	28
4	Southarm	8/23/95	0
4	Southarm	8/25/95	20
4	Southarm	8/26/95	25
4	Southarm	8/28/95	10
4	Southarm	8/30/95	20
5	Northarm	8/23/95	0
5	Northarm	8/25/95	64
5	Northarm	8/26/95	0
5	Northarm	8/28/95	83
5	Northarm	8/30/95	86
6	Long Bay	8/23/95	0
6	Long Bay	8/25/95	220
6	Long Bay	8/26/95	224
6	Long Bay	8/28/95	40
6	Long Bay	8/29/95	219
6	Long Bay	8/30/95	292
7	Head of Tenakee	8/23/95	136
7	Head of Tenakee	8/25/95	102
7	Head of Tenakee	8/26/95	98
7	Head of Tenakee	8/28/95	58
7	Head of Tenakee	8/29/95	90
8	Grassy	8/23/95	0
8	Grassy	8/25/95	58
8	Grassy	8/26/95	67
8	Grassy	8/28/95	260
8	Grassy	8/29/95	0
8	Grassy	8/30/95	67
9	Mid I. S.	8/23/95	49
9	Mid I. S.	8/25/95	22
9	Mid I. S.	8/26/95	37
9	Mid I. S.	8/28/95	54
9	Mid I. S.	8/30/95	66
10	Saltry Bay	8/23/95	0
10	Saltry Bay	8/25/95	0
10	Saltry Bay	8/26/95	0
10	Saltry Bay	8/28/95	0
10	Saltry Bay	8/29/95	0
10	Saltry Bay	8/30/95	0
11	Crab Bay	8/23/95	152
11	Crab Bay	8/25/95	245
11	Crab Bay	8/26/95	198
11	Crab Bay	8/28/95	180
11	Crab Bay	8/29/95	200

SITE #	SITE NAME	DATE	# SEALS
11	Crab Bay	8/30/95	267
12	Strawberry Rk	8/23/95	0
12	Strawberry Rk	8/25/95	10
12	Strawberry Rk	8/26/95	0
12	Strawberry Rk	8/28/95	0
12	Strawberry Rk	8/29/95	0
12	Strawberry Rk	8/30/95	1
13	Tenakee Rk	8/23/95	271
13	Tenakee Rk	8/25/95	220
13	Tenakee Rk	8/26/95	375
13	Tenakee Rk	8/28/95	315
13	Tenakee Rk	8/29/95	346
13	Tenakee Rk	8/30/95	240
14	Appletree	8/23/95	363
14	Appletree	8/25/95	163
14	Appletree	8/26/95	179
14	Appletree	8/28/95	117
14	Appletree	8/29/95	217
14	Appletree	8/30/95	334
15	Pt Hayes	8/23/95	33
15	Pt Hayes	8/25/95	34
15	Pt Hayes	8/26/95	60
15	Pt Hayes	8/28/95	53
15	Pt Hayes	8/30/95	0
16	Traders	8/23/95	0
16	Traders	8/25/95	47
16	Traders	8/26/95	40
16	Traders	8/28/95	30
16	Traders	8/30/95	5
17	Midway	8/23/95	77
17	Midway	8/25/95	15
17	Midway	8/26/95	43
17	Midway	8/28/95	48
17	Midway	8/30/95	8
18	Plover	8/23/95	160
18	Plover	8/25/95	116
18	Plover	8/26/95	114
18	Plover	8/28/95	134
18	Plover	8/30/95	78
19	Pt. Moses	8/23/95	0
19	Pt. Moses	8/25/95	45
19	Pt. Moses	8/26/95	83
19	Pt. Moses	8/28/95	29
19	Pt. Moses	8/30/95	52
20	Krugloi	8/23/95	0
20	Krugloi	8/25/95	179
20	Krugloi	8/26/95	101
20	Krugloi	8/28/95	116
20	Krugloi	8/30/95	34

Appendix III. Harbor seal survey data from the Kodiak area trend count route.

SITE #	SITE NAME	DATE	# SEALS
1	Long I	8/26/92	6
1	Long I	8/28/92	21
1	Long I	8/29/92	14
1	Long I	8/30/92	23
1	Long I	8/31/92	17
2	Cliff Pt	8/26/92	17
2	Cliff Pt	8/28/92	28
2	Cliff Pt	8/29/92	33
2	Cliff Pt	8/30/92	29
2	Cliff Pt	8/31/92	26
3	Broad Pt	8/26/92	3
3	Broad Pt	8/28/92	0
3	Broad Pt	8/29/92	0
3	Broad Pt	8/30/92	0
3	Broad Pt	8/31/92	0
4	Kalsin B	8/26/92	56
4	Kalsin B	8/28/92	43
4	Kalsin B	8/29/92	46
4	Kalsin B	8/30/92	38
4	Kalsin B	8/31/92	1
5	Ugak I	8/26/92	63
5	Ugak I	8/27/92	143
5	Ugak I	8/28/92	135
5	Ugak I	8/29/92	139
5	Ugak I	8/30/92	61
5	Ugak I	8/31/92	152
6	W. Pasagshak	8/26/92	28
6	W. Pasagshak	8/27/92	39
6	W. Pasagshak	8/28/92	48
6	W. Pasagshak	8/29/92	32
6	W. Pasagshak	8/30/92	24
6	W. Pasagshak	8/31/92	23
7	Upper Ugak B.	8/26/92	50
7	Upper Ugak B.	8/27/92	7
7	Upper Ugak B.	8/28/92	26
7	Upper Ugak B.	8/29/92	1
7	Upper Ugak B.	8/30/92	21
7	Upper Ugak B.	8/31/92	72
8	Shearwater B	8/27/92	14
8	Shearwater B	8/28/92	34
8	Shearwater B	8/29/92	29
8	Shearwater B	8/30/92	42
8	Shearwater B	8/31/92	38

SITE #	SITE NAME	DATE	# SEALS
10	Black Pt	8/26/92	13
10	Black Pt	8/27/92	38
10	Black Pt	8/28/92	55
10	Black Pt	8/29/92	28
10	Black Pt	8/30/92	40
10	Black Pt	8/31/92	27
11	Rolling B	8/26/92	11
11	Rolling B	8/27/92	31
11	Rolling B	8/28/92	26
11	Rolling B	8/29/92	28
11	Rolling B	8/30/92	17
11	Rolling B	8/31/92	8
13	Geese I N	8/26/92	134
13	Geese I N	8/27/92	64
13	Geese I N	8/28/92	48
13	Geese I N	8/29/92	118
13	Geese I N	8/30/92	39
13	Geese I N	8/31/92	116
14	Geese I SE	8/26/92	9
14	Geese I SE	8/27/92	17
14	Geese I SE	8/28/92	7
14	Geese I SE	8/29/92	12
14	Geese I SE	8/30/92	10
14	Geese I SE	8/31/92	20
15	Geese I SW	8/26/92	10
15	Geese I SW	8/27/92	14
15	Geese I SW	8/28/92	3
15	Geese I SW	8/29/92	11
15	Geese I SW	8/30/92	6
15	Geese I SW	8/31/92	3
18	Sunstrom I	8/27/92	0
18	Sunstrom I	8/28/92	3
18	Sunstrom I	8/29/92	15
18	Sunstrom I	8/30/92	13
18	Sunstrom I	8/31/92	9
19	N. Sitkinak Lgn	8/27/92	25
19	N. Sitkinak Lgn	8/28/92	35
19	N. Sitkinak Lgn	8/29/92	32
19	N. Sitkinak Lgn	8/30/92	15
19	N. Sitkinak Lgn	8/31/92	44
20	Sitkinak I SE	8/31/92	158
20	Sitkinak I SE	9/1/92	144
21	S. Sitkinak Lgn	8/27/92	142

SITE #	SITE NAME	DATE	# SEALS
21	S. Sitkinak Lgn	8/28/92	123
21	S. Sitkinak Lgn	8/29/92	165
21	S. Sitkinak Lgn	8/30/92	89
21	S. Sitkinak Lgn	8/31/92	198
22	SE Tugidak Bars	8/27/92	160
22	SE Tugidak Bars	8/28/92	131
22	SE Tugidak Bars	8/29/92	199
22	SE Tugidak Bars	8/30/92	105
22	SE Tugidak Bars	8/31/92	233
22	SE Tugidak Bars	9/1/92	82
23	SW Tugidak	8/27/92	563
23	SW Tugidak	8/28/92	119
23	SW Tugidak	8/29/92	348
23	SW Tugidak	8/30/92	38
23	SW Tugidak	8/31/92	381
24	N. Tugidak (out)	8/27/92	72
24	N. Tugidak (out)	8/28/92	0
24	N. Tugidak (out)	8/29/92	80
24	N. Tugidak (out)	8/30/92	18
24	N. Tugidak (out)	8/31/92	70
24	N. Tugidak (out)	9/1/92	227
25	NE Tugidak (out)	8/27/92	197
25	NE Tugidak (out)	8/28/92	80
25	NE Tugidak (out)	8/29/92	153
25	NE Tugidak (out)	8/31/92	186
25	NE Tugidak (out)	9/1/92	110
26	Tugidak Lag in	8/27/92	123
26	Tugidak Lag in	8/28/92	97
26	Tugidak Lag in	8/29/92	177
26	Tugidak Lag in	8/30/92	69
26	Tugidak Lag in	8/31/92	135
26	Tugidak Lag in	9/1/92	26
1	Long I	9/2/93	33
1	Long I	9/3/93	37
1	Long I	9/4/93	28
1	Long I	9/6/93	25
1	Long I	9/7/93	28
1	Long I	9/8/93	39
2	Cliff Pt	9/2/93	27
2	Cliff Pt	9/3/93	16
2	Cliff Pt	9/4/93	44
2	Cliff Pt	9/6/93	13
2	Cliff Pt	9/7/93	41
2	Cliff Pt	9/8/93	56
3	Broad Pt	9/3/93	0

SITE #	SITE NAME	DATE	# SEALS
3	Broad Pt	9/4/93	2
3	Broad Pt	9/6/93	0
3	Broad Pt	9/7/93	0
3	Broad Pt	9/8/93	0
4	Kalsin B	9/2/93	4
4	Kalsin B	9/4/93	78
4	Kalsin B	9/6/93	45
4	Kalsin B	9/7/93	51
4	Kalsin B	9/8/93	36
5	Ugak I	9/2/93	238
5	Ugak I	9/3/93	157
5	Ugak I	9/6/93	220
5	Ugak I	9/7/93	213
5	Ugak I	9/8/93	172
6	W. Pasagshak	9/2/93	74
6	W. Pasagshak	9/3/93	64
6	W. Pasagshak	9/6/93	44
6	W. Pasagshak	9/7/93	57
6	W. Pasagshak	9/8/93	62
7	Upper Ugak B.	9/2/93	10
7	Upper Ugak B.	9/3/93	20
7	Upper Ugak B.	9/6/93	39
7	Upper Ugak B.	9/7/93	22
7	Upper Ugak B.	9/8/93	34
8	Shearwater B	9/2/93	58
8	Shearwater B	9/3/93	49
8	Shearwater B	9/6/93	41
8	Shearwater B	9/7/93	64
8	Shearwater B	9/8/93	39
9	Barnabas Rks	9/2/93	33
9	Barnabas Rks	9/3/93	22
9	Barnabas Rks	9/6/93	27
9	Barnabas Rks	9/7/93	3
9	Barnabas Rks	9/8/93	31
10	Black Pt	9/2/93	85
10	Black Pt	9/3/93	54
10	Black Pt	9/6/93	33
10	Black Pt	9/7/93	27
10	Black Pt	9/8/93	50
11	Rolling B	9/2/93	22
11	Rolling B	9/3/93	16
11	Rolling B	9/6/93	4
11	Rolling B	9/7/93	19
11	Rolling B	9/8/93	38
12	O. Kaguyak	9/2/93	6

SITE #	SITE NAME	DATE	# SEALS
12	O. Kaguyak	9/3/93	4
12	O. Kaguyak	9/6/93	0
12	O. Kaguyak	9/7/93	9
12	O. Kaguyak	9/8/93	11
13	Geese I N	9/2/93	162
13	Geese I N	9/6/93	149
13	Geese I N	9/7/93	98
13	Geese I N	9/8/93	85
14	Geese I SE	9/2/93	14
14	Geese I SE	9/6/93	11
14	Geese I SE	9/7/93	11
14	Geese I SE	9/8/93	2
15	Geese I SW	9/2/93	5
15	Geese I SW	9/6/93	1
15	Geese I SW	9/7/93	0
15	Geese I SW	9/8/93	0
16	Aiaktalik L	9/2/93	10
16	Aiaktalik L	9/6/93	0
16	Aiaktalik L	9/7/93	0
16	Aiaktalik L	9/8/93	0
17	Aiaktalik Is	9/2/93	63
17	Aiaktalik Is	9/6/93	75
17	Aiaktalik Is	9/7/93	68
17	Aiaktalik Is	9/8/93	55
18	Sunstrom I	9/2/93	0
18	Sunstrom I	9/6/93	0
18	Sunstrom I	9/7/93	0
18	Sunstrom I	9/8/93	0
19	N. Sitkinak Lgn	9/2/93	36
19	N. Sitkinak Lgn	9/6/93	26
19	N. Sitkinak Lgn	9/7/93	29
19	N. Sitkinak Lgn	9/8/93	23
20	Sitkinak I SE	9/2/93	147
20	Sitkinak I SE	9/6/93	148
20	Sitkinak I SE	9/8/93	103
21	S. Sitkinak Lgn	9/2/93	172
21	S. Sitkinak Lgn	9/6/93	228
21	S. Sitkinak Lgn	9/7/93	168
21	S. Sitkinak Lgn	9/8/93	203
22	SE Tugidak Lgn	9/2/93	0
22	SE Tugidak Lgn	9/6/93	0
22	SE Tugidak Lgn	9/7/93	0
22	SE Tugidak Lgn	9/8/93	0
23	SW Tugidak	9/2/93	825
23	SW Tugidak	9/6/93	505

SITE #	SITE NAME	DATE	# SEALS
23	SW Tugidak	9/7/93	838
23	SW Tugidak	9/8/93	844
24	N. Tugidak (out)	9/2/93	421
24	N. Tugidak (out)	9/6/93	351
24	N. Tugidak (out)	9/7/93	423
24	N. Tugidak (out)	9/8/93	391
25	NE Tugidak (out)	9/2/93	0
25	NE Tugidak (out)	9/6/93	0
25	NE Tugidak (out)	9/7/93	0
25	NE Tugidak (out)	9/8/93	0
26	Tugidak Lag in	9/2/93	343
26	Tugidak Lag in	9/6/93	277
26	Tugidak Lag in	9/7/93	274
26	Tugidak Lag in	9/8/93	203
1	Long I	8/23/94	38
1	Long I	8/24/94	33
1	Long I	8/25/94	29
1	Long I	8/27/94	24
1	Long I	8/28/94	37
1	Long I	8/29/94	36
2	Cliff Pt	8/23/94	51
2	Cliff Pt	8/24/94	28
2	Cliff Pt	8/25/94	30
2	Cliff Pt	8/27/94	42
2	Cliff Pt	8/28/94	46
2	Cliff Pt	8/29/94	44
3	Broad Pt	8/23/94	3
3	Broad Pt	8/24/94	6
3	Broad Pt	8/25/94	0
3	Broad Pt	8/27/94	0
3	Broad Pt	8/28/94	0
3	Broad Pt	8/29/94	0
4	Kalsin B	8/23/94	122
4	Kalsin B	8/24/94	122
4	Kalsin B	8/25/94	106
4	Kalsin B	8/27/94	101
4	Kalsin B	8/28/94	91
4	Kalsin B	8/29/94	112
5	Ugak I	8/23/94	303
5	Ugak I	8/24/94	280
5	Ugak I	8/25/94	288
5	Ugak I	8/27/94	335
5	Ugak I	8/28/94	295
5	Ugak I	8/29/94	291
6	W. Pasagshak	8/23/94	93

SITE #	SITE NAME	DATE	# SEALS
6	W. Pasagshak	8/24/94	102
6	W. Pasagshak	8/25/94	127
6	W. Pasagshak	8/27/94	83
6	W. Pasagshak	8/28/94	134
6	W. Pasagshak	8/29/94	88
7	Upper Ugak B.	8/23/94	71
7	Upper Ugak B.	8/24/94	13
7	Upper Ugak B.	8/25/94	31
7	Upper Ugak B.	8/27/94	82
7	Upper Ugak B.	8/28/94	3
7	Upper Ugak B.	8/29/94	10
8	Shearwater B	8/23/94	49
8	Shearwater B	8/24/94	43
8	Shearwater B	8/25/94	59
8	Shearwater B	8/27/94	60
8	Shearwater B	8/28/94	51
8	Shearwater B	8/29/94	50
9	Barnabas Rks	8/23/94	51
9	Barnabas Rks	8/24/94	70
9	Barnabas Rks	8/25/94	48
9	Barnabas Rks	8/27/94	64
9	Barnabas Rks	8/28/94	69
9	Barnabas Rks	8/29/94	65
10	Black Pt	8/23/94	53
10	Black Pt	8/24/94	112
10	Black Pt	8/27/94	82
10	Black Pt	8/28/94	42
10	Black Pt	8/29/94	58
11	Rolling B	8/23/94	33
11	Rolling B	8/24/94	45
11	Rolling B	8/27/94	33
11	Rolling B	8/28/94	57
11	Rolling B	8/29/94	31
12	O. Kaguyak	8/23/94	9
12	O. Kaguyak	8/24/94	21
12	O. Kaguyak	8/27/94	9
12	O. Kaguyak	8/28/94	14
12	O. Kaguyak	8/29/94	12
13	Geese I N	8/23/94	212
13	Geese I N	8/24/94	226
13	Geese I N	8/27/94	241
13	Geese I N	8/28/94	163
13	Geese I N	8/29/94	221
14	Geese I SE	8/23/94	18
14	Geese I SE	8/24/94	20
14	Geese I SE	8/27/94	7
14	Geese I SE	8/28/94	8
14	Geese I SE	8/29/94	11
15	Geese I SW	8/23/94	16
15	Geese I SW	8/24/94	1
15	Geese I SW	8/27/94	4
15	Geese I SW	8/28/94	2
15	Geese I SW	8/29/94	3
16	Aiaktalik L	8/23/94	110
16	Aiaktalik L	8/24/94	64
16	Aiaktalik L	8/27/94	95
16	Aiaktalik L	8/28/94	78
16	Aiaktalik L	8/29/94	98
18	Sunstrom I	8/23/94	0
18	Sunstrom I	8/24/94	17
18	Sunstrom I	8/27/94	7
18	Sunstrom I	8/28/94	27
18	Sunstrom I	8/29/94	9
19	N. Sitkinak Lgn	8/23/94	43
19	N. Sitkinak Lgn	8/27/94	27
19	N. Sitkinak Lgn	8/28/94	18
19	N. Sitkinak Lgn	8/29/94	24
20	Sitkinak I SE	8/23/94	175
20	Sitkinak I SE	8/27/94	251
20	Sitkinak I SE	8/28/94	239
20	Sitkinak I SE	8/29/94	192
21	S. Sitkinak Lgn	8/23/94	108
21	S. Sitkinak Lgn	8/27/94	148
21	S. Sitkinak Lgn	8/28/94	151
21	S. Sitkinak Lgn	8/29/94	142
22	SE Tugidak Lgn	8/23/94	226
22	SE Tugidak Lgn	8/27/94	202
22	SE Tugidak Lgn	8/28/94	185
22	SE Tugidak Lgn	8/29/94	186
23	SW Tugidak	8/23/94	705
23	SW Tugidak	8/27/94	755
23	SW Tugidak	8/28/94	747
23	SW Tugidak	8/29/94	883
24	N. Tugidak (out)	8/23/94	0
24	N. Tugidak (out)	8/27/94	95
24	N. Tugidak (out)	8/28/94	0
24	N. Tugidak (out)	8/29/94	0
25	NE Tugidak (out)	8/23/94	399
25	NE Tugidak (out)	8/27/94	339
25	NE Tugidak (out)	8/28/94	336

SITE #	SITE NAME	DATE	# SEALS
25	NE Tugidak (out)	8/29/94	452
26	Tugidak Lag in	8/23/94	305
26	Tugidak Lag in	8/27/94	304
26	Tugidak Lag in	8/28/94	240
26	Tugidak Lag in	8/29/94	58
1	Long I	8/26/95	33
1	Long I	8/29/95	44
1	Long I	8/30/95	47
1	Long I	9/1/95	41
1	Long I	9/2/95	33
1	Long I	9/3/95	52
2	Cliff Pt	8/26/95	2
2	Cliff Pt	8/29/95	0
2	Cliff Pt	8/30/95	9
2	Cliff Pt	9/1/95	6
2	Cliff Pt	9/2/95	10
2	Cliff Pt	9/3/95	6
3	Broad Pt	8/26/95	1
3	Broad Pt	8/29/95	1
3	Broad Pt	8/30/95	0
3	Broad Pt	9/1/95	0
3	Broad Pt	9/2/95	0
3	Broad Pt	9/3/95	0
4	Kalsin B	8/26/95	99
4	Kalsin B	8/29/95	66
4	Kalsin B	8/30/95	108
4	Kalsin B	9/1/95	110
4	Kalsin B	9/2/95	123
4	Kalsin B	9/3/95	101
5	Ugak I	8/26/95	222
5	Ugak I	8/30/95	234
5	Ugak I	9/1/95	295
5	Ugak I	9/2/95	228
5	Ugak I	9/3/95	319
6	W. Pasagshak	8/26/95	121
6	W. Pasagshak	8/29/95	79
6	W. Pasagshak	8/30/95	119
6	W. Pasagshak	9/1/95	109
6	W. Pasagshak	9/2/95	107
6	W. Pasagshak	9/3/95	153
7	Upper Ugak B.	8/26/95	19+
7	Upper Ugak B.	8/29/95	26+
7	Upper Ugak B.	8/30/95	9+
7	Upper Ugak B.	9/1/95	95
7	Upper Ugak B.	9/2/95	28+

SITE #	SITE NAME	DATE	# SEALS
7	Upper Ugak B.	9/3/95	12+
8	Shearwater B	8/26/95	63
8	Shearwater B	8/29/95	66
8	Shearwater B	8/30/95	82
8	Shearwater B	9/1/95	94
8	Shearwater B	9/2/95	59
8	Shearwater B	9/3/95	57
9	Barnabas Rks	8/26/95	58
9	Barnabas Rks	8/29/95	69
9	Barnabas Rks	8/30/95	66
9	Barnabas Rks	9/1/95	67
9	Barnabas Rks	9/2/95	65
9	Barnabas Rks	9/3/95	29+
10	Black Pt	8/26/95	97
10	Black Pt	8/29/95	102
10	Black Pt	8/30/95	71
10	Black Pt	9/1/95	136
10	Black Pt	9/2/95	46+
10	Black Pt	9/3/95	58
11	Rolling B	8/26/95	41
11	Rolling B	8/29/95	50
11	Rolling B	8/30/95	67
11	Rolling B	9/1/95	33
11	Rolling B	9/2/95	59
11	Rolling B	9/3/95	97
12	O. Kaguyak	8/26/95	11
12	O. Kaguyak	8/29/95	20
12	O. Kaguyak	8/30/95	7
12	O. Kaguyak	9/1/95	16
12	O. Kaguyak	9/2/95	21
12	O. Kaguyak	9/3/95	13
13	Geese I N	8/26/95	34+
13	Geese I N	8/29/95	186
13	Geese I N	8/30/95	228
13	Geese I N	9/1/95	247
13	Geese I N	9/2/95	242
13	Geese I N	9/3/95	228
14	Geese I SE	8/26/95	49
14	Geese I SE	8/29/95	26
14	Geese I SE	8/30/95	14
14	Geese I SE	9/1/95	22
14	Geese I SE	9/2/95	22
14	Geese I SE	9/3/95	23
15	Geese I SW	8/26/95	5
15	Geese I SW	8/29/95	11

SITE #	SITE NAME	DATE	# SEALS
15	Geese I SW	8/30/95	3
15	Geese I SW	9/1/95	4
15	Geese I SW	9/2/95	5
15	Geese I SW	9/3/95	4
16	Aiaktalik L	8/26/95	37
16	Aiaktalik L	8/29/95	13
16	Aiaktalik L	8/30/95	26
16	Aiaktalik L	9/1/95	2
16	Aiaktalik L	9/2/95	4
16	Aiaktalik L	9/3/95	5
17	Aiaktalik Is	8/26/95	32
17	Aiaktalik Is	8/29/95	161
17	Aiaktalik Is	8/30/95	84
17	Aiaktalik Is	9/1/95	98
17	Aiaktalik Is	9/2/95	119
17	Aiaktalik Is	9/3/95	72
18	Sunstrom I	8/26/95	15
18	Sunstrom I	8/29/95	22
18	Sunstrom I	8/30/95	9
18	Sunstrom I	9/1/95	9
18	Sunstrom I	9/2/95	4
18	Sunstrom I	9/3/95	5
19	N. Sitkinak Lgn	8/26/95	72
19	N. Sitkinak Lgn	8/29/95	130
19	N. Sitkinak Lgn	8/30/95	101
19	N. Sitkinak Lgn	9/1/95	127
19	N. Sitkinak Lgn	9/2/95	86
19	N. Sitkinak Lgn	9/3/95	115
20	Sitkinak I SE	8/26/95	111
20	Sitkinak I SE	8/29/95	126
20	Sitkinak I SE	8/30/95	86+
20	Sitkinak I SE	9/1/95	124
20	Sitkinak I SE	9/2/95	147
20	Sitkinak I SE	9/3/95	141
21	S. Sitkinak Lgn	8/26/95	72
21	S. Sitkinak Lgn	8/29/95	146
21	S. Sitkinak Lgn	8/30/95	79+
21	S. Sitkinak Lgn	9/1/95	151
21	S. Sitkinak Lgn	9/2/95	119
21	S. Sitkinak Lgn	9/3/95	177
22	SE Tugidak Bars	8/26/95	151
22	SE Tugidak Bars	8/29/95	188
22	SE Tugidak Bars	8/30/95	230
22	SE Tugidak Bars	9/1/95	256
22	SE Tugidak Bars	9/2/95	251

SITE #	SITE NAME	DATE	# SEALS
22	SE Tugidak Bars	9/3/95	184
23	SW Tugidak	8/26/95	fog
23	SW Tugidak	8/29/95	695
23	SW Tugidak	8/30/95	490+
23	SW Tugidak	9/1/95	823
23	SW Tugidak	9/2/95	593+
23	SW Tugidak	9/3/95	964
24	N. Tugidak (out)	8/26/95	207
24	N. Tugidak (out)	8/29/95	188
24	N. Tugidak (out)	8/30/95	250
24	N. Tugidak (out)	9/1/95	242
24	N. Tugidak (out)	9/2/95	168
24	N. Tugidak (out)	9/3/95	162
25	NE Tugidak (out)	8/26/95	0
25	NNE Tugidak (out)	8/26/95	124
25	NE Tugidak (out)	8/29/95	191
25	NE Tugidak (out)	8/30/95	171
25	NE Tugidak (out)	9/1/95	254
25	NE Tugidak (out)	9/2/95	258
25	NE Tugidak (out)	9/3/95	250
26	Tugidak Lag in	8/26/95	126
26	Tugidak Lag in	8/29/95	213
26	Tugidak Lag in	8/30/95	198
26	Tugidak Lag in	9/1/95	222
26	Tugidak Lag in	9/2/95	148
26	Tugidak Lag in	9/3/95	208
27	NNE Tugidak (out)	8/29/95	198
27	NNE Tugidak (out)	8/30/95	154
27	NNE Tugidak (out)	9/1/95	194
27	NNE Tugidak (out)	9/2/95	83
27	NNE Tugidak (out)	9/3/95	0
28	Upper Kiliuda	8/26/95	0
28	Upper Kiliuda	8/29/95	26+
28	Upper Kiliuda	8/30/95	50+
28	Upper Kiliuda	9/1/95	94
28	Upper Kiliuda	9/2/95	86
28	Upper Kiliuda	9/3/95	78
29	Womens Bay marker	8/26/95	34
29	Womens Bay marker	8/29/95	40
29	Womens Bay marker	8/30/95	56
29	Womens Bay marker	9/1/95	21
29	Womens Bay marker	9/2/95	55
29	Womens Bay marker	9/3/95	60

SITE #	SITE NAME	DATE	# SEALS
30	Chiniak marker	8/26/95	7
30	Chiniak marker	8/30/95	0
30	Chiniak marker	9/1/95	0
30	Chiniak marker	9/2/95	0
30	Chiniak marker	9/3/95	0

Appendix IV. Counts of harbor seals on southwestern Tugidak Island.

YEAR	MONTH	DAY	NO_SEALS
1976	6	1	2819
1976	6	3	2574
1976	6	6	1824
1976	6	8	1304
1976	6	10	1039
1976	6	11	1335
1976	6	12	2278
1976	6	16	1974
1976	6	21	2785
1976	6	22	3566
1976	6	24	2525
1976	8	21	8716
1976	8	22	2800
1976	8	23	7645
1976	8	25	3700
1976	8	26	6735
1976	8	27	6781
1976	8	28	6437
1976	8	30	9042
1976	8	31	9300
1976	9	2	7785
1976	9	4	6904
1976	9	5	7182
1978	6	1	731
1978	6	2	981
1978	6	3	715
1978	6	4	1332
1978	6	5	1725
1978	6	6	1439
1978	6	7	812
1978	6	8	892
1978	6	9	714
1978	6	10	1078
1978	6	12	1965
1978	6	13	2086
1978	6	14	1570
1978	6	15	1460
1978	6	16	1773
1978	6	17	851
1978	6	21	1148
1978	6	22	909
1978	6	24	893
1978	6	25	1637
1978	6	26	1348
1978	6	27	939
1978	6	28	927
1978	6	29	765
1978	6	30	853
1978	8	20	2532

YEAR	MONTH	DAY	NO_SEALS
1978	8	23	2587
1978	8	24	3983
1978	8	25	4814
1978	8	27	5966
1978	8	29	5372
1978	8	31	5599
1978	9	1	5758
1978	9	2	5257
1978	9	3	6817
1978	9	4	4576
1978	9	5	4805
1979	6	5	1356
1979	6	6	1071
1979	6	8	1296
1979	6	9	960
1979	6	10	908
1979	6	11	1049
1979	6	12	914
1979	6	13	398
1979	6	16	1165
1979	6	17	1350
1979	6	18	1263
1979	6	19	869
1979	6	20	887
1979	6	21	820
1979	8	18	4689
1979	8	19	4886
1979	8	20	4068
1979	8	22	4532
1979	8	23	4248
1979	8	24	4660
1979	8	26	3601
1979	8	28	4197
1979	8	29	3009
1979	8	30	2808
1979	8	31	2572
1979	9	1	4011
1979	9	2	3911
1979	9	6	3118
1979	9	7	2789
1979	9	8	2978
1979	9	9	2756
1979	9	10	4876
1979	9	11	4413
1979	9	12	4378
1979	9	13	4050
1982	8	30	2197
1982	8	31	2323
1982	9	1	660

YEAR	MONTH	DAY	NO_SEALS
1982	8	31	2323
1982	9	1	660
1982	9	2	1035
1982	9	3	800
1982	9	4	1121
1982	9	5	1693
1982	9	6	1914
1982	9	7	2103
1982	9	8	1904
1984	8	28	1037
1984	8	29	789
1984	8	30	838
1984	9	1	1350
1984	9	2	1339
1984	9	3	1630
1984	9	4	1153
1984	9	5	2187
1984	9	6	2187
1977	6	1	811
1977	6	4	770
1977	6	7	858
1977	6	10	1295
1977	6	13	1500
1977	6	21	1075
1977	6	30	1900
1977	8	23	6595
1977	8	24	6640
1964	6	3	571
1964	6	7	2321
1964	6	13	7000
1964	6	21	831
1964	6	28	1128
1964	6	30	3328
1986	6	13	517
1986	6	14	610
1986	6	15	660
1986	6	16	676
1986	8	29	639
1986	8	30	1468
1986	8	31	1493
1986	9	1	1486
1986	9	2	1236
1986	9	3	1287
1986	9	4	1673

YEAR	MONTH	DAY	NO_SEALS
1986	9	5	1286
1986	9	9	1034
1986	9	10	1096
1988	8	25	1437
1988	8	26	788
1988	8	27	605
1988	8	28	1008
1988	8	29	1219
1988	8	30	1089
1988	8	31	980
1988	9	1	806
1988	9	2	1171
1988	9	5	1033
1990	8	29	433
1990	8	30	861
1990	8	31	902
1990	9	1	1034
1990	9	2	1098
1990	9	3	1096
1990	9	4	1019
1990	9	5	1283
1990	8	28	918
1992	8	26	1005
1992	8	27	997
1992	8	28	381
1992	8	29	122
1992	8	30	515
1992	8	31	407
1994	8	21	410
1994	8	22	580
1994	8	23	715
1994	8	24	605
1994	8	25	786
1994	8	26	457
1994	8	27	730
1994	8	28	652
1994	8	29	857
1994	8	30	894
1995	8	25	443
1995	8	26	473
1995	8	27	752
1995	8	28	584
1995	8	29	781

APPENDIX V

Aerial Surveys of Harbor Seals Along the South Side of the Alaska Peninsula, the Semidi Islands, and Chirikof Island, August 1995

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INTRODUCTION

A harbor seal (*Phoca vitulina richardsi*) aerial survey trend count route was established in August 1995 along a portion of the south side of the Alaska Peninsula, and the Semidi Islands and Chirikof Island. The survey route was in areas that had been surveyed by the National Marine Fisheries Service (NMFS) in 1992 (Loughlin 1993) so the results could be examined for changes in abundance.

METHODS

Surveys were flown at an 800 foot altitude in a twin-engine high-wing AeroCommander Shrike aircraft with the pilot in the left front seat and one observer in the right front seat. One survey was flown each day from 24 through 30 August 1995. Surveys were timed such that counts were made within the time from 2 hours before to 2 hours after low tide.

When hauled out harbor seals were located the aircraft circled and the observer counted all seals (including those in the water near haulouts) through 7 power binoculars and took 35mm photographs (ASA 400) with an autowind, autofocus camera with 80-210mm zoom lens.

The survey aircraft was based out of Larsen Bay on the west side of Kodiak Island. Each survey began on the Alaska Peninsula at Katmai Bay and progressed southwestward to Eagle Island, then southward offshore to the Semidi Islands and Chirikof Island (Figure 1). Initially, search surveys were flown along the entire mainland coast and all offshore islands, reefs, and rocks. Each harbor seal haulout located was entered as a Global Positioning System (GPS) waypoint. For the last 4 surveys, the route of flight was direct from 1 identified haulout to the next, but coastline and rocks along the flightline were also searched for seals.

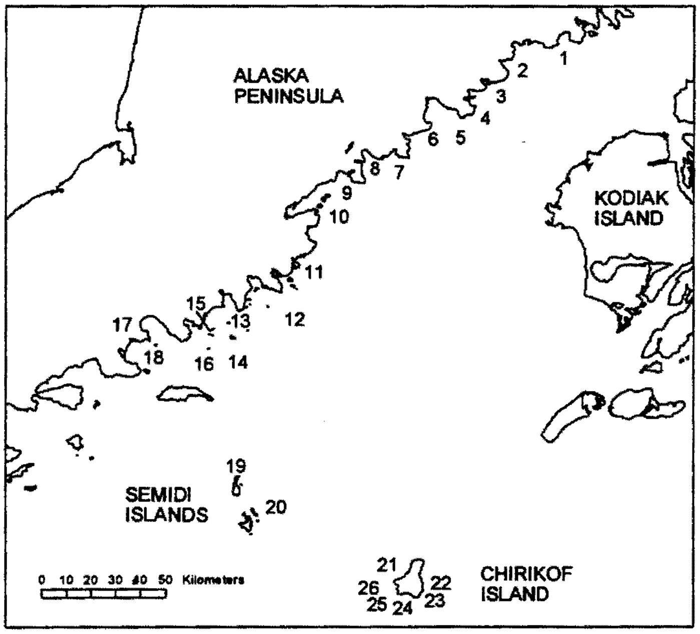

Figure 1. Harbor seal trend count route for the southern Alaska Peninsula, Semidi Islands and Chirikof Island. Site numbers correspond with locations in Table 1.

RESULTS

Approximately 20 minutes of flying was required to transit from Larsen Bay to the first count site north of Katmai Bay. Because of the time required to search all the coastline and offshore rocks the first day of survey covered only as far as Yantari Bay on the Alaska Peninsula, before going to the Semidis and Chirikof. On the second survey day the flight extended along the Peninsula as far as Eagle Island. On each of those days 2.6 hours was spent surveying along the Peninsula. In order to maintain a safe and adequate fuel reserve it was necessary to stop at Akhiok on the south end of Kodiak Island and transfer fuel into the plane from drums before returning to Larsen Bay. On subsequent days the flight line was based on GPS waypoints identifying haulouts, and less time was spent searching. Using that method it was possible to fly sites along the Peninsula in less than 2 hours, which eliminated the necessity to stop and fuel at Akhiok on the return flight.

Harbor seals were seen at 38 specific locations which were grouped into 26 trend count sites (Table 1). Eighteen trend sites were along the Alaska Peninsula, 2 in the Semidi Islands, and 6 at Chirikof Island. Most haulouts were on rocks or low reefs near the mainland shore, or on rocky offshore islands.

Counts made on the 7 individual survey days are summarized in Table 2. Coverage of the route was relatively complete on five days, while on 2 days very low overcast and fog precluded surveys in much of the area. The number of replicate counts at each trend site ranged from 3 to 6. The largest haulout sites were at Alinchak Bay, Wide Bay, Aiugnak Columns, Ugaiushak Island, and Chirikof Island. Based on the sum of mean counts at individual haulout sites, and average of 804 seals was counted along the Alaska Peninsula, 48 in the Semidi Islands, and 214 at Chirikof Island, for an average total of 1,066 seals counted on the trend count route.

DISCUSSION

The NMFS counted harbor seals in the area covered by this survey in August 1992 (Loughlin 1993). During the 1995 surveys I attempted to replicate the counts made by NMFS so that a comparison could be made to look for changes in numbers. Based on locations I attempted to equate the 1995 trend sites with the NMFS count locations (Table 3). This was somewhat difficult for sites along the Alaska Peninsula and in several instances it was not possible to be certain that identical sites were counted in the two years. Differences may be due to different observers and survey platforms, changes in coastline topography, or shifts in seal distribution. At the Semidi Islands and Chirikof Island it was easy to ensure that all the coastline was searched. Also, the pilot and aircraft were the same in 1992 and 1995 surveys, therefore the counts in those areas should be directly comparable.

Counts made by NMFS were assigned to the 26 trend count sites used in this study, and mean values calculated for each site (Table 4). Mean counts made during 1995 and 1992 are compared in Table 2. Counts made during the two years varied considerably for the sites along the Alaska Peninsula. For eight sites 1995 counts were higher, for four sites 1992 counts were higher, and for 5 sites counts were about the same. The total mean count for the 18 sites was 804, which is 53% greater than the 1992 total of 526.

During 1992 NMFS identified three haulout sites in the Semidi Islands. In 1995 no seals were seen at NMFS site 160 (Aghiyuk Island NW) during any of the surveys. The entire coastline of the Semidis was searched three times and no new haulouts were found. A comparison of 1995 mean counts (48) with 1992 (114) indicates a decline in seal numbers of 58% (Table 2).

At Chirikof Island, all sites identified in 1992 were used in 1995 (Table 2). Mean counts for Chirikof sites combined suggest a decline of 14% from 1992 (248) to 1995 (214).

Conclusions

Considerably more seals were counted along the portion of the Alaska Peninsula surveyed in 1995 than in 1992. However, because of lack of standardization of sites and observers the data should not be used to conclude that seal numbers have increased in that region.

Counts made in the Semidis and at Chirikof in 1992 and 1995 should be comparable. If those two regions are combined, the data indicate a decrease in mean counts from 362 in 1992 to 262 in 1995, a decline of 28%.

ACKNOWLEDGMENTS

I thank Tom Blaesing for his expert piloting of the aircraft used in the surveys and the Carlsen family at Larsen Bay Lodge for logistic support. Financial support for these surveys was provided by the National Marine Fisheries Service through NOAA award NA37FX0142.

LITERATURE CITED

Loughlin, T. R. 1993. Abundance and distribution of harbor seals (*Phoca vitulina richardsi*) in the Gulf of Alaska and Prince William Sound in 1992. Annual Report from NMFS National Marine Mammal Laboratory to MMPA Assessment Program, NOAA NMFS, Silver Spring, MD. 19 pp.

Table 1. Locations and descriptions of harbor seal haulout sites on the south Alaska Peninsula, Semidis, Chirikof Island trend count route.

ADF&G #s	NMFS #s	Geographic location	GPS Coordinates	Description
1	65,62-64?	Katmai Bay E	58°00.45'N 154°45.71'W	small rocks just offshore N. of Bay
2	60,61	Kashvik Bay	57°57.06'N 155°03.42'W	low reef off N point
			57°53.93'N 155°03.19'W	tidal rocks just underwater
3	59	Alinchak Bay N	57°51.52'N 155°07.59'W	reef to E of grassy peninsula
			57°51.20'N 155°10.27'W	tidal reefs inside bay
			57°50.92'N 155°10.57'W	tidal reefs inside bay
4	58	Alinchak Bay S	57°46.44'N 155°18.94'W	low reefs inside bay
			57°45.89'N 155°14.99'W	low reefs S entrance of bay
			57°45.90'N 155°16.69'W	low reefs S entrance of bay
5	56,57?	Puale Bay Rocks	57°41.60'N 155°24.98'W	offshore rocks closest to mainland
6	55	Cape Aklek	57°40.47'N 155°34.70'W	boulders along mainland shore
7	--	Jute Bay	57°33.17'N 155°49.35'W	rocks off low reef from mainland
			57°33.15'N 155°51.15'W	reef inside island in mid bay
8	53,54	Portage Bay	57°33.50'N 156°01.10'W	small reef near head of bay
			57°30.91'N 156°02.51'W	small reef off mainland peninsula
9	51,52	Wide Bay N	57°27.40'N 156°11.59'W	low reefs inside N part of bay
			57°27.31'N 156°10.87'W	low reefs inside N part of bay
10	50,49?	Wide Bay S	57°20.01'N 156°16.68'W	low reefs outside islands
11	48	Agripina Bay	57°06.92'N 156°26.92'W	rock by islet inside bay on W side
			57°06.36'N 156°25.90'W	rock to S of other haulout

Table 1. Continued.

ADF&G #s	NMFS #s	Geographic location	GPS Coordinates	Description
12	46,47,45?	Aiugnak Columns	56°52.73'N 156°34.40'W	offshoremost 2 rocky islands
13	44	Ugaiushak Island	56°48.00'N 156°50.85'W	flat rock on NE side of island
14	43	Toee Reef	56°45.72'N 156°51.67'W	long reef south of island
15	40	Isl SE Yantari Bay	56°47.88'N 157°00.97'W	rocks off islets to E of bay
16	42	Hydra Island	56°44.60'N 157°00.43'W	rock to E of offshore islet
17	39	Amber Bay	56°50.84'N 157°24.44'W	sandbar at head of bay
			56°49.94'N 157°26.76'W	small reef inside bay on W side
			56°48.45'N 157°23.74'W	big low reef W side outer bay
18	38	Eagle Island	56°45.51'N 157°20.84'W	rocky reefs around island
19	159,160?	Aghiyuk Island NE	56°12.76'N 156°46.70'W	3rd to 5th beaches to south
20	161	Anowik Island	56°04.95'N 156°40.39'W	rocky ledges between island parts
			56°04.25'N 156°38.53'W	rock at S end island
21	165	Chirikof E Nagai	55°49.65'N 155°44.87'W	low reefs offshore
22	162	Chirikof E	55°48.87'N 155°33.26'W	small rocks nearshore
23	163	Chirikof SE	55°47.58'N 155°33.22'W	round reef nearshore
24	--	Chirikof S	55°46.68'N 155°40.87'W	small rocks just offshore
25	166	Chirikof S house	55°47.99'N 155°43.75'W	mainland rocks bay side facing house
26	164	Chirikof N house	55°48.29'N 155°44.60'W	long line of rocks N of house

Table 2. Summary of harbor seal counts along the south Alaska Peninsula, Semidis, and Chirikof Island trend count route, August 24-30 1995.

Site #	Location	8/24	8/25	8/26	8/27	8/28	8/29	8/30	Mean
1	Katmai Bay E	13	12	7	nc	12	21	26	15.2
2	Kashvik Bay	36	41	27	nc	45	23	5	29.5
3	Alinchak Bay N	26	42	14	nc	46	29	31	31.3
4	Alinchak Bay S	27	105	103	nc	155	136	70	99.3
5	Puale Bay Rocks	25	27	18	nc	27	32	20	24.8
6	Cape Aklek	nc	10	0	nc	0	1	0	2.2
7	Jute Bay	6	21	16	nc	13	16	0	12.0
8	Portage Bay	13	22	16	nc	24	13	0	14.6
9	Wide Bay N	45	76	70	nc	82	19	59	58.5
10	Wide Bay S	117	137	141	nc	229	148	163	155.8
11	Agripina Bay	nc	15	34	nc	44	34	32	31.8
12	Aiugnak Columns	124	133	132	nc	121	153	95	126.3
13	Ugaiushak Island	105	83	48	nc	86	72	77	78.5
14	Toee Reef	10	18	5	nc	17	8	9	11.1
15	Isl SE Yantari Bay	9	4	nc	nc	10	7	1	6.2
16	Hydra Island	nc	15	nc	nc	27	33	28	25.8
17	Amber Bay	nc	60	nc	nc	46	33	36	43.8
18	Eagle Island	nc	55	nc	nc	nc	17	40	37.3
19	Aghiyuk Island NE	nc	0	nc	25	45	38	16	25.8
20	Anowik Island	0	29	nc	8	13	44	39	22.1

Table 2. Continued.

Site #	Location	8/24	8/25	8/26	8/27	8/28	8/29	8/30	Mean
21	Chirikof E Nagai	31	42	nc	nc	61	47	59	48.0
22	Chirikof E	43	26	76	nc	63	57	33	49.7
23	Chirikof SE	56	58	80	nc	76	71	37	63.0
24	Chirikof S	3	0	nc	nc	0	3	0	1.2
25	Chirikof S house	nc	0	nc	nc	8	1	7	4.0
26	Chirikof N house	22	42	nc	nc	48	77	54	48.6

Table 3. Harbor seal counts by the NMFS along the south Alaska Peninsula, Semidis, and Chirikof Island trend count route, August 26-September 1, 1992 (from Loughlin 1993).

Site #	Location	8/26	8/27	8/28	8/29	8/30	8/31	9/01	Mean
1	Katmai Bay E	124	nc	63	59	nc	nc	nc	82.0
2	Kashvik Bay	2	nc	3	34	nc	nc	nc	13.0
3	Alinchak Bay N	nc	nc	11	14	nc	nc	nc	12.5
4	Alinchak Bay S	26	nc	0	0	nc	nc	nc	8.7
5	Puale Bay Rocks	5	nc	3	0	nc	nc	nc	2.7
6	Cape Aklek	11	nc	0	0	nc	nc	nc	3.6
7	Jute Bay	--	--	--	--	--	--	--	--
8	Portage Bay	23	nc	23	31	nc	nc	nc	25.7
9	Wide Bay N	64	nc	0	10	nc	nc	nc	24.7
10	Wide Bay S	107	nc	70	85	nc	nc	80	85.5
11	Agripina Bay	69	nc	nc	nc	nc	nc	0	34.5
12	Aiugnak Columns	54	nc	nc	nc	nc	nc	56	55.0
13	Ugaiushak Island	100	nc	nc	nc	nc	nc	85	92.5
14	Toee Reef	8	nc	nc	nc	nc	nc	0	4.0
15	Isl SE Yantari Bay	11	nc	nc	nc	nc	nc	55	33.0
16	Hydra Island	69	nc	nc	nc	nc	nc	0	34.5
17	Amber Bay	10	nc	nc	nc	nc	nc	0	5.0
18	Eagle Island	5	nc	nc	nc	nc	nc	13	9.0
19	Aghiyuk Island NE	75	nc	nc[1]	nc	44	66	58	60.8
20	Anowik Island	45	nc	27	nc	57	74	63	53.2

Table 3. Continued.

Site #	Location	8/26	8/27	8/28	8/29	8/30	8/31	9/01	Mean
21	Chirikof E Nagai	45	nc	31	54	49	43	62	47.3
22	Chirikof E	40	nc	25	90	60	116	98	71.5
23	Chirikof SE	80	nc	32	30	27	75	72	52.7
24	Chirikof S	--	--	--	--	--	--	--	--
25	Chirikof S house	25	nc	10	10	3	10	20	13.0
26	Chirikof N house	111	nc	23	23	14	98	111	63.3

[1] not included because only 1 of 2 sites counted on this day

Table 4. Comparison of harbor seal counts along the south Alaska Peninsula, Semidis, and Chirikof Island trend count route, August 24-30 1995 and August 26-September 1, 1992.

		ADF&G-1995		NMFS-1992		
Site #	Location	mean #	counts	mean #	counts	Comment
1	Katmai Bay E	15.2	6	82.0	3	NMFS #65, 62-64?
2	Kashvik Bay	29.5	6	13.0	3	NMFS #60-61
3	Alinchak Bay N	31.3	6	12.5	2	NMFS #59
4	Alinchak Bay S	99.3	6	8.7	3	NMFS #58
5	Puale Bay Rocks	24.8	6	2.7	3	NMFS #56, 57?
6	Cape Aklek	2.2	5	3.6	3	NMFS #55
7	Jute Bay	12.0	6	--	--	no NMFS #
8	Portage Bay	14.6	6	25.7	3	NMFS #53-54
9	Wide Bay N	58.5	6	24.7	3	NMFS #51-52
10	Wide Bay S	155.8	6	85.5	4	NMFS #50, 49?
11	Agripina Bay	31.8	5	34.5	2	NMFS #48
12	Aiugnak Columns	126.3	6	55.0	2	NMFS #46-47, 45?
13	Ugaiushak Island	78.5	6	92.5	2	NMFS #44
14	Toee Reef	11.1	6	4.0	2	NMFS #43
15	Isl SE Yantari Bay	6.2	5	33.0	2	NMFS #40, 41?
16	Hydra Island	25.8	4	34.5	2	NMFS #42
17	Amber Bay	43.8	4	5.0	2	NMFS #39
18	Eagle Island	37.3	3	9.0	2	NMFS #38

Table 4. Continued.

Site #	Location	ADF&G-1995 mean #	counts	NMFS-1992 mean #	counts	Comment
19	Aghiyuk Island NE	25.8	5	60.8	4	NMFS #159, 160?
20	Anowik Island	22.1	6	53.2	5	NMFS #161
21	Chirikof E Nagai	48.0	5	47.3	6	NMFS #165
22	Chirikof E	49.7	6	71.5	6	NMFS #162
23	Chirikof SE	63.0	6	52.7	6	NMFS #163
24	Chirikof S	1.2	5	--	--	no NMFS #
25	Chirikof S house	4.0	4	13.0	6	NMFS #166
26	Chirikof N house	48.6	5	63.3	6	NMFS #164

CHAPTER TWO

OBJECTIVE 2

Describe the distribution and use of harbor seal haulouts in Southeast Alaska and the Kodiak Archipelago during the pupping and molting periods, including temporal and spatial patterns of haulout use.

OBJECTIVE 3

Describe the areas and depths used for feeding by harbor seals in Southeast Alaska and the Kodiak Archipelago

MOVEMENTS, HAULOUT, AND DIVING BEHAVIOR OF HARBOR SEALS IN SOUTHEAST ALASKA AND KODIAK ISLAND

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INTRODUCTION

The harbor seal population in Alaska has declined throughout much of its range (Sease 1992, Loughlin 1993, Alaska Department of Fish and Game 1995). The greatest decline in harbor seal numbers has been observed in southcentral Alaska, from Prince William Sound through the Kodiak Archipelago. Populations at Tugidak Island and in the Kodiak Archipelago have declined by 90% since the mid-1970s (Pitcher and Calkins 1979, Pitcher 1990, Loughlin 1992). In Prince William Sound, harbor seal numbers have decreased by 57% between 1984 and 1993, and only part of this decline is attributable to the Exxon Valdez oil spill in 1989 (Frost and Lowry 1994). Meanwhile populations in Southeast Alaska appear stable since 1983 and may be increasing (Pitcher 1989, ADF&G 1995).

Harbor seals, Steller sea lions, and northern fur seals as well as several species of sea birds have all declined in numbers in Alaska since the 1960s. Causes for the declines are not well understood (Pitcher 1990, Swartzman and Hoffman 1991, Springer 1993). Factors possibly involved in the declines include natural population fluctuations, direct and indirect effects from commercial fisheries, subsistence harvest, pollution, disease, predation, and reduced habitat (Sease 1992, Hoover-Miller 1994). One of the principal causes for the recent declines in Steller sea lion abundance is hypothesized to be a decrease in prey availability which could be caused by environmental changes and/or commercial fishing activities (Loughlin and Merrick 1989; Lowry et al. 1989, Merrick 1995).

Recent developments in instrumentation have provided new methods to measure movements and diving behavior of pinnipeds at sea (*e.g.*, Croxall et al. 1985, Kooyman et al. 1986, Stewart et al. 1989, Hindell et al. 1991, Bengston et al. 1993). Foraging theory predicts an animal should optimize its behavior to maximize energy intake under changing environmental conditions (Stephens and Krebs 1986); thus, foraging behavior would be expected to vary in response to changes in prey distribution and abundance. Past research on otariids suggests foraging patterns and activity budgets are likely to change during periods of nutritional stress to meet energy demands (*e.g.*, Ono et al. 1987, Croxall et al.

1988, Trillmich et al. 1991, Boyd et al. 1994). Differences in prey availability and diet were shown to be related to changes in harbor seals' foraging and haulout distribution in Moray Firth in Scotland (Thompson et al. 1995). The similarities between the harbor seal and Steller sea lion declines in Alaska suggest that the harbor seal decline may also be related to nutritional factors, and diving is likely to be a good measure of foraging activity.

Few data on the diving behavior of harbor seals are available. Much of the previous research focused on behavioral observations of foraging and habitat use (Hoover-Miller 1983, Harvey 1988, Thompson and Miller 1990). Studies in Scotland and Nova Scotia have used time-depth recorders (TDRs) and VHF telemetry to study the aquatic behavior of harbor seal males during the mating season (Coltman et al. 1995, Van Parijs et al. 1995), the characteristics of harbor seal foraging trips (Mackay et al. 1995), and the development of diving in juvenile harbor seals (Corpe et al. 1995). Stewart et al. (1989) investigated at-sea behavior and movements of a single harbor seal in California using satellite telemetry. Using more sophisticated satellite-linked depth recorders (SDRs), the movements and diving behavior of harbor seals in Prince William Sound have been investigated since 1993 (Frost and Lowry 1994, Frost et al. 1995, Frost et al. 1996). Studies on the foraging behavior of harbor seals in Southeast Alaska, where by contrast the population is stable or increasing, have not been undertaken with the exception of a study which used VHF transmitters to describe haulout behavior (Withrow and Loughlin 1994). There have been no studies investigating the diving behavior of harbor seals elsewhere in Alaska. Differences in the prey available to the stable and decreasing populations of harbor seals could lead to different foraging strategies and prey utilization, which could influence the divergent population dynamics of the different populations.

The goal of this study was to enhance our understanding of the foraging ecology of harbor seals and, in particular, to investigate the foraging behavior of harbor seals in Southeast Alaska (SE) and Kodiak Island (KO). The study examined the movements and diving behavior of harbor seals by using SDRs to collect information on at-sea behavior. The main objectives of the study were to (1) describe the movements and diving behavior, (2) investigate behavioral indices of foraging effort, and (3) attempt a preliminary determination of whether differences in movements and diving behavior (and thus, presumably foraging behavior) could indicate differences in prey availability for the two populations.

METHODS

Seal Capture

Harbor seals were captured at locations throughout SE and KO during April and September/October 1993 and September/October 1994. They were captured by entanglement in a multifilament nylon net deployed near their haulout sites. The net was 240 m long and 8 m deep with a 28 cm stretch mesh, a float-core line and a lead line. The net was set from a 7 m boat by a swimmer who carried one end of the net into the water and to shore while the boat continued to encircle the haulout. A second 6 m boat approached the haulout to ensure the seals stayed within the deployed net. The seals became entangled in the net as they attempted to swim away from the presence of boats and people. Once the net was deployed, both boats tended it. When the seals became entangled in the capture net, they were removed, brought into the boats, and placed into temporary holding nets ("hoop nets"). Seals were handled and processed either on a nearby beach or on the support vessel.

Seals were immobilized using a mixture of ketamine and diazepam administered intramuscularly at dosages of 5.5 mg/kg and 0.09 mg/kg, respectively. Each seal was weighed, measured, and tagged with flipper tags. Samples such as blood, skin, and whiskers were collected from each animal to address other research questions.

Instrumentation

SDRs were glued with netting and fast-setting epoxy resin (Fedak et al. 1984) to the fur of the mid-dorsal region of the harbor seal. The 0.5 watt ST-6 transmitters, packaged as Type III SDRs (Wildlife Computers), measured 14.8 cm x 10 cm x 3.8 cm and weighed approximately 750 g. In September/October 1994, a smaller version of the 0.5 watt SDR which measured 11.9 cm x 5.1 cm x 4.5 cm and weighed 385 g was used on two of the seals. These smaller transmitters used 2/3A batteries in place of C-cell batteries, which greatly reduced the size of the SDR. The epoxy attachments and SDRs were shed when the seals molted, which generally occurred in June or July. The SDRs were equipped with pressure sensors to determine depths of dives. Salinity (conductivity) sensors were used to determine whether the SDR was immersed in water or dry (i.e., whether the harbor seal was hauled out on land or at sea). Pressure transducers were capable of measuring depths from 0-500 m with 2 m resolution. The pressure sensor was sampled at 10 second intervals, and these data were summarized into histogram bins prior to transmission. Programmable micro-processors collected and summarized data on maximum dive depths and durations and stored them for later transmissions.

The SDRs merged generalized time-depth recorder (TDR) capabilities with the data-relaying capabilities of the Service ARGOS data collection and location system (Fancy et al. 1988, Keating et al. 1991). The SDRs transmitted information to two polar-orbiting satellites administered by the National Oceanic and Atmospheric Administration (NOAA). Information could be received only when the harbor seal was hauled out on land or at the ocean surface and when the satellite was in direct line of sight of the transmitter. For analysis and presentation of the data, Greenwich dates and times, as reported by ARGOS, were converted to local solar time by subtracting 9-11 hours to account for the actual position of the sun.

The Type III SDRs stored, summarized, and transmitted dive data as histograms. A histogram is a set of "bins", each of which contains counts for a given range of dive depths or dive duration. The daily counts were accumulated into four 6-hr "histogram periods", (2100-0300, 0300-0900, 0900-1500, 1500-2100 local sun time). Dive depths and durations were summarized separately for the same four periods and stored in a "transmit buffer" that contained the previous four histogram periods (24 hours). Each histogram contained six separate bins which were set prior to deployment. The minimal depth for a dive was set as 4 m. Dive-depth and dive-duration bins differed among transmitters. The dive-depth bins for most of the SDRs were 4-20 m, 20-50 m, 50-100 m, 100-150 m, 150-200 m and > 200 m. Dive-duration bins were 0-2 min, 2-4 min, 4-6 min, 6-8 min, 8-10 min, and > 10 min. Four of the 1994 SDRs (5047, 5049, 5050, and 5051) summarized data in only five depth bins (4-20 m, 20-50 m, 50-100 m, 100-150 m, and 150-200 m) and in only five duration bins (0-2 min, 2-4 min, 4-6 min, 6-8 min, and 8-10 min). In addition, a maximum depth field gave the precise maximum dive depth recorded for each 24 hour period. Some of the SDRs we deployed were equipped with software that collected and reported the amount of time that the seal spent at the surface in the two previous six hour periods. The maximum depth for accumulating "at surface" time was set between 0-4 m, depending on the transmitter.

Data Analyses

Records from all 27 instruments were used in our analysis. Bin data on dive depth and duration were summarized into standard bins. Harbor seals from each area (SE and KO) were grouped into three categories for many of the analyses: adult females, adult males, and subadults (juveniles).

Movements

The ARGOS system recorded the date and time of each satellite uplink and calculated a location for the SDR whenever sufficient signals were received during a satellite overpass. The accuracy of locations calculations varied based in part on the number of uplinks that occurred during a satellite overpass. When only one uplink occurred, sensor data were recorded but no location was determined.

Service ARGOS assigned a quality ranking to each calculated location. Prior to June 1994, locations resulting from standard data processing were ranked as either 1, 2, or 3, with quality 3 providing the highest degree of accuracy. Special data processing provided locations from satellite passes with few uplinks or other potential problems. These locations were assigned a quality of 0 and given a location indicator value of 0 to -10.

Records that failed validation tests performed by Service ARGOS (i.e. given location indicators of -6 to -10) were deleted from the database. An error index was then calculated for each remaining location according to the equation described by Keating (1994). This index value accounts for the distances and directions between sequential locations and was used to identify erroneous locations based on the assumption that records indicating a single, large movement followed immediately by a return to a point near the origin are likely to be in error. All location records that had an error index of greater than 25 were removed from the database.

Other inaccurate locations were identified by accounting for possible movement speeds of seals following the methods developed by Frost et al. (1996). Time, distance, and speed between each sequential pair of locations were calculated for all location records remaining in the database. A three-stage process was used to mark records that produced improbable movements. These were based on the following speeds: 1) calculated speeds of more than 10km/hr for a period of more than 5 minutes, 2) calculated speeds of more than 100km/hr for a period of more than 1 minutes, and 3) calculated speeds of more than 500km/hr for any length of time. Flagged records were inspected visually, and the locations that were most distant from adjacent records were removed from the database. Finally, an error index was recalculated for each remaining record and any records with an error index of greater than 25 were deleted. Locations described in this report include only those remaining records.

Haulout Behavior

The SDRs reported with each transmission whether the seal was dry (hauled-out on land) or wet (at-sea) based on the status of the conductivity sensors. The length of time a seal spent at sea or on land was then estimated from these transmissions. A datafile was created that indicated when haulouts began and ended, as in Frost et al. (1995, 1996). A seal was considered to be hauled-out between the first and last on-land transmissions and at sea between the first and last at-sea transmissions. The time between the last on-land and first at-sea and between the last at-sea and first on-land transmissions were classified as "activity undetermined." These data summarized by month the number of hours that each seal was determined to be at sea, on land, or for which haulout status could not be assessed. The proportion of time hauled-out by month was calculated for each animal by dividing the total time spent hauled-out by the total time spent hauled-out and at-sea combined for each month. Time for which haulout status could not be determined was excluded from this calculation. For each animal, only those months for which at least 15 days of data were obtained were used in the data analysis.

Time "at surface" will be analyzed in the future and will provide a measure of how much time harbor seals spent on land and at or near the surface of the water.

Diving Behavior

The total number of dives in each depth and duration bin were summed for each 6-hr histogram period prior to transmission to the satellite. For each period, mean dive depths and durations were determined based on the number of dives in each of the six duration or depth categories (bins) multiplied by the average duration or depth of that category approximated from an exponential curve fit to the data combined across classification variables; mean depths and durations for each category were calculated separately for each location. Dive frequencies were calculated directly from the duration histograms by summing the number of dives for each 6-hr period. Mean dive frequencies were determined for each sex and age class and for each location.

Statistical Techniques

For haulout behavior, t-tests were used to determine if the proportion of time spent hauled out varied by sex, age class, and geographic area. Analysis of variance was used to determine if there were monthly variations in the proportion of time hauled out.

Four variables were analyzed to compare diving behavior between locations (SE and KO) and among age and sex classes (adult females, adult males, juveniles), months, and time of day (2100-0300, 0300-0900, 0900-1500, 1500-2100). These variables were number of dives (in a 6 hr period), average dive duration, average dive depth, and dive diversity. Because not all age/sex classes had data for all months, especially atKO, several analyses were used to investigate comparisons of interest using as much of the data as possible while balancing the need for comparable data. Dive diversity was calculated using Shannon's diversity index (Odum 1971:144); this was used to assess how evenly the dive effort was distributed across the six dive bins. All of these measures were compared among the factors (location, age/sex, month, and time period) using analysis of variance procedures appropriate for unbalanced data (SAS type III and IV; Milliken and Johnson 1984). Individual animals, nested within locations and age/sex classes and the individual by time-period interaction (within location and age/sex class) were included as random effects in the analyses. Satterthwaite's approximation (Milliken and Johnson 1984) was used to adjust hypothesis tests for the unbalanced data. Observations (i.e., histograms) with no dives were deleted for analysis of duration, depth, and diversity.

RESULTS

A total of 27 harbor seals were captured for SDR deployment in 1993 and 1994; 14 adults and 3 subadults in SE and 8 adults and 2 subadults in KO. Harbor seals were captured in a several locations in Southeast Alaska and the Kodiak Island area (Table 1). The five SDRs on SE harbor seals and the four SDRs on KO harbor seals studied during April-August 1993 yielded data during average deployments of 120.0 and 78.3 days, respectively. The six SDRs that were attached in SE during fall 1993 transmitted data for an average of 153.7 days; the six SDRs attached in SE and the five SDRs attached in KO in fall 1994 recorded data for an average of 234.3 days and 216.2 days, respectively. Overall, the period of time over which data were received ranged from 18-305 days (Table 1).

Movements

Movements of tagged harbor seals were highly variable (Table 1A, Appendix I). ARCVIEW (Environmental Systems Research Institute, Inc.) representations of locations received from these seals are also found in Appendix I.

Southeast Alaska

In SE, nine seals remained within 30-50 km of where they were tagged (Seals 93SE9, 93SE10, 93SE15, 93SE18, 93SE20, 94SE2, 94SE3, 94SE7, 94SE9) (Figures 4A, 7A, 8A, 9A, 10A, 13A, 14A, 15A, 17A, Appendix I). Seven of these were adult males, one was an adult female and one was a subadult male.

Three other seals (93SE2, 93SE7, and 94SE8 made one or more long trips ranging from a week to a month to other bays 30 km to 150 km away (Figures 1A, 5A, 16A) In each case, the seal returned to the tagging site at a later date. Two of these seals were adult females and the third was an adult male.

Three seals (93SE3 and 93SE4, 93SE19) moved to the glacial fjords in Tracy Arm or LeConte Bay and to the Stikine River (Figures 2A, 3A, 11A). An adult male (93SE3) made frequent trips from Frederick Sound to Tracy Arm. These trips lasted 3 to 5 days with the seal returning to Frederick Sound after each trip. These trips occurred in late May through early July which coincides with the breeding period for harbor seals. Another subadult male seal (93SE4), tagged at the Brothers Island in Frederick Sound, made one trip to LeConte Glacier. This trip started on approximately June 22 and the first location at the glacier was received on July 1. Locations were received from this seal at the glacier until July 11 when it returned to its capture site by July 14. A subadult female seal (93SE19) remained near Gambier Bay where it was tagged from September 18 through March 11, when it moved first to the Stikine River mouth and then to the LeConte Glacier. This seal remained in the area from March 13 through April 27 when the last transmission was received. During this period, outmigrating salmon smolt (*Onchorhynchus* spp.) and a large congregation of spawning eulachon (*Thaleicthys pacificus*) are known to be present in the Stikine River.

Finally, one adult male seal (93SE16) and one adult female seal (94SE5) traveled extensively in a northeast direction from their place of tagging at Gambier Bay to the mainland bays of Endicott Arm, Tracy Arm, Stephens Passage, the Taku River, Lynn Canal, and Berners Bay (Figures 6A, 12A). Both of these seals made frequent trips between these sites and Gambier Bay and appeared to be exploiting a wide variety of habitats throughout the year. In both cases, these seals were at or very near their original place of tagging when the last transmissions were received.

Kodiak

Seals near KO were tagged in two general locations. Five seals were tagged at Sitkinak Island at the southern end of Kodiak Island and five seals were tagged in either Ugak or Kiliuda Bays on the eastern side of Kodiak Island. Seals in the Kodiak Island area either remained in the vicinity of tagging or moved to a new haulout after tagging.

Seals 93KO1, 93KO2, 93KO3 were all tagged at Sitkinak Island in the spring of 1993 and remained there until the SDRs stopped transmitting (Figures 18A, 19A, 20A). Based on observations and body measurements, all three of these adult female seals were believed to be pregnant at their time of capture. Subsequent dive data analysis indicated perinatal periods. Three adult male seals (94KO1, 94KO2, 94KO8) were captured in October 1994 in either Ugak Bay or Kiliuda Bay on the eastern side of Kodiak Island (Figures 24A,25A,27A). Each of these seals remained at the heads of the bay in which they were tagged and made only infrequent trips to the mouth of the bay. There were no long distance movements.

A subadult female seal (94KO4) was tagged in October 1994 in Ugak Bay (Figure 23A). Location plots indicate a single long distance movement south to the Geese Islands. This movement began two days after tagging and the entire 250 km roundtrip lasted eight days. It returned to Ugak Bay and remained there until the last transmission was received on January 1995.

Three other seals (93KO4, 93KO5, 94KO9) moved to new haulouts after capture and did not return (Figures 21A, 22A, 26A) . Seal 94KO9 (tagged in October 1994) moved from Kiliuda Bay to Ugak Island within three days of tagging. This subadult female made two short trips to Kiliuda Bay and northern Sitkalidak Island but otherwise remained near Ugak Island. Ugak Island is a known seal haulout where many seals are usually present.

Two adult female seals (93KO4, 93KO5) moved from their capture location on Sitkinak Island to other nearby seal haulouts at either Tugidak Island (40km away), Cape Alitak (60 km away) (93KO5), or Aiaktalik Island (25 km away) (93KO4). Seal 93KO4 also made one long distance roundtrip of 13 days to Ugak Island (130 km away) (Figures 21A, 22A,26A).

Haulout Behavior

Overall, satellite-tagged harbor seals spent 18% of the time hauled-out (Table 2). There was a tendency for males to spend more time hauled out (20.3%) than females (14.8%), however, the difference was not significant ($t=-1.667$, $p=0.0977$). Adults (18.2%) and subadults (17.8%) spent similar amounts of time hauled-out ($t=0.084$, $p=0.933$). Harbor seals from SE (17.9%) and KO (18.4%) spent a comparable proportion of time hauled-out ($t=0.135$, $p=0.893$). The proportion of time hauled-out varied by month (F=3.5728, p=0.0002). Proportion of time spent hauled-out peaked during summer and reached lowest levels during mid-winter (Figure 1).

Diving Behavior

Depth histograms summarized data from 378,094 dives made by seals in SE and 124,842 dives made by seals in KO from April 1993 to July 1995 (Table 3). For all 17 seals in SE, 43% of the total number of dives were less than 20 m, 56% were to depths less than 50 m, and only 2% of all dives exceeded 150 m. For the 10 seals in KO, 26% of the total dives were less than 20 m, 57% were to depths less than 50 m, and less than 1% were greater than 150 m (Figure 2).

In SE during September - July, mean dive depths for all dives greater than 4 m for seals was 42.9 m (sd=24.8) for adult females, 47.4 m (sd=32.5) for adult males, and 40.2 m (22.0) for subadults. InKO from October to January, mean dive depths for adult females, adult males, and subadults were 26.7 m (sd=14.5), 46.7 m (sd=24.0), and 56.3 m (sd=23.3). The analysis for mean dive depths for KO seals was restricted to these months to allow comparison between the age and sex classes. There were no significant differences in dive depths between the different age and sex classes for either area (p>0.42 and p>0.25), although significant interactions (p<0.0001) between age/sex class and month indicated mean dive depths varied among classes according to month (see below). Considerable variability existed among individual seals.

The maximum depths of dives were summarized for each seal (Table 4). The deepest recorded dive was 508 m for two adult males in SE (seals 93SE9 and 93SE15). These dives were made on 14 May in Frederick Sound (93SE9) and on 28 January in Endicott Arm (93SE15). Seal 93SE9 was monitored during the spring and summer and dove consistently to maximum depths close to 500 m on a daily basis from the beginning of April to the end of June. During July, the last month in which data were recorded, maximum dive depths varied from 172 m to 496 m, particularly during the first half of the month. Maximum daily dive depths for seal 93SE15 were deeper and varied more during the winter than in the spring and fall. A subadult male in SE dove as deeply as the adult seals (504 m), and one fourth of its maximum depth dives exceeded 400 m. Maximum dive depths for the two other subadults in SE were 416 m and 420 m. The average maximum daily dive depth for all seals in SE ranged from.146 m to 362 m.

InKO, maximum dive depths were shallower and ranged from 108 m to 320 m (Table 4). The shallower depths were most likely due to differences in bathymetry between SE and KO. Bathymetric differences were also indicated by the maximum dive depths of the five females studied at Sitkinak (mean 168 m) compared to the five seals studied in other parts of the Kodiak Island area (mean 271 m). During periods of two to three weeks in June, the three Sitkinak adult females dove only to very shallow depths: maximum depths for seal 93KO1 did not exceed 12 m during June 1-26; maximum depths for seal 93KO2 did not exceed 28 m during June 1-15; and maximum depths for seal 93KO3 did not exceed 12 m during June 3-26. Maximum daily dive depths for all seals inKO waters ranged from 47 m for an adult female in spring and summer to 193 m for an adult female in fall and winter.

Clear seasonal patterns in dive depths were evident in both areas (Figures 3 and 4). During January and February, 58% of the dives of all seals in SE were to depths greater than 50 m compared to 4-8% during June and July. After July, the proportion of deeper dives increased again steadily and was 51% in November and 58% in December. The percentage of shallow dives (4-20 m) gradually increased from 27% in January to a peak of 76% in July and then gradually declined again to 35% in November and 27% in December. Seals in KO showed a similar seasonal pattern, although gradual seasonal increases and decreases in dive depths were less apparent. The proportion of shallow dives (4-20 m) declined from 32% in October to 20% in December and from 27% in January to 9% in March, then increased from 19% in April to 51% in June before decreasing to 20% in July. In July, however, there was a marked increase in the percentage of dives between 20-50 m; 72% of all dives were 20-50 m compared to 14-29% during January to April, 47-48% during May and June, and 22-31% during October to December. Dives were also deeper during the winter and fall. During January to April and October to December, 44-67% of all dives exceeded 50 m compared to 1-8% during May to July. As with dive depths, there was considerable variability among seals (Figure 5), although distinct seasonal patterns were evident for most seals.

Average dive depth had complex associations ($p<0.05$) with the explanatory variables. In SE during September to July, dive depth varied strongly with age/sex class, month, and time-of-day (Figure 6a). The only evident patterns were of deeper dives by adults in the winter compared to other times of the year (Figures 6b, 6c) and of shallower dives by adult females during May to July (Figure 6b), which corresponded to their increased dive frequency during the summer (Figure 6d). All of the age/sex classes appear to have the most shallow average dives in July (Figures 6b, 6c, 6d). InKO from October to January, adult females tend to dive to shallower depths than adult males or juveniles (Figure 7). Comparisons of adult males and juveniles during October to May between the two areas indicate that juveniles in KO dive deeper than those in SE, especially during mid-day (0900-1500) (Figure 8). The reverse is true for adult males; adult males in SE dove deeper in winter than adult males in KO. Average dive depths were comparable in both areas during the fall and spring (Figure 9).

Duration histogram data were collected on 347,279 dives in SE and 158,078 dives in KO. The number of dives containing duration and depth information differed because of the difference in the number of depth and duration histograms successfully transmitted to the satellite. Mean dive duration for all dives by seals in SE was 3.8 min (sd = 2.08) for adult females, 3.5 min (sd=1.97) for adult males, and 2.7 min (sd=1.15) for subadults. For seals in KO waters during October through January, mean dive durations were 2.8 min (sd=1.19) for adult females, 3.2 min (sd=1.34) for adult males, and 3.1 (sd=1.09) for subadults. Most dives were short: 40% were less than 2 min and 30% were 2-4 min in SE, and 31% were less than 2 min and 38% were 2-4 min in KO

(Figure 10). The SDR software did not record maximum dive duration, so maximum dive duration was considered equal to that of the longest bin which contained dives. The maximum dive duration for all seals was greater than 10 min

As with dive depths, there were no significant differences in dive durations between the different age and sex classes for SE and KO ($p>0.59$ and $p>0.87$), although significant interactions ($p<0.0001$) between age/sex class and month indicated that mean dive durations differed between age and sex classes depending on the month. Significant ($p<0.0004$) variability existed among individual seals. Durations appeared shorter than other seals for subadults in SE and adult females in KO. Comparisons between KO and SE indicate that juveniles in KO have longer average dive durations than those in SE, especially during February through April. In contrast, adult males in SE seem to have longer dives than male seals from KO, especially during the winter.

Dive duration corresponded with dive depth in the distribution of the proportion of dives in the various depth and duration bins. Generally, harbor seals with a high proportion of shallow dives had a high proportion of short dives. Most dives were 0-2 min for all harbor seals in SE except for four seals during September to April: for two adult males (93SE15 and 93SE16) and one subadult male (93SE20) 62-75% of their dives were between 2-6 min; for one adult female (94SE2) 54% of the dives were 4-8 min. In KO, the majority of dives (32-54%) tended to be 2-4 min except for an adult male during October to April with 50% of his dives between 2-4 min and a subadult female monitored at the same time with 54% of her dives between 4-6 min. As with dive depths, dive durations changed during the seasons. Dives tended to be shorter in the summer and longer in the winter, especially for adult females that had much shorter dives in May through July. Adult males had a similar pattern but with smaller changes during the year. Juvenile dive duration was more consistent than that of adults both throughout the year and for various times of day.

The mean number of dives per 6-hr period were summarized by sex and age class and by area (Table 5). Mean dive frequencies ranged from 36.1 to 46.3 dives per 6-hr period for seals in SE compared to 51.1 to 86.5 dives per 6-hr period in KO. In KO, data from only October to January were available for all age and sex classes. Although not significant ($p>0.4$ and $p>0.2$) in overall comparisons, subadults in both areas had the highest dive frequencies. Significant diurnal patterns in dive frequency were not evident (Figure 11), however, seals in SE tended to dive more at night (2100-0300) and during the late afternoon and early evening (1500-2100). Sixty-three percent of their dives occurred during these periods.

The average number of dives in a 6hr period was related ($p<0.05$), in complex ways, to location, age/sex class, month, time-of-day and their interactions. Also, within these complex patterns there were substantial individual differences ($p<0.001$). In SE the principal patterns were the increase in dive frequency by adult females in May and June (Figures 12a, 12b) and a smaller increase by adult males in June and July (Figures 12a, 12c). Juveniles had a higher dive frequency than adults during the winter, although this was seen only for time-of-day periods 0 and 3 (Figures 12a, 12d). In KO, the principal pattern was the higher dive frequency of juveniles (Figure 13). In an analysis that included both areas, only adult males and juveniles could be included with data from October to May. In general, juveniles at both locations dove more frequently than adult males (58 vs 39 dives/6-hr period) (p=0.06). Although the magnitude of differences varied among months and time-of-day periods, seals of both these age/sex classes dove more frequently at KO than in SE (p<0.004) (Figures 14 and 15).

Dive diversity (a measure of how evenly the dive data were distributed across the six dive bins) also had complex associations with the explanatory variables (location, age/sex class, month, and time of day), and there were significant interactions among these variables (p<0.05). There were substantial individual differences (p<0.0001) which may have masked any differences between age and sex class and location. In SE, adult males showed seasonal fluctuations in dive diversity (Figure 16a) with a higher dive diversity in winter and spring (April - May). The higher dive diversity in winter corresponded to greater dive depths observed during this time. Juvenile dive diversity seemed to increase from September through June (Figure 16b). Dive diversity was more consistent for adult females, although diversity may have been less in summer (Figures 16c, 16b). Both adult males and adult females had a lower dive diversity during the day (0900 - 1500) except during the summer months. Juveniles had less variation in dive diversity throughout the day than other age/sex classes (Figure 16b).

In KO during October to January, adult males appeared to have had a higher dive diversity than adult females or subadults. Adults males had a higher dive diversity than juveniles in fall and winter (Figure 17). There were some indications that seals in SE had a higher dive diversity than seals in KO.

DISCUSSION

Movements, diving, and time spent at sea varied widely among individuals. Seasonal and diurnal variations in diving patterns suggest the frequency, depth and duration of individual dives could be influenced by the rate of prey encounter, as has been documented for a variety of otariid species (e.g., Feldkamp et al. 1988, Boyd et al. 1994). Considerable variation in foraging behavior between individuals also suggests that individuals can adjust their foraging strategies to differences in habitat and prey availability. Interpretation of results is confounded by small and unequal sample sizes and because not all age and sex classes are represented in all months. For example, data on subadult seals is restricted to three seals in SE and two in KO. The conclusions that can be drawn are limited, and results presented in this report should be considered preliminary.

Movements

Seals carrying SDRs in SE and KO have either remained in the immediate vicinity of their capture location or have made roundtrips of up to 300 km. Some seals have made frequent long trips from what appears to be their central place of "residency" only to return, while others have made only one or two short trips to other areas for only very short periods. It is also possible that some of these short trips are for some other biologically important event such as birthing or weaning a pup, or breeding. No tagged seal has undertaken a long distance, one way movement that could be considered emigration.

It appears as though harbor seals in both SE and KO have a diverse strategy for exploiting various habitats. Individual movements within each area were highly variable and the small sex and age class sample sizes currently available preclude meaningful comparisons. SDRs small enough to deploy on young of the year seals were not available until 1995. We currently have results from an additional 21 SDRs deployed in SE and KO and will incorporate data from those seals into our database and future analyses.

Another potential use for this type of location data is to integrate dive and location data to describe the diving behavior on a much finer scale. We will continue to examine location and dive data to determine when seals of various sex and age classes are exploiting particular habitats. By looking at seasonal changes in movements and associated dive behavior, we hope to determine which habitats, and by inference what food resources, are seasonally important to harbor seals.

Haulout Behavior

While we found no differences in the proportion of time hauled-out between sexes, age classes, or areas, larger sample sizes and more complete seasonal coverage would allow a more detailed analysis, and it is possible that such differences could be found. Findings of seasonal variation in time spent hauled-out, with peak haulout during summer months, was expected, as this time period corresponds with pupping, pup rearing, breeding, and molting which are all activities centered around haulout sites.

Results should be interpreted with caution because of the limitations of the 'land/sea' sensor data. Information on whether a harbor seal is on land or at sea at a particular time is limited to the times of the satellite overpasses. The information is also biased by incomplete satellite coverage and the greater probability of signal reception when the harbor seal is on land. It is possible for an animal to go out to sea, for no signals to reach the satellite, and for the animal to return to land without any record of the at-sea time in the 'land/sea' sensor data. Time at sea would be underestimated. Interpretation of data is further biased by the SDR programming which suspends transmissions after six hours "hauled-out". A haulout ends after the SDR is "wet" for four consecutive at-sea transmissions. Therefore, the amount of time a seal spends on land after a six hour haulout was not recorded, and time hauled-out would be underestimated.

Because of these limitations in the data collection, different approaches for estimating the proportion of time at sea and on land will be explored in the future. Alternative estimates could use dive histogram or 'time-at-depth' data that are not subject to these biases because the data are not dependent on actual transmission times.

Diving Behavior

The diving behavior of harbor seals is characterized by relatively short and shallow dives. The majority of dives were less than 4 min and less than 50 m in depth. Harbor seals rarely dove deeper than 150 m with 2% or less of all dives being to greater depths. The distribution of dives among different depth categories varied considerably by seal and by area. Seals in SE tended to show a bimodal pattern with most of the dives either less than 20 m or greater than 50 m. In KO, the highest proportion (35%) of dives ranged between 50-100 m. Differences in the proportion of dives to different depths by seals from SE and KO may simply reflect differences in bathymetry. The shallower depths shown by adult females in May and June is most likely related to the pupping period, whereas the shallower dives of the adult female in KO during the winter reflects habitat differences.

The maximum depth data seemed to indicate harbor seals are diving to the bottom at least some of the time. Seals in SE dove deeper reflecting the deeper bathymetry of the area; depths of 500 m are generally not available to the seals in KO. The maximum dive depth recorded for any seal was 508 m, which actually exceeded the depth range of the transmitter, so in fact the seals may have been diving even deeper. This was deeper than the maximum dive depths of 404 m recorded for seals in Prince William Sound (Frost and Lowry 1994) and 446 m for a harbor seal in southern California (Stewart and Yochem 1994). In general, the deepest dives occurred during the winter. The smaller body size of the subadults did not appear to affect their diving abilities, as has been shown for pups two to four months of age (Corpe et al. 1995). Maximum depths as well as the distribution of dives among the different depth and duration increments for subadults were comparable to that of the adults.

Depth data indicated that diving behavior varied by geographic location. Seal 93SE4 dove no deeper than 68-200 m when near the LeConte Glacier during a short period in July, whereas maximum daily dive depths were usually greater than 300 m in Frederick Sound. The maximum daily dive depth for seal 93SE16 was about 250 m when the seal was in Gambier Bay and Seymour Canal (September-November) and rarely exceeded 300 m. When the seal moved to the deeper waters of Tracy Arm for six days in December, maximum dive depths ranged from 480-496 m. Likewise, when the same seal moved to the mouth of the Taku River, maximum depths did not exceed 24-104 m. In general, seals that showed very little movement had consistent daily maximum depths, whereas those that traveled had considerable more variation in their daily maximum dive depths. Future analyses link location data more closely with the dive data.

Maximum depth data also provided indirect evidence about pupping dates and perinatal periods for the three adult females in Kodiak. They appeared to give birth in early June (June 1-3) and to be closely tied to land for 14 to 25 days, as maximum depths almost never exceeded 12 m. This period could be the nursing period which usually lasts three to six weeks (Johnson 1976, Hoover 1983). Since these females appeared to be pregnant when they were tagged in April, it is likely that this was a period when the females were closely attending their pups and when the diving skills of the pups were developing.

Harbor seals in both areas showed strong seasonal patterns in dive depth. The percentage of shallow dives (4-20 m) increased markedly during the late spring and summer while deeper dives (50-100 m) were more common during the fall and winter. Dives among other depth increments showed no seasonal patterns in SE. In KO, dives to 20-50 m increased markedly during the summer while deep dives (>100 m) were virtually absent. The increased proportion of shallower dives in late spring and summer corresponds to a time when fish such as herring (*Clupea harengus*), eulachon (*Thaleicthys pacificus*) and salmon are abundant in the area.

Significant diurnal patterns in dive frequency were not evident for harbor seals, although dives tended to occur more often at night and during the late afternoon and evening, especially in SE. In general, there was a correspondence between dive depths and dive frequency; for example, the increase in dive frequency by adult females in May and June corresponded to an increase in the number of shallow dives. Subadults tended to dive more frequently than adults, although differences in dive depths were not apparent.

Differences in diving behavior between SE and KO may be masked by variability among seals. This may simply reflect different individual foraging strategies and adjustments to local and temporal conditions, as individual diving performance seemed related to location and perhaps to water depth. Subadults in KO dove deeper and more frequently than subadults in SE, although very small sample sizes preclude definite conclusions. Adult males also dove more frequently in KO than in SE. As dive frequency can be considered a potential index of foraging effort, the greater frequency in KO is suggestive of greater foraging effort and hence decreased food availability. Future analyses will investigate other potential indices of foraging effort, such as the actual time spent diving (i.e., time submerged). There are large differences among seals in the total number of dives which also needs to be examined in the future. For example, seals 94SE7 and 94SE2 were monitored for a similar amount of time (Sept to June/July), yet the total number of dives recorded differed greatly (70,708 vs. 18,039). This could indicate a greater foraging effort by seal 94SE7.

The predictive value of foraging behavior in terms of prey distribution and abundance has been well documented for otariids (e.g., Bengston 1988; Costa et al 1991; Trillmich and Ono 1991; Boyd et al. 1994), however, the measures need to be sensitive enough to discriminate large variations between individuals. Harbor seals show a plasticity in behavioral responses which suggests that individuals have a suite of foraging repertoires they can adjust to changing local conditions. Individual strategies may differ but translate to the same net energy intake. Behavioral parameters measured thus far may not be adequately sensitive to discern any differences in prey distribution and abundance. Additional analyses of foraging data will occur in 1996.

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Table 1. Duration of deployments of 27 SDR-tagged harbor seals in Southeast Alaska and Kodiak Island during spring and fall 1993-94.

SDR (Seal No.)	Sex	Age	Mass (kg)	Tagging Location	Dates Operational	Total Days Operational
SOUTHEAST					***1993***	
3086 (93SE2)	F	Adult	53	Gambier Bay	5 April - 21 July	108
3087 (93SE3)	M	Adult	88	Sail Is.	8 April - 25 Aug	140
3088 (93SE4)	M	Subadult	43	The Brothers	9 April - 29 July	112
3089 (93SE9)	M	Adult	98	The Brothers	9 April - 14 Aug	128
3090 (93SE7)	M	Adult	74	The Brothers	9 April - 29 July	112
2085 (93SE16)	M	Adult	62	Price Is.	17 Sept - 11 April	207
2086 (93SE20)	M	Subadult	44	Price Is.	17 Sept - 21 April	217
2087 (93SE18)	M	Adult	67	Price Is.	17 Sept - 5 Oct	19
2089 (93SE10)	M	Adult	93	Price Is.	14 Sept - 1 Oct	18
2090 (93SE15)	M	Adult	61	Price Is.	17 Sept - 11 May	237
2094 (93SE19)	F	Subadult	43	Price Is.	17 Sept - 28 April	224
					1994	
5039 (94SE5)	F	Adult	56	Price Is.	13 Sept - 3 Feb	144
5045 (94SE7)	M	Adult	88	Price Is.	13 Sept - 14 July	305
5047 (94SE2)	F	Adult	75	Price Is.	13 Sept - 7 June [1]	268
5049 (94SE3)	M	Adult	94	Price Is.	13 Sept - 2 May [1]	232
5050 (94SE8)	F	Adult	77	Price Is.	13 Sept - 12 May [1]	242
5051 (94SE9)	M	Adult	82	Price Is.	13 Sept - 15 April [1]	215
KODIAK					***1993***	
5044 (93KO1)	F	Adult	104	Sitkinak	22 April - 25 July	95
5045 (93KO2)	F	Adult	115	Sitkinak	24 April - 20 July	88
5046 (93KO3)	F	Adult	114	Sitkinak	26 April - 12 July	78
5047 (93KO4)	F	Adult	74	Sitkinak	26 April - 16 June	52
5048 (93KO5)	F	Adult	62	Sitkinak	2 Oct - 18 Jan	109
					1994	
5041 (94KO4)	F	Subadult	32	Ugak Bay	6 Oct - 20 Jan	107
5042 (94KO1)	M	Adult	88	Ugak Bay	5 Oct - 21 April	199
5043 (94KO2)	M	Adult	94	Ugak Bay	5 Oct - 9 July [1]	278
5044 (94KO9)	F	Subadult	36	Kiliuda Bay	8 Oct - 23 June	259
5046 (94KO8)	M	Adult ?	48	Kiliuda Bay	8 Oct - 2 June	238

[1] Very few transmissions received during the last month of deployment.

Table 2. Proportion of time spent hauled-out by month for satellite tagged harbor seals in Southeast Alaska and the Kodiak Island area..

SOUTHEAST ALASKA

Seal	Age[a]	Sex	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
93S16	Ad	M	.451	.126	.825							.319	.167	.370
93S20	Sub	M	.089	.044	.080	.169						.075	.086	
93S10	Ad	M									.196			
93S15	Ad	M	.093	.169	.211	.954						.156	.112	.116
93S19	Sub	F	.070	.047	.084	.163						.201	.201	.087
93S2	Ad	F				.096	.161	.119	.135					
93S3	Ad	M				.166	.244	.194	.166	.333				
93S4	Sub	M				.087	.490	.151	.963					
93S9	Ad	M				.170	.217	.165	.062					
93S7	Ad	M				.251	.267	.179	.392					
94S5	Ad	F	.005								.030	.074	.021	.133
94S7	Ad	M	.067	.145	.192	.143	.271	.933			.108	.337	.095	.111
93S2	Ad	F	.043	.038							.086	.056	.053	.043
94S3	Ad	M	.082	.137	.122						.326	.140	.053	.092
94S8	Ad	F	.056	.071	.101						.166	.067	.048	.108
94S9	Ad	M	.094	.107	.095						.303	.175	.095	.073
MEAN			0.105	0.098	0.214	0.244	0.275	0.290	0.344	0.333	0.174	0.160	0.093	0.126

Table 2. Continued.

KODIAK ISLAND AREA

Seal	Age[a]	Sex	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
94K4	Sub	F	.002									.044	.053	.018
94K1	Ad	M	.421	.465	.391	.346						.028	.109	.192
94K2	Ad	M	.235	.015	.094	.076	.168					.037	.045	.067
94K9	Sub	F	.099	.293	.177	.216	.201	.613				.488	.057	.050
93K1	Ad	F					.117	.252	.507					
94K8	Ad	M	.072	.133	.104	.170	.105					.027	.027	.047
93K3	Ad	F					.093	.237						
93K5	Ad	F	.030									.042	.087	.053
93K2	Ad	F					.018	.845	.962					
94K4	Ad	F					.038	.114						
MEAN			0.143	0.227	0.192	0.202	0.106	0.412	0.734			0.111	0.063	0.071

[a] Age: Ad = Adult, Sub = Subadult

Table 3. Dive depths for 27 SDR-tagged harbor seals in Southeast Alaska (SE) and Kodiak Island (KO) during 1993-95.

SDR No. (Seal No.)	No. of Dives	Dates	Percentage of Total Dives < 20 m	20 - 50 m	50 - 100 m	100 - 150 m	> 150 m
SE - Adult Males							
3087 (93SE3)	22,474	April-Aug	64.47	9.65	12.13	8.14	5.61
3089 (93SE9)	26,027	April-Aug	80.42	6.19	6.21	5.66	1.51
3090 (93SE7)	12,566	April-July	52.47	14.68	18.41	7.66	6.78
2085 (93SE16)	19,319	Sept-April	33.59	10.14	51.20	3.11	1.96
2087 (93SE18)	3,344	Sept-Oct	53.14	27.09	19.05	0.66	0.06
2089 (93SE10)	2,663	Sept-Oct	56.21	14.57	13.86	6.23	9.12
2090 (93SE15)	29,967	Sept-May	23.50	15.74	54.70	5.70	0.35
5045 (94SE7)	70,993	Sept-July	22.24	1.34	65.00	8.62	2.78
5049 (94SE3)	19,513	Sept-May	58.89	13.86	22.53	4.14	0.57
5051 (94SE9)	13,431	Sept-April	33.35	7.58	28.14	8.85	22.09
All	220,297		47.83	12.08	29.12	5.88	5.08
SE - Adult Females							
3086 (93SE2)	25,099	April-July	62.51	25.08	12.34	0.07	0.00
5039 (94SE5)	11,333	Sept-Feb	55.43	20.92	21.49	1.98	0.19
5047 (94SE2)	18,063	Sept-June	21.92	11.27	54.12	12.10	0.59
5050 (94SE8)	21,425	Sept-May	41.51	12.55	38.22	7.22	0.50
All	75,920		45.34	17.45	31.54	5.34	0.32
SE - Subadults							
3088 (93SE4)^{M}	10,576	April-July	57.76	8.69	10.92	17.77	4.86
2086 (93SE20)^{M}	32,459	Sept-April	27.07	19.96	50.35	2.51	0.11
2094 (93SE19)^{F}	38,842	Sept-April	53.86	24.24	20.46	1.06	0.37
All	81,877		46.23	17.63	27.24	7.11	1.78

Table 3. Continued.

SDR No. (Seal No.)	No. of Dives	Dates	Percentage of Total Dives < 20 m	20 - 50 m	50 - 100 m	100 - 150 m	> 150 m
KO - Adult Males							
5042 (94KO1)	5,810	Oct-April	50.98	17.78	28.98	2.10	0.16
5043 (94KO2)	14,052	Oct-July	26.71	45.43	27.76	0.10	0.00
5046 (94KO8)	18,205	Oct-June	23.64	18.92	43.15	13.07	1.22
All	38,067		33.78	27.38	33.30	5.09	0.46
KO - Adult Females							
5044 (93KO1)	10,558	April-July	39.81	59.73	0.46	0.00	0.00
5045 (93KO2)	6,936	April-July	53.40	38.34	7.40	0.87	0.00
5046 (93KO3)	6,350	April-July	23.54	73.78	2.68	0.00	0.00
5047 (93KO4)	5,484	April-June	51.31	32.73	14.97	0.88	0.11
5048 (93KO5)	11,188	Oct-Jan	34.78	56.05	8.97	0.20	0.00
All	40,516		40.57	52.13	6.90	0.39	0.02
KO - Subadults							
5041 (94KO4)[F]	11,503	Oct-Jan	33.86	26.28	32.38	7.48	0.00
5044 (94KO9)[F]	34,756	Oct-June	4.47	9.64	74.53	9.09	2.26
All	46,259		19.16	17.96	53.46	8.29	1.13

For Subadults: [M] = Male; [F] = Female

Table 4. Maximum dive depths (m) for 27 SDR-tagged harbor seals in Southeast Alaska and Kodiak Island, April 1993 - July 1995.

SDR (Seal No.)	Sex	Age[a]	Deployment Dates	n[b]	Max Depth	Mean Max Depth	Range	Maximum Depth Date[c]	Comments
SOUTHEAST			***Spring 1993***						
3086 (93SE2)	F	Ad	April-July	80	268	145.5	84-268	5/31/93	
3087 (93SE3)	M	Ad	April-August	80	504	442.2	12-504	5/14 & 8/16/93	
3089 (93SE9)	M	Ad	April-August	92	368	283.5	36-368	5/2/93	Apr through June consistent max. depth dives to 300m
3090 (93SE7)	M	Ad	April-July	66	508	449.2	32-508	5/14/93	consistent max. dives to 500m
3088 (93SE4)	M	Sub	April-July	58	504	339.7	12-504	5/20/93	subadult max. depth fluctuates more than adults in spring
			Fall 1993						
2085 (93SE16)	M	Ad	Sept-April	136	496	242.6	24-496	12/10-11 & 1/19/94	peaks of deep dives in early Nov, mid Dec and Jan
2087 (93SE18)	M	Ad	Sept-Oct	17	368	218.6	60-368	9/23/93	
2089 (93SE10)	M	Ad	Sept-Oct	17	492	404.9	128-492	9/16-30/93 (10)	
2090 (93SE15)	M	Ad	Sept-May	175	508	243.6	80-508	1/28/94	
2094 (93SE19)	F	Sub	Sept-April	186	420	174.7	8-420	10/11/93	Nov. through Mar. consistent max. depth dives to 170-180m
2086 (93SE20)	M	Sub	Sept-April	168	416	215.3	128-416	2/28/94	consistent max. dives to 200m
			Fall 1994						
5045 (94SE7)	M	Ad	Sept-July						data not available
5049 (94SE3)	M	Ad	Sept-May	183	492	243.5	8-492	10/30 & 12/22/93	
5051 (94SE9)	M	Ad	Sept-April	189	472	362.3	68-472	10/19-3/5/95 (26)	most deep dives in Dec-Jan
5039 (94SE5)	F	Ad	Sept-Feb	67	468	189.0	0-468	11/17/94	
5047 (94SE2)	F	Ad	Sept-June	168	376	236.4	16-376	2/25/95	
5050 (94SE8)	F	Ad	Sept-May	189	388	213.6	28-388	2/2/95	

Table 4. Continued.

Animal (Seal No.)	Sex	Age[a]	Deployment Dates	n[b]	Max Depth	Mean Max Depth	Range	Maximum Depth Date[c]	Comments
KODIAK			***Spring 1993***						
5044 (93KO1)	F	Ad	April-July	44	108	66.3	8-108	7/7/93	Natal period 6/1-6/26 (max depth did not exceed 12m)
5045 (93KO2)	F	Ad	April-July	31	248	75.0	8-248	7/9/93	Natal period 6/1-6/15 (max depth did not exceed 28m)
5046 (93KO3)	F	Ad	April-July	29	112	47.0	8-112	7/4/93	Natal period 6/3-6/26 (max depth did not exceed 12m)
5047 (93KO4)	F	Sub	April-June	74	140	105.8	76-368	5/15/93	Movements to Aiaktalik, Ugak
5048 (93KO5)	F	Ad	Oct - Jan	52	236	105.9	8-236	11/18/93	Movements to Tugidak, C. Alitak. Max depths highly variable.
			Fall 1994						
5042 (94KO1)	M	Sub	Oct-April	115	260	103.4	12-260	12/12/94	
5043 (94KO2)	M	Ad	Oct-July	201	268	116.5	8-268	5/14/95	
5046 (94KO8)	M	Ad?	Oct-June	126	320	123.6	0-320	12/23/94	Max depth data through March only
5041 (94KO4)	F	Ad	Oct-Jan	37	236	193.4	84-236	10/10/94	
5044 (94KO9)	F	Sub	Oct-June						data not available

[a] Ad = Adult; Sub = Subadult

[b] The number of days with maximum daily dive depths.

[c] The dates of the dive with the maximum depth are given. When more than one date recorded the maximum dive, the dates or range of dates are given. Parentheses () give the total number of maximum depth dives.

Table 5. Mean dive frequencies for 27 SDR-tagged harbor seals in Southeast Alaska and the Kodiak Island area during 1993-1995.

Sex/Age Class [a]	Dates	No. of 6-hr periods [b]	Dive frequency [c]
SOUTHEAST			
AF	Sept - July	2091	38.8 (33.39)
AM	"	4869	36.1 (35.84)
Sub	"	1762	46.3 (33.70)
KODIAK			
AF	Oct - Jan	227	51.1 (35.00)
AM	"	657	53.9 (30.72)
Sub	"	281	86.5 (63.84)

[a] AF = Adult female, AM = Adult Male, Sub = Subadult.

[b] No. of 6-hr periods (histograms) in which data was collected.

[c] Mean no. of dives per 6-hr period (sd).

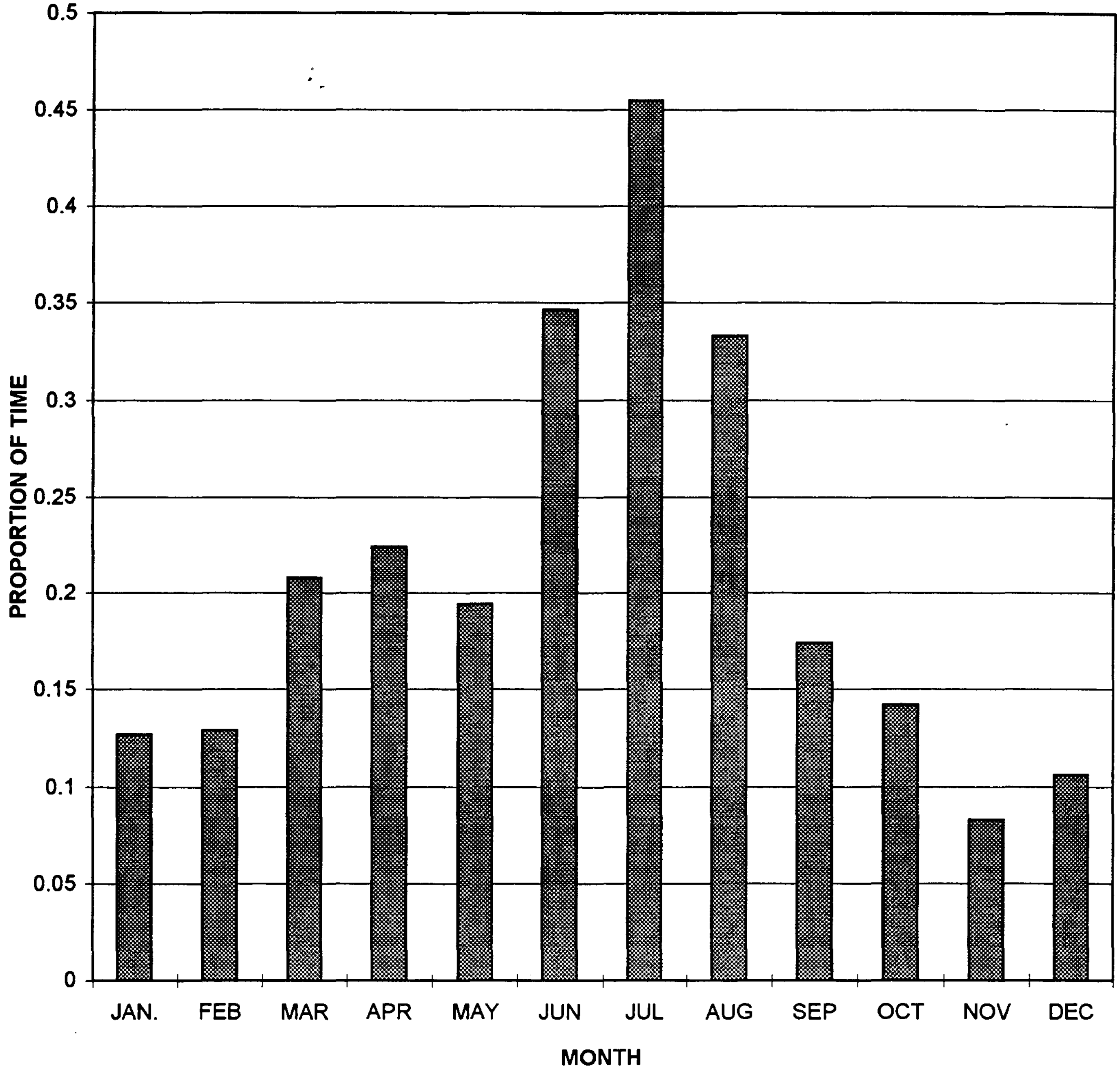


Figure 1. Proportion of time spent hauled out by 27 SDR-tagged harbor seals in Southeast Alaska and the Kodiak Island area, April 1993 - July 1995.

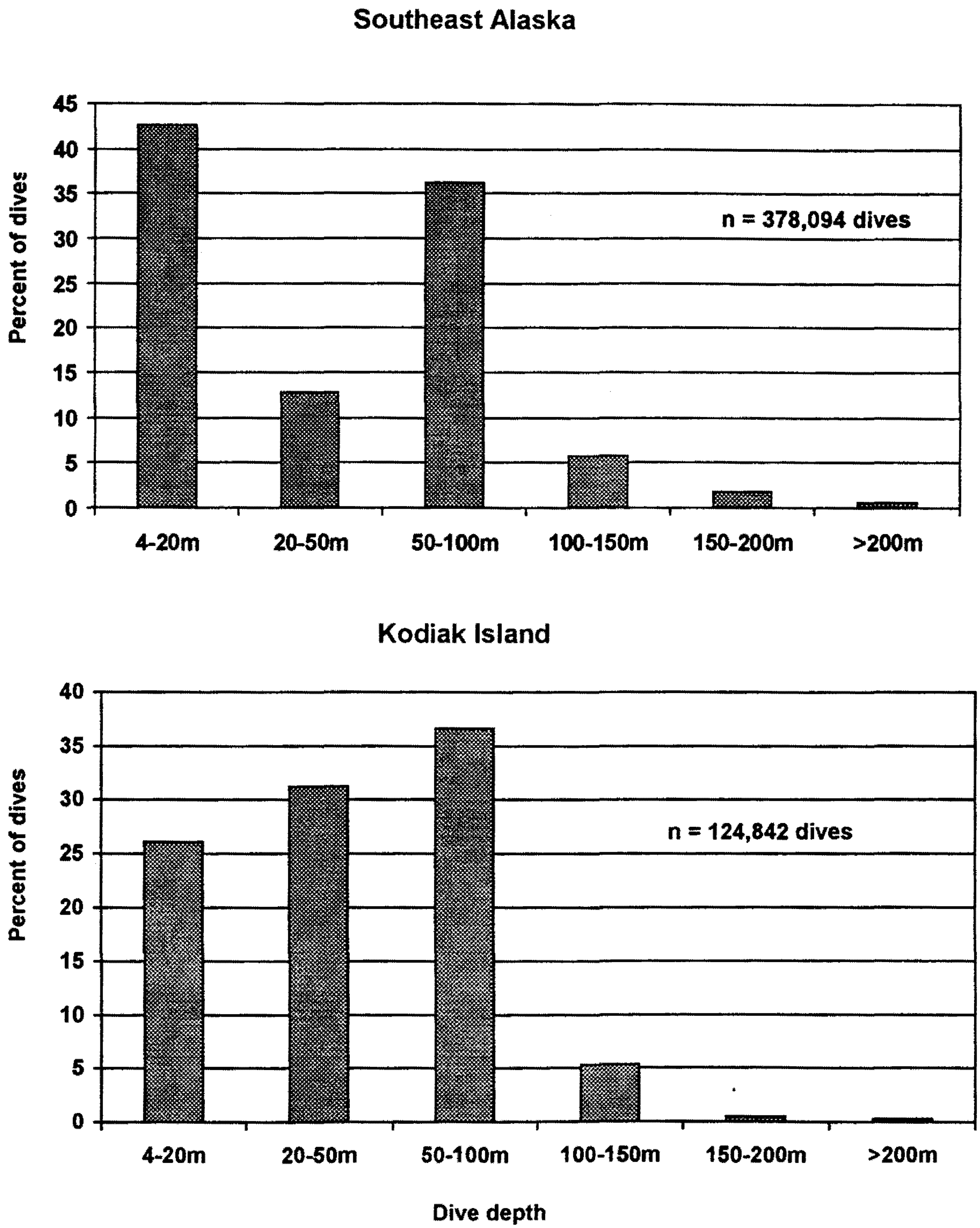


Figure 2. Percentage of all dives by depth category (bin) for 27 SDR-tagged harbor seals in Southeast Alaska and the Kodiak Island area, April 1993 - July 1995.

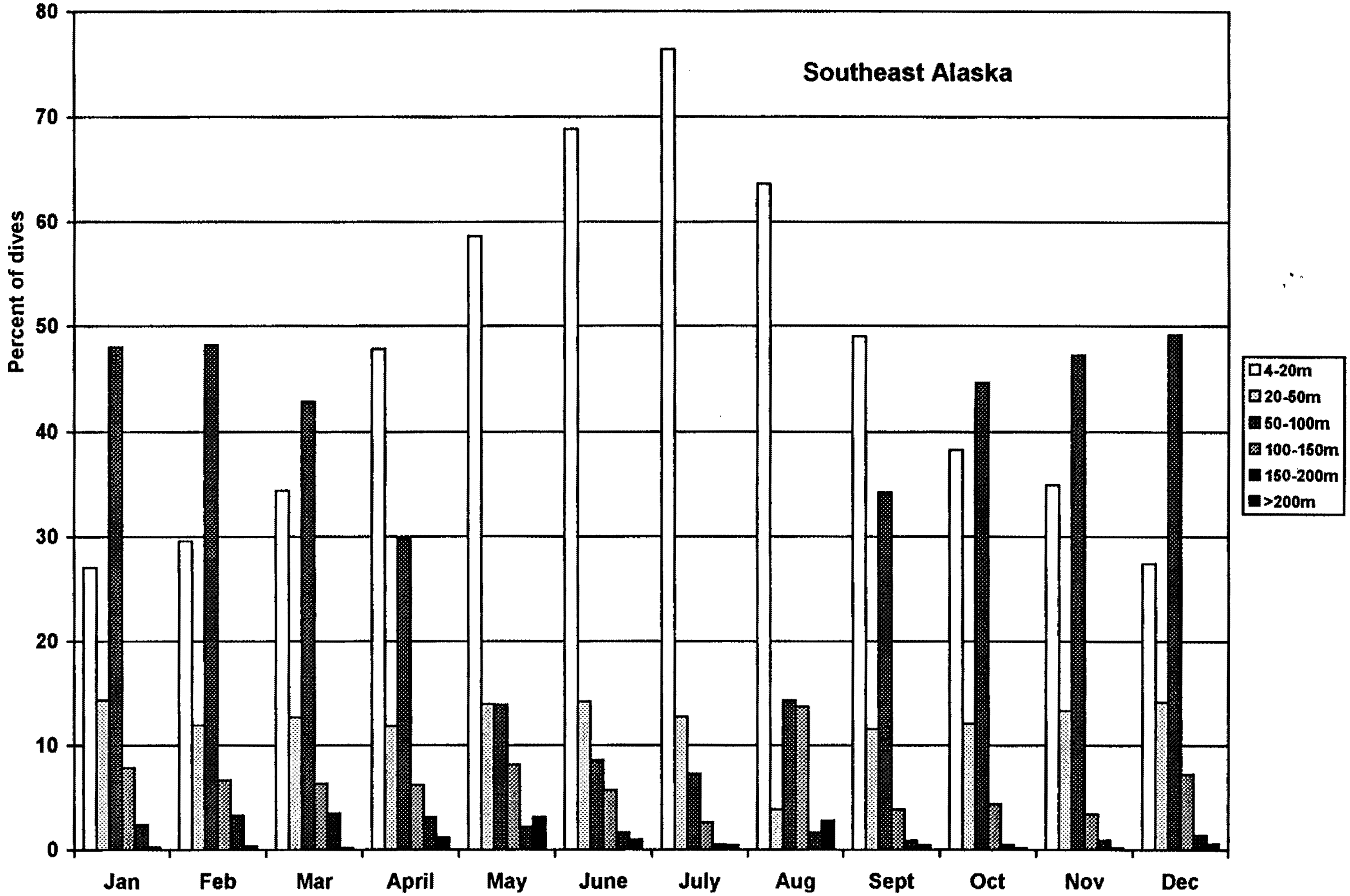


Figure 3. Seasonal distribution of dive depths (m) for 17 SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995.

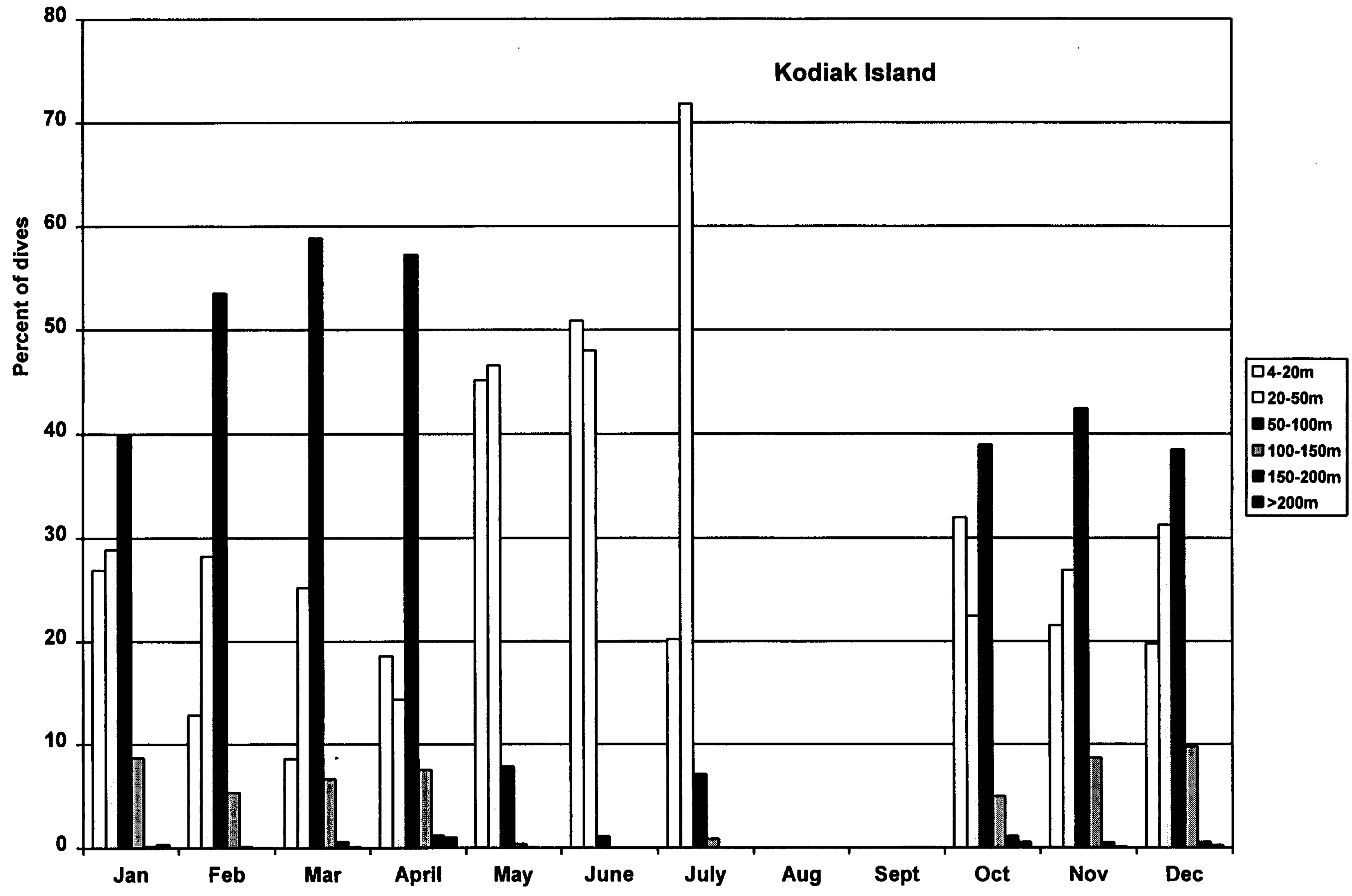


Figure 4. Seasonal distribution of dive depths (m) for 10 SDR-tagged harbor seals in the Kodiak Island area, April 1993 - July 1995.

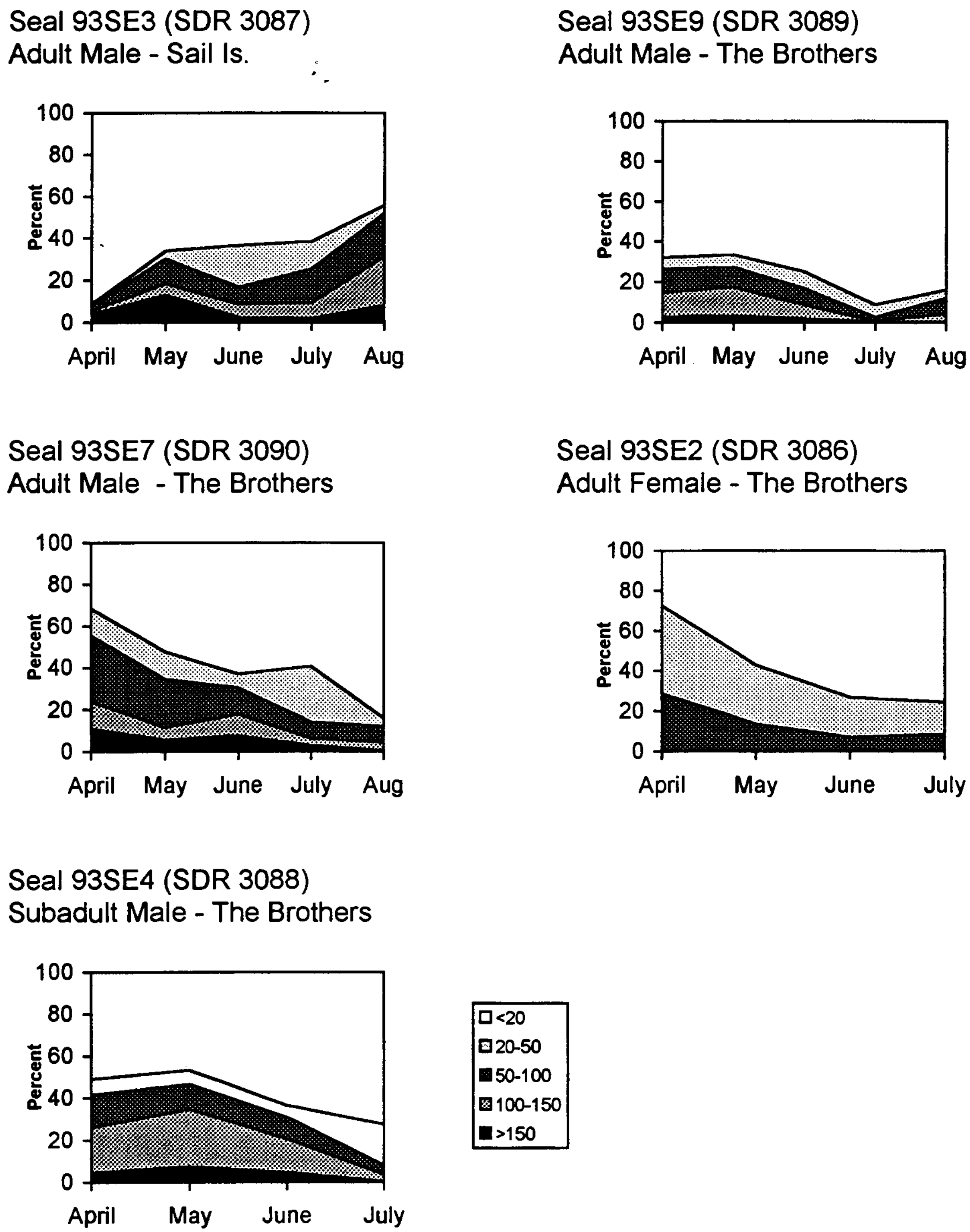


Figure 5. Monthly distribution of dive depths (m) for 5 SDR-tagged harbor seals in Southeast Alaska, April-August 1993.

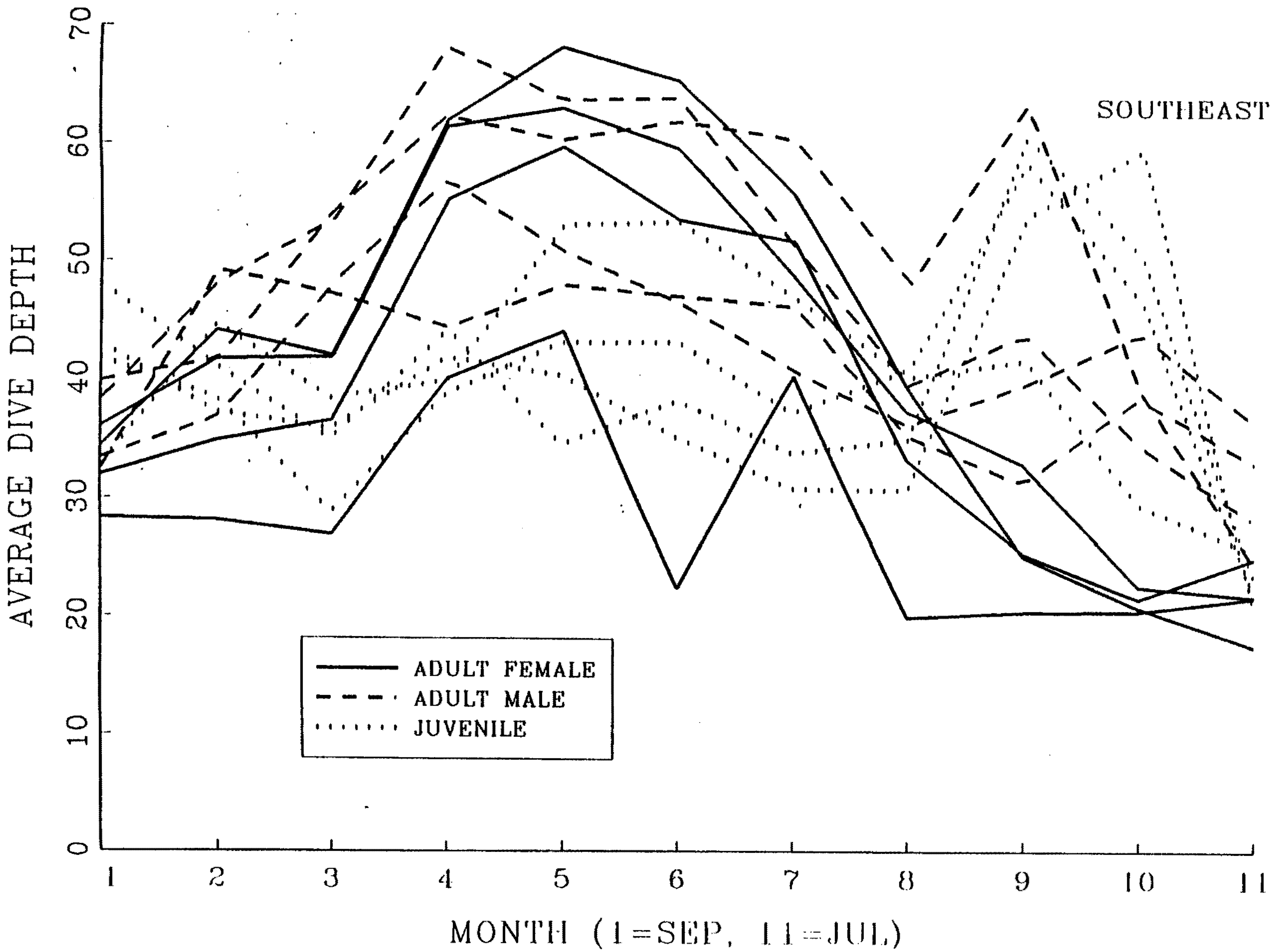


Figure 6a. Average dive depth by month for 17 SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995 (n=4 adult females, 10 adult males, 3 juveniles). The four lines per sex and age class represent different times of day.

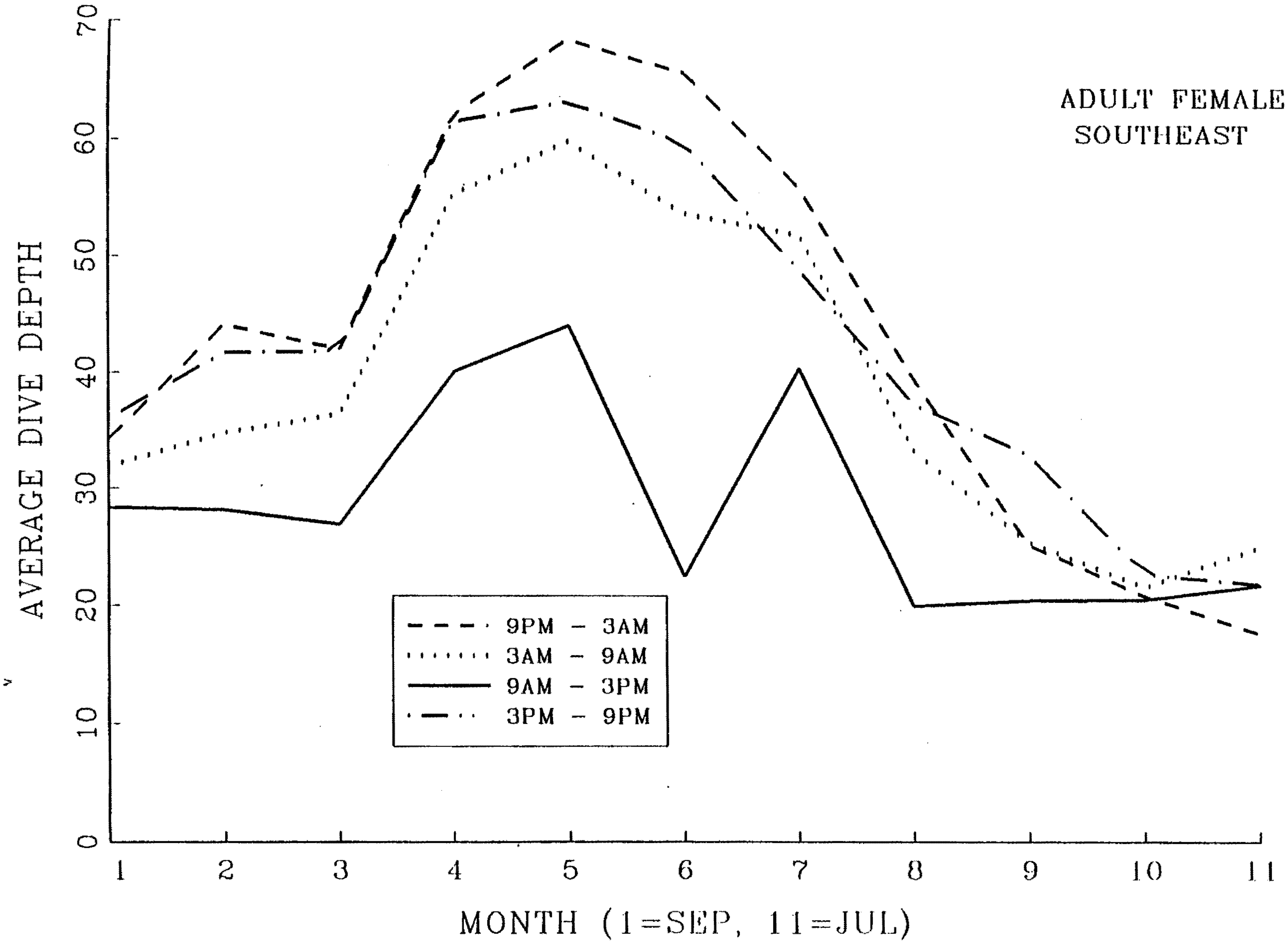


Figure 6b. Average dive depth by month and time of day for 4 adult female SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995.

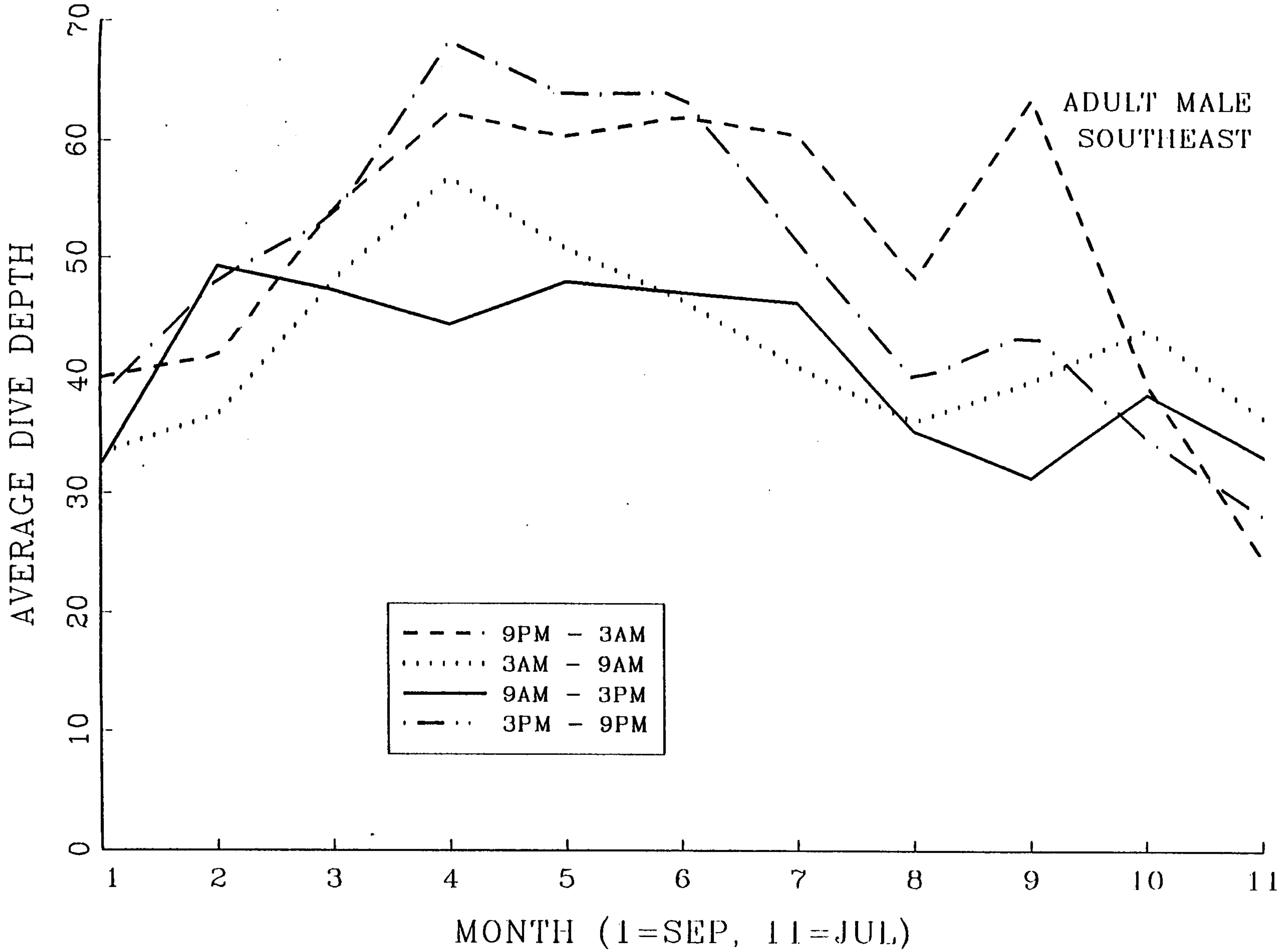


Figure 6c. Average dive depth by month and time of day for 10 adult male SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995.

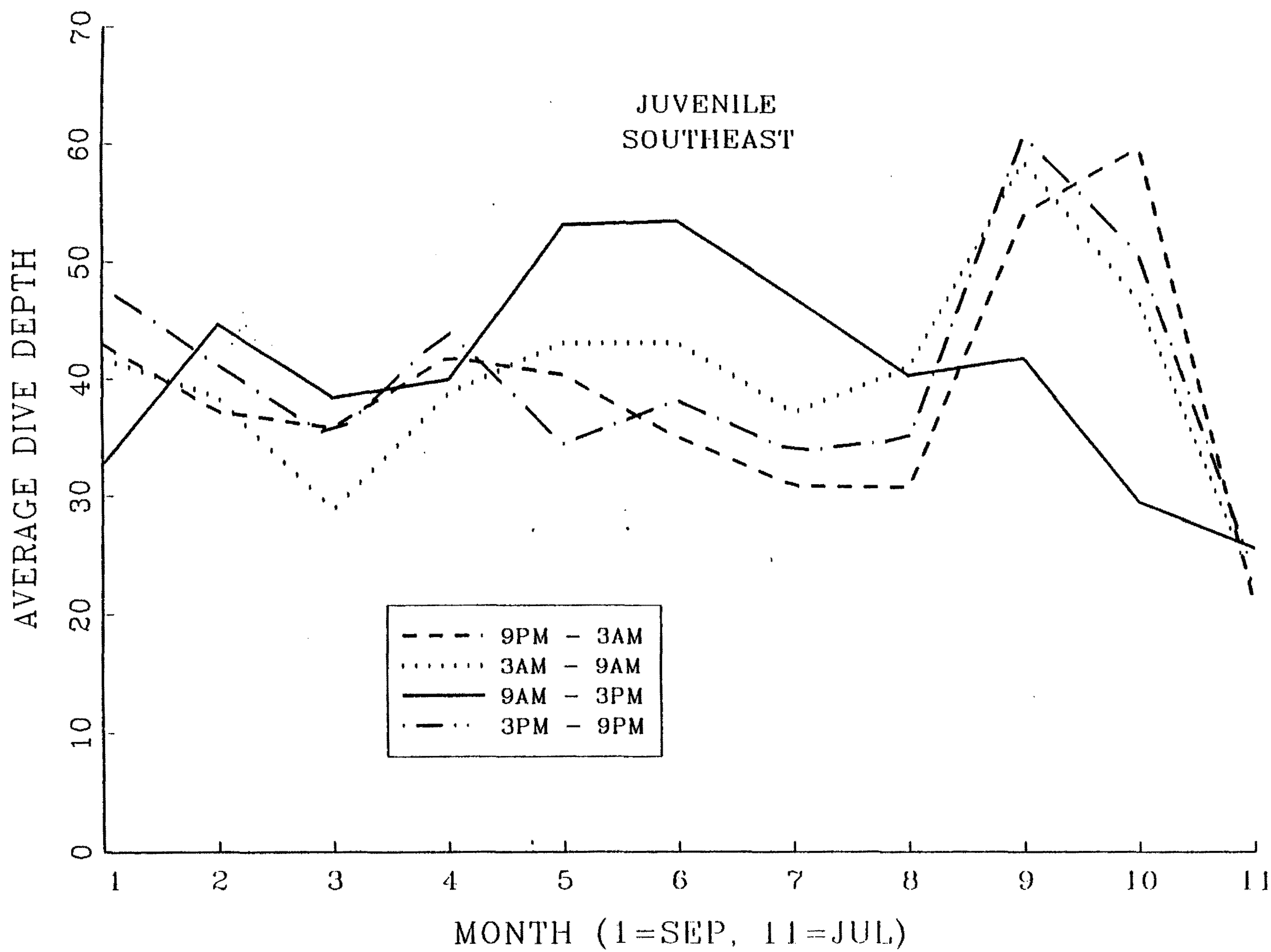


Figure 6d. Average dive depth by month and time of day for 3 juvenile SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995.

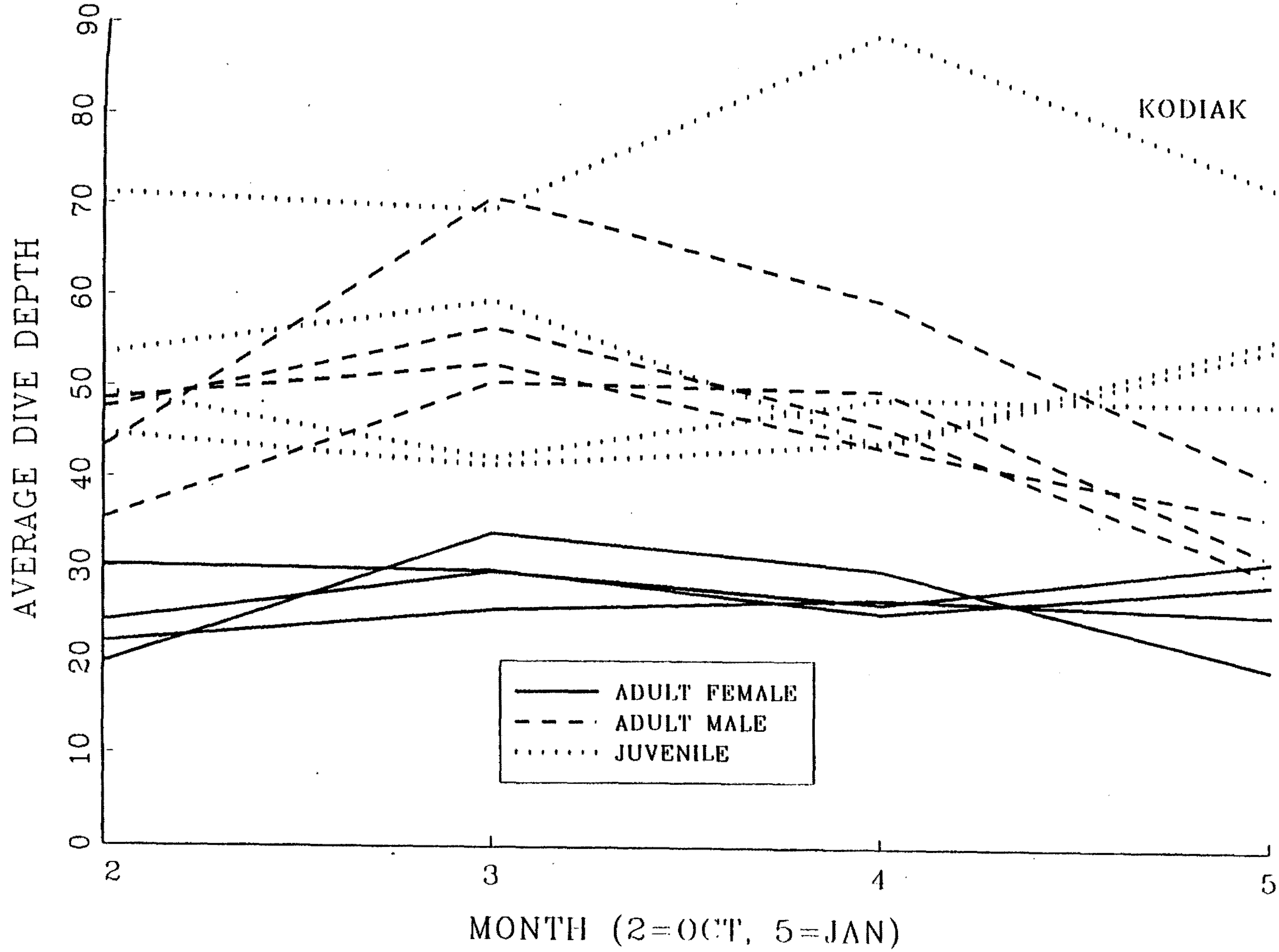


Figure 7. Average dive depth by month for 10 SDR-tagged harbor seals in the Kodiak Island area, April 1993 - July 1995 (n=5 adult females, 3 adult males, 2 juveniles).

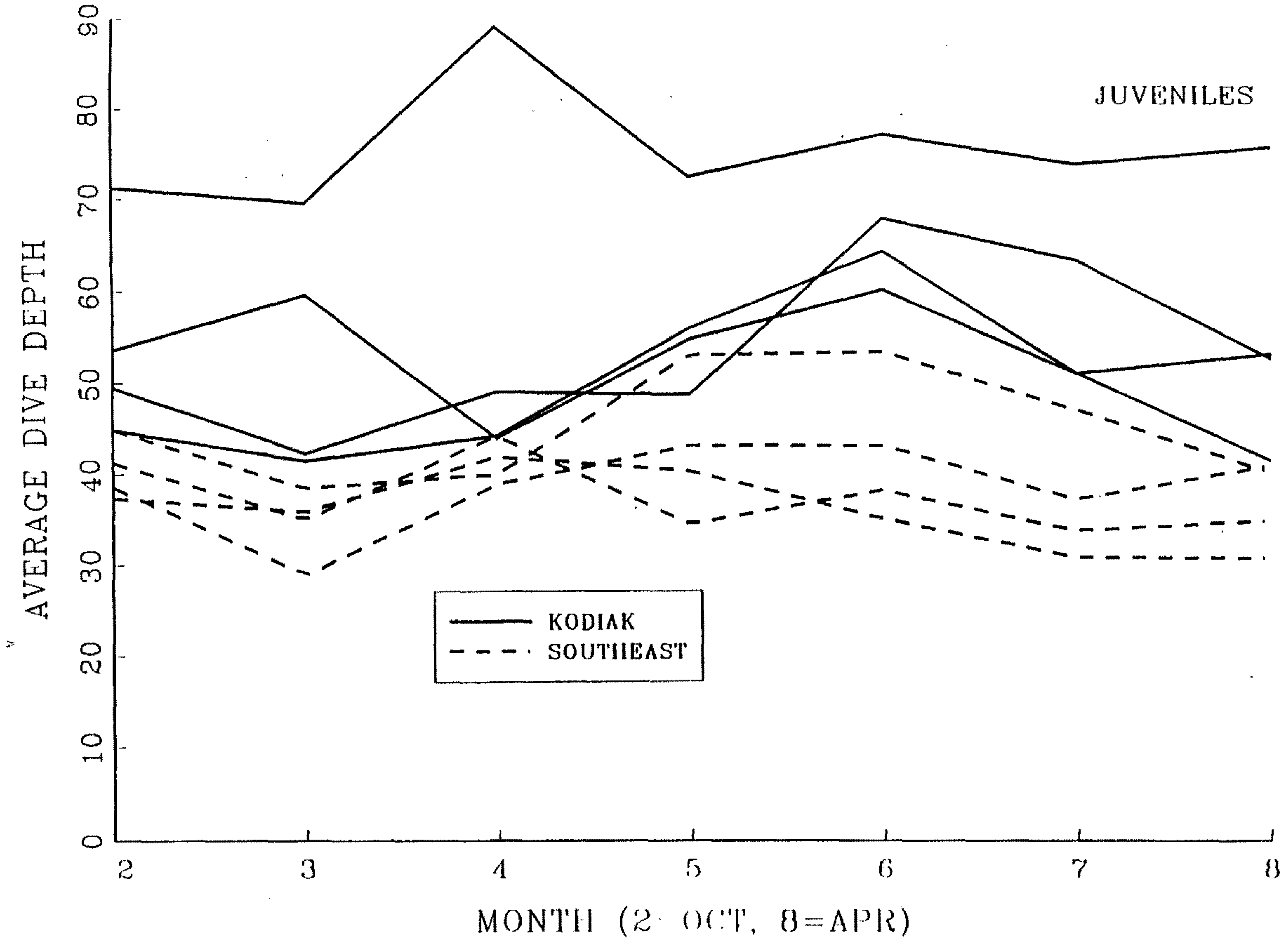


Figure 8. A comparison of average dive depth between juvenile SDR-tagged harbor seals in Southeast Alaska and the Kodiak Island area, April 1993 - July 1995 (n=3 in Southeast Alaska, n=2 in Kodiak). The four lines per area represent different times of day.

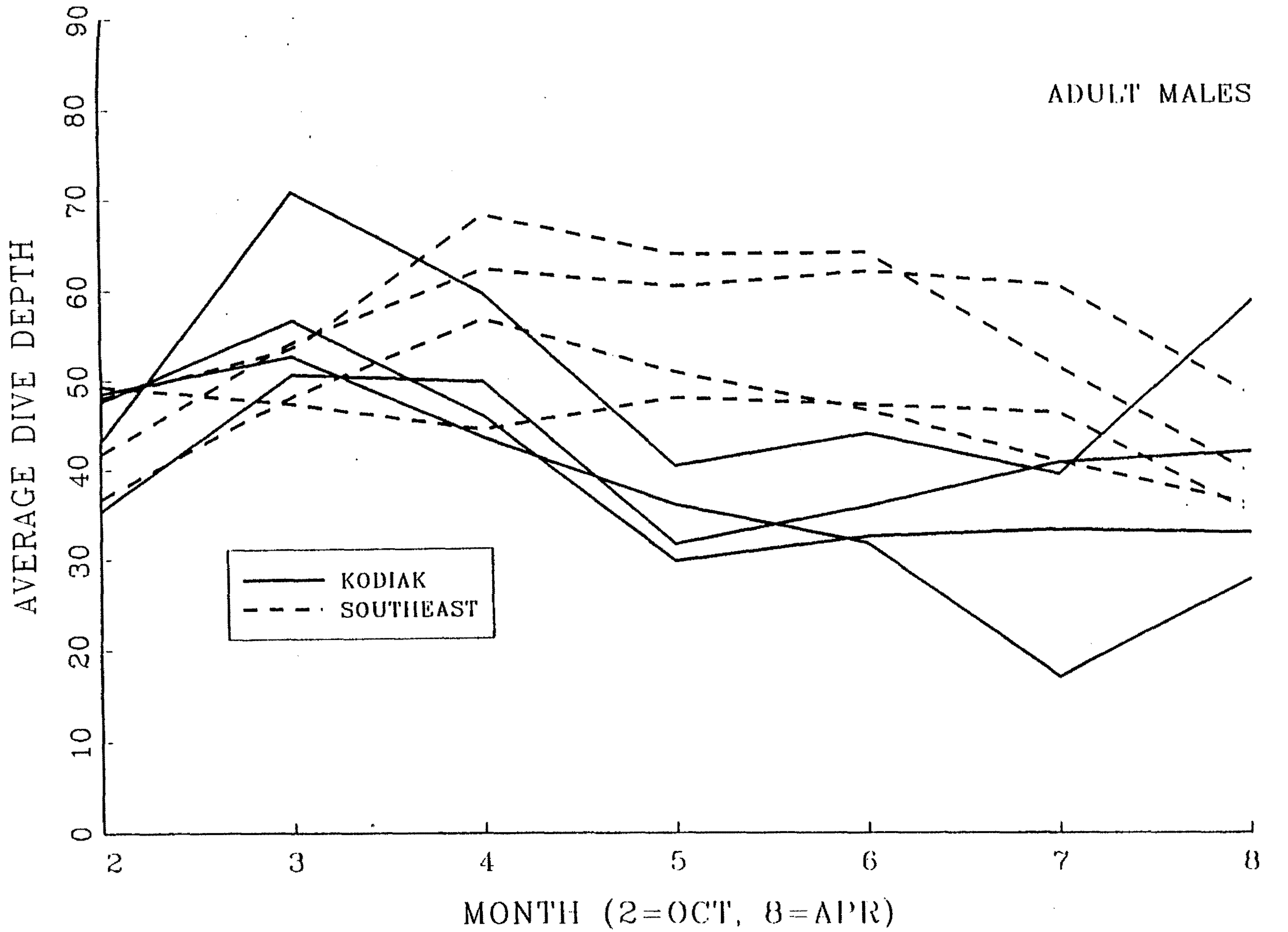


Figure 9. A comparison of average dive depth between adult male SDR-tagged harbor seals in Southeast Alaska and the Kodiak Island area, April 1993 - July 1995 (n=10 in Southeast Alaska, n=3 in Kodiak). The four lines per area represent different times of day.

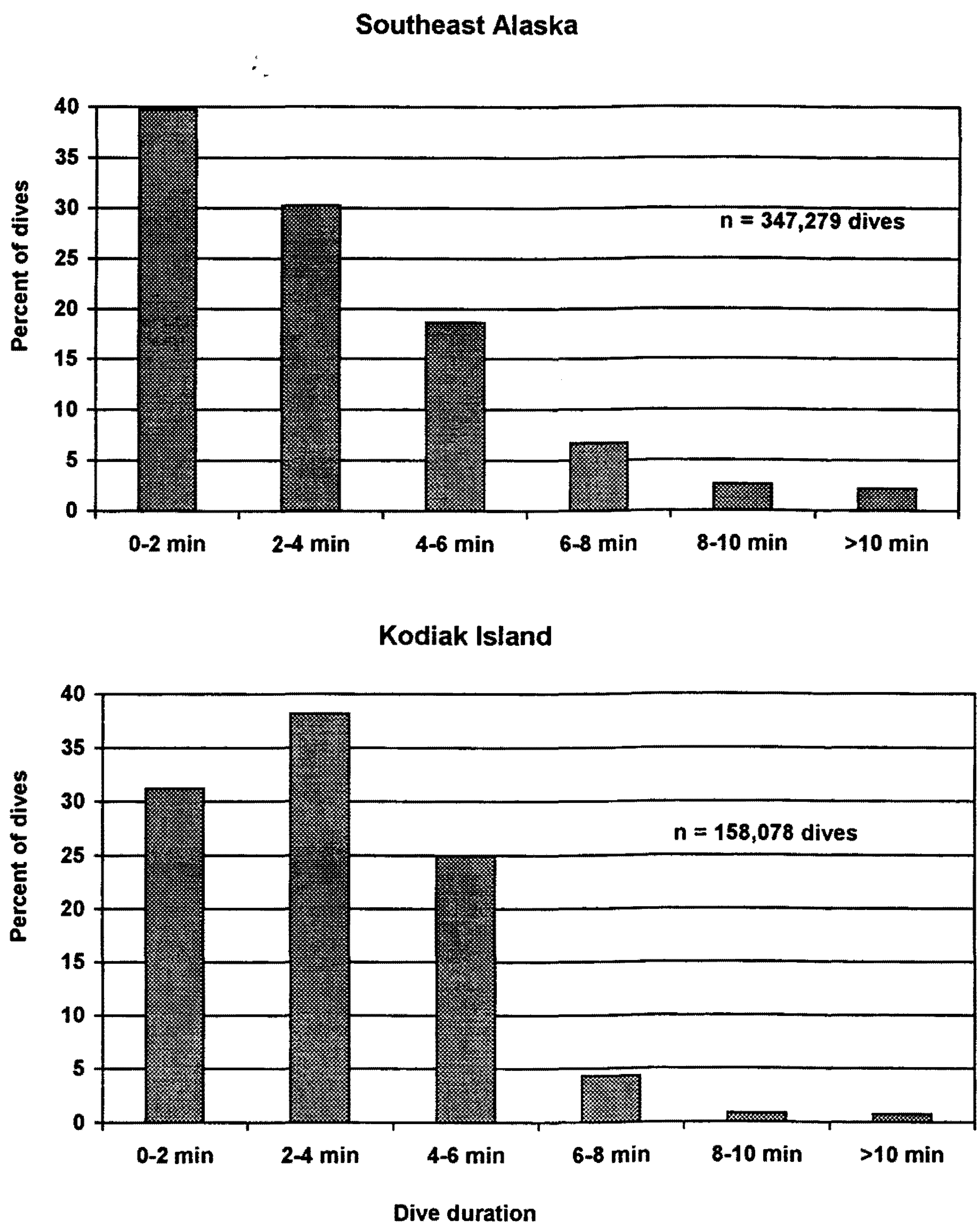
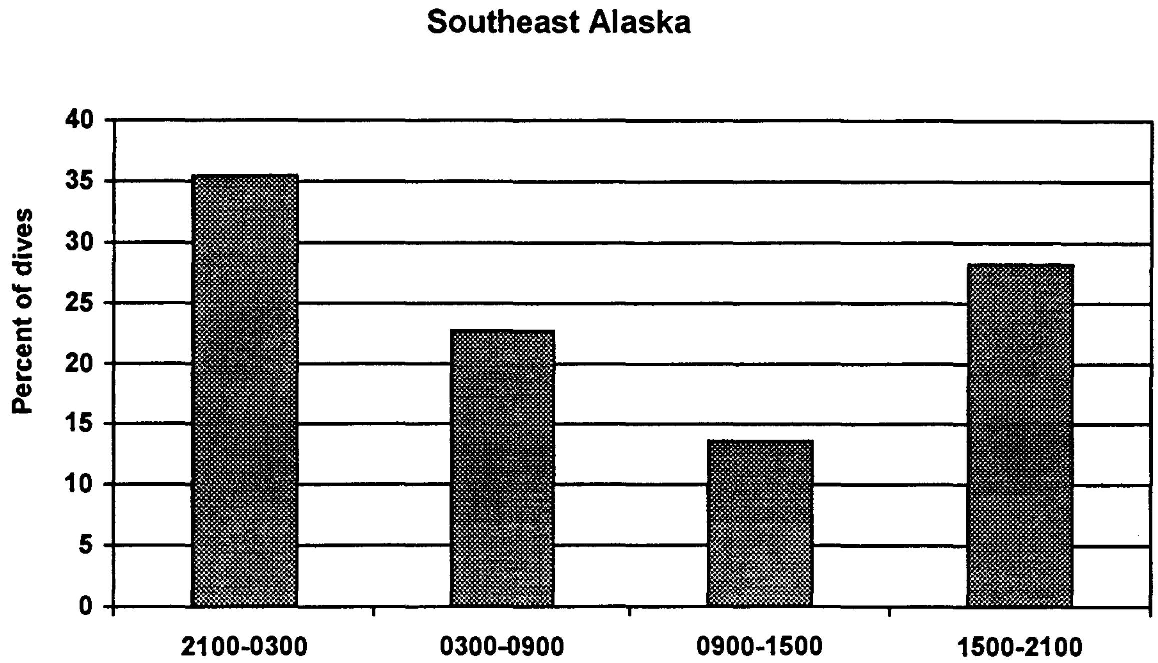


Figure 10. Percentage of all dives by duration category (bin) for 27 SDR-tagged harbor seals in Southeast Alaska and the Kodiak Island area, April 1993 - July 1995.



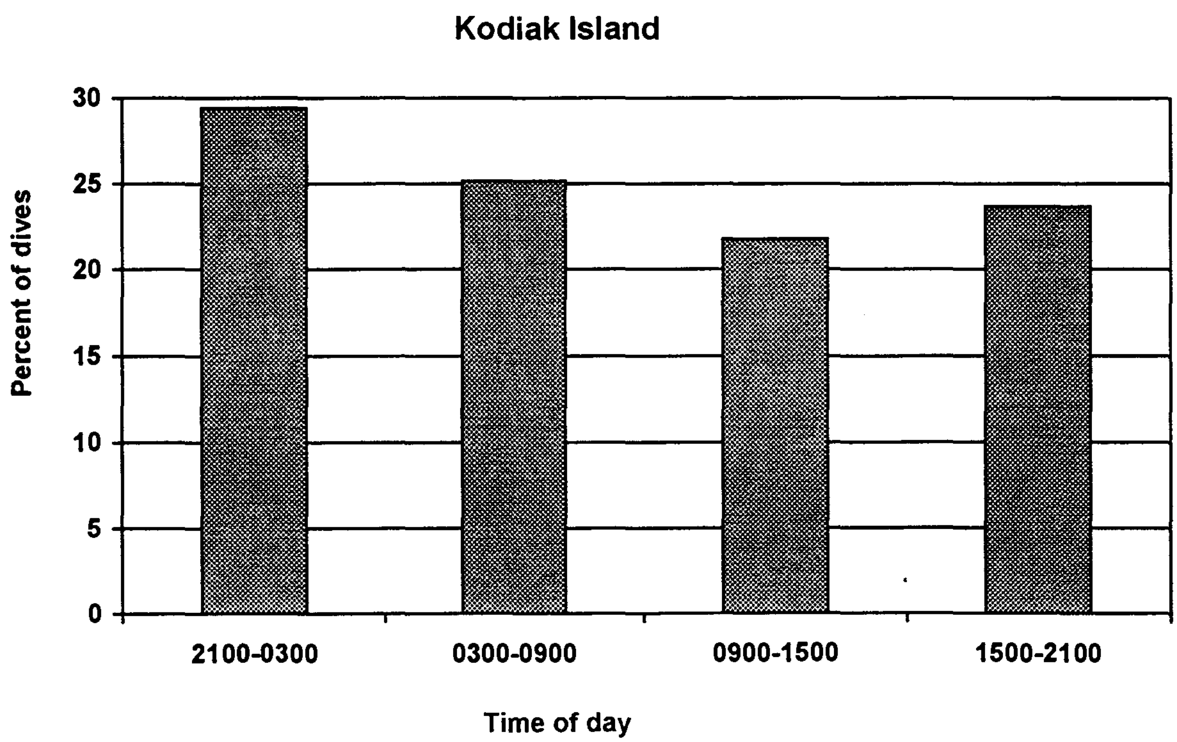


Figure 11. Dive frequency by time of day for 27 SDR-tagged harbor seals in Southeast Alaska and the Kodiak Island area, April 1993 - July 1995.

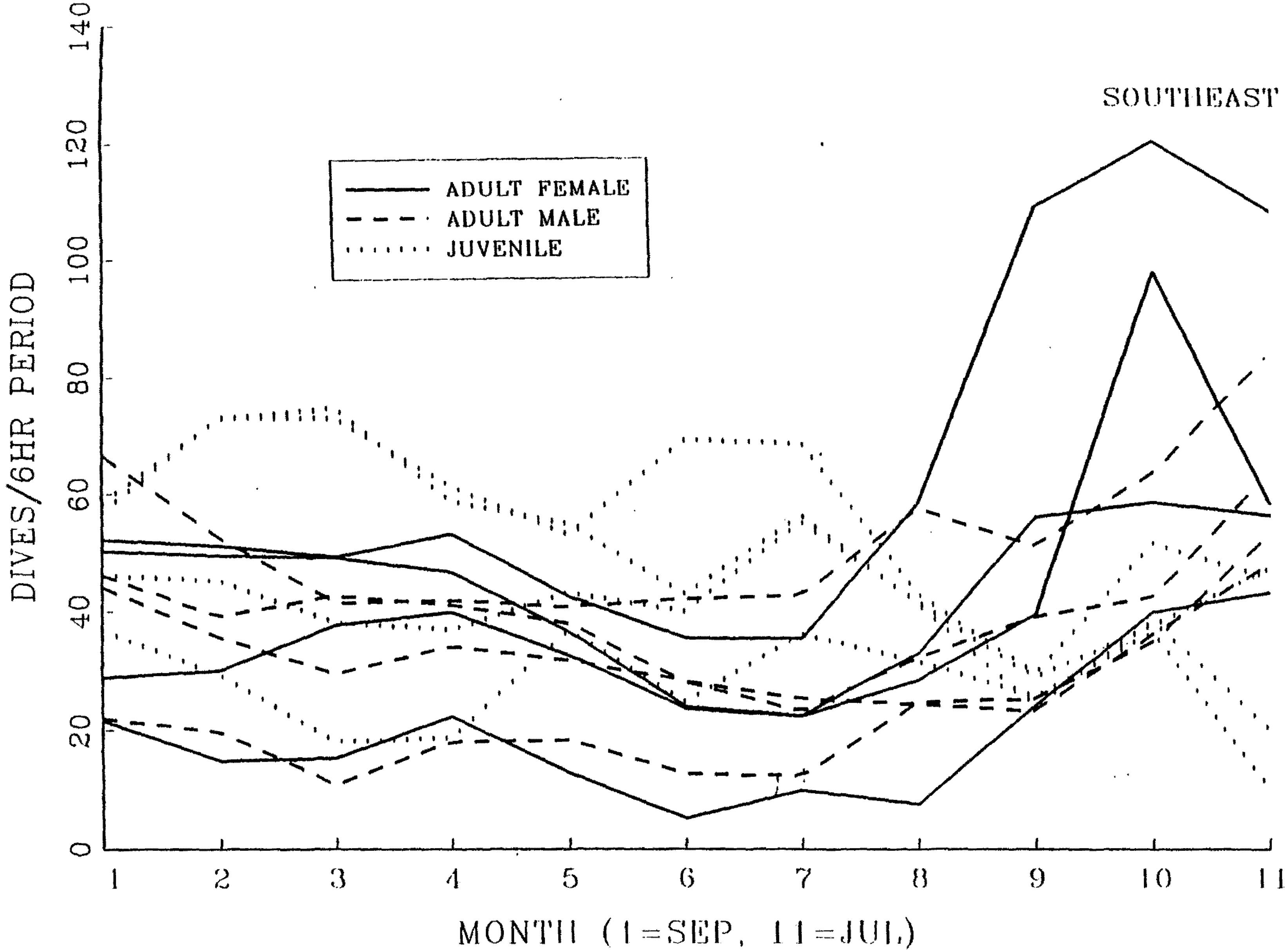


Figure 12a. Dive frequency (no. of dives/6-hr period) by month for 17 SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995 (n=4 adult females, 10 adult males, 3 juveniles).

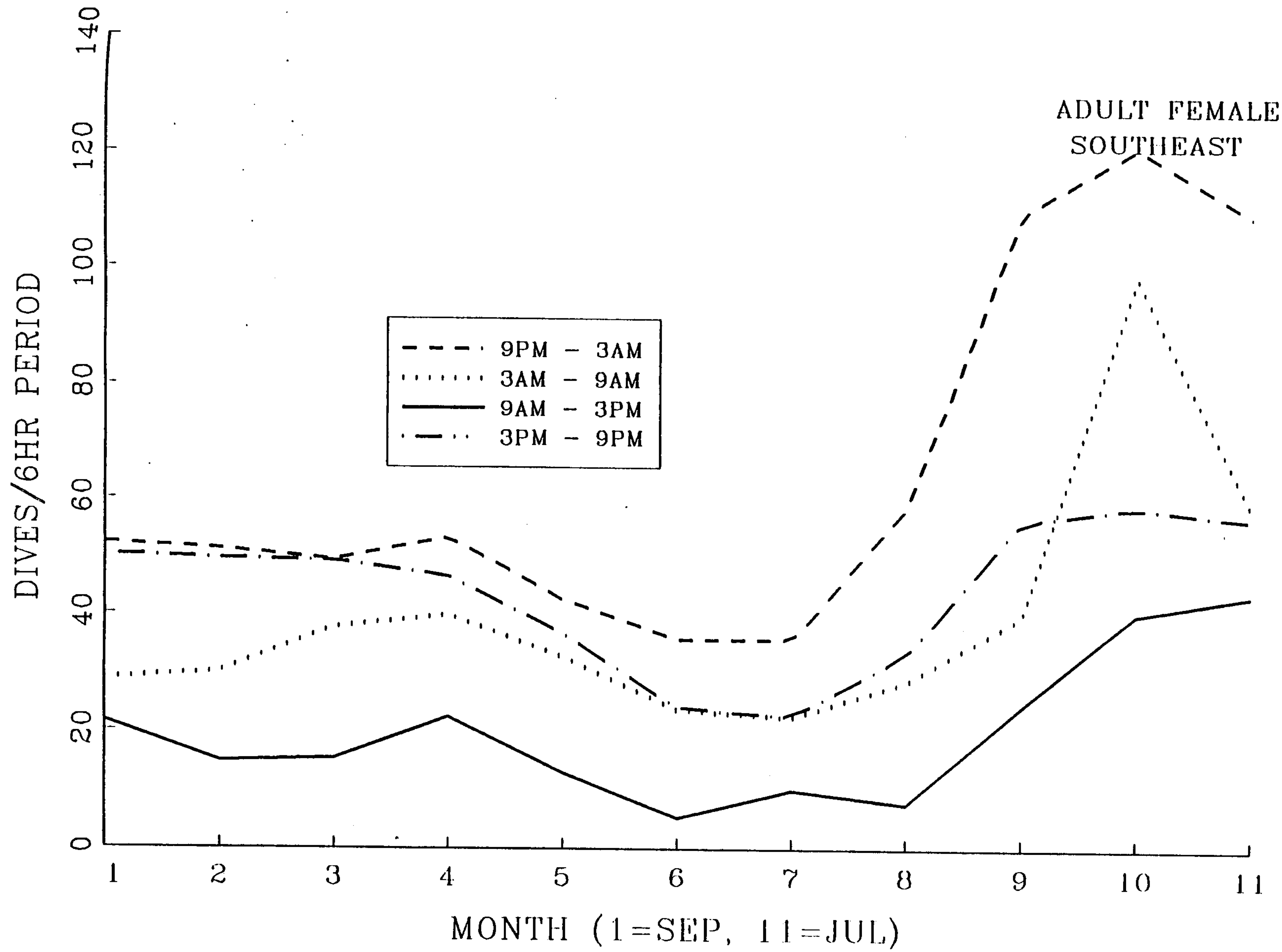


Figure 12b. Dive frequency (no. of dives/6-hr period) by month and time of day for 4 adult female SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995.

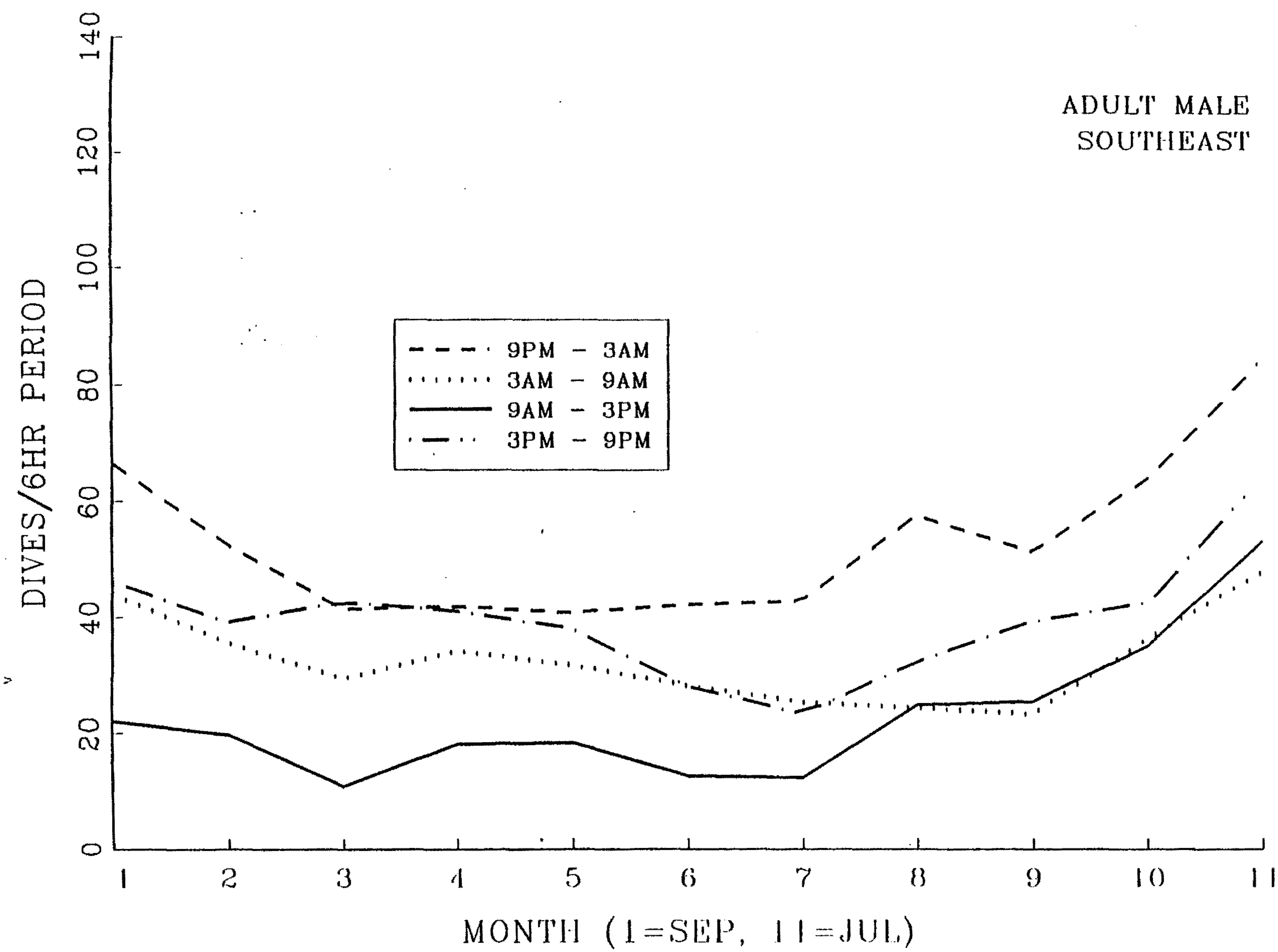


Figure 12c. Dive frequency (no. of dives/6-hr period) by month and time of day for 10 adult male SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995.

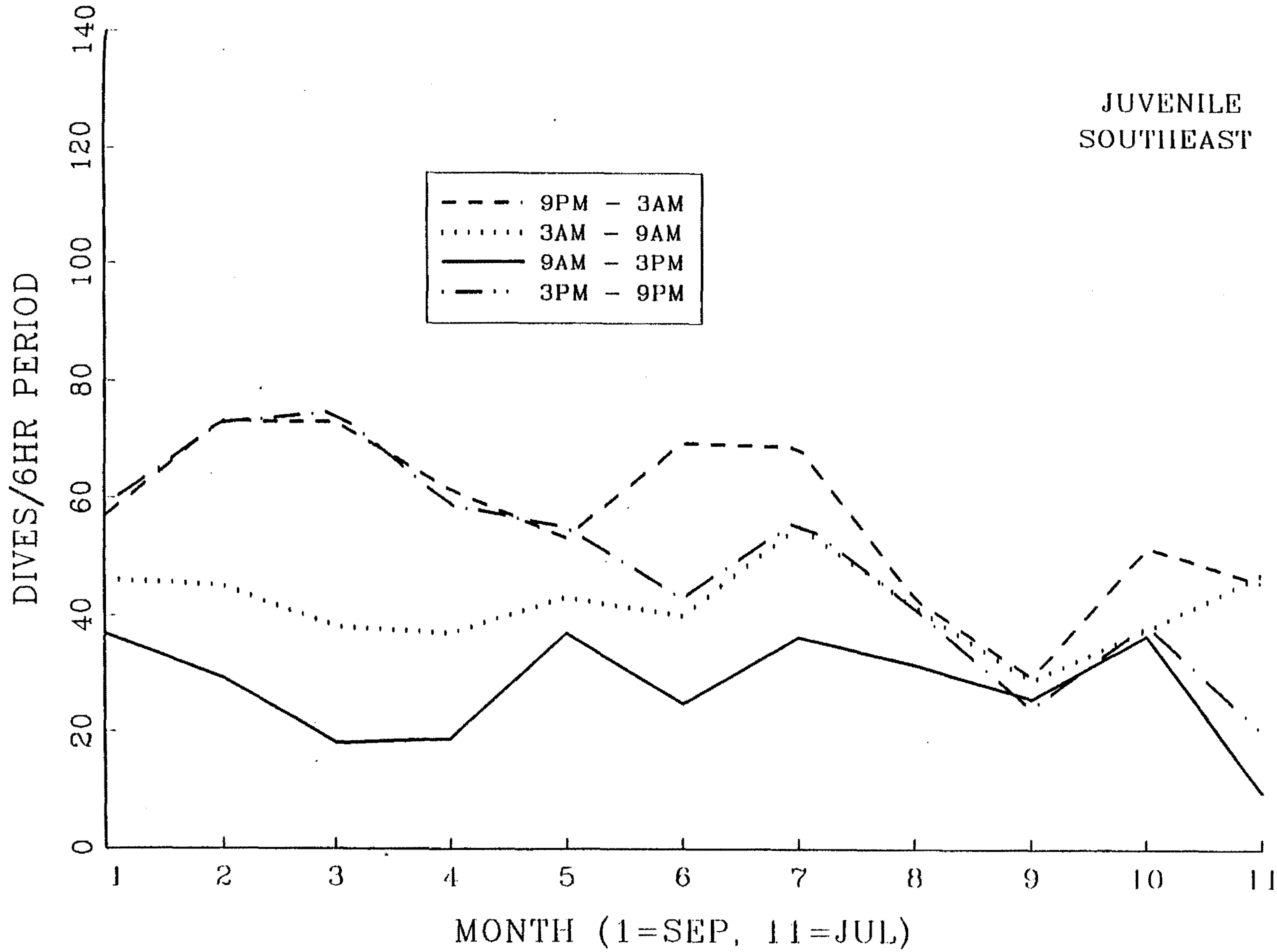


Figure 12d. Dive frequency (no. of dives/6-hr period) by month and time of day for 3 juvenile SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995.

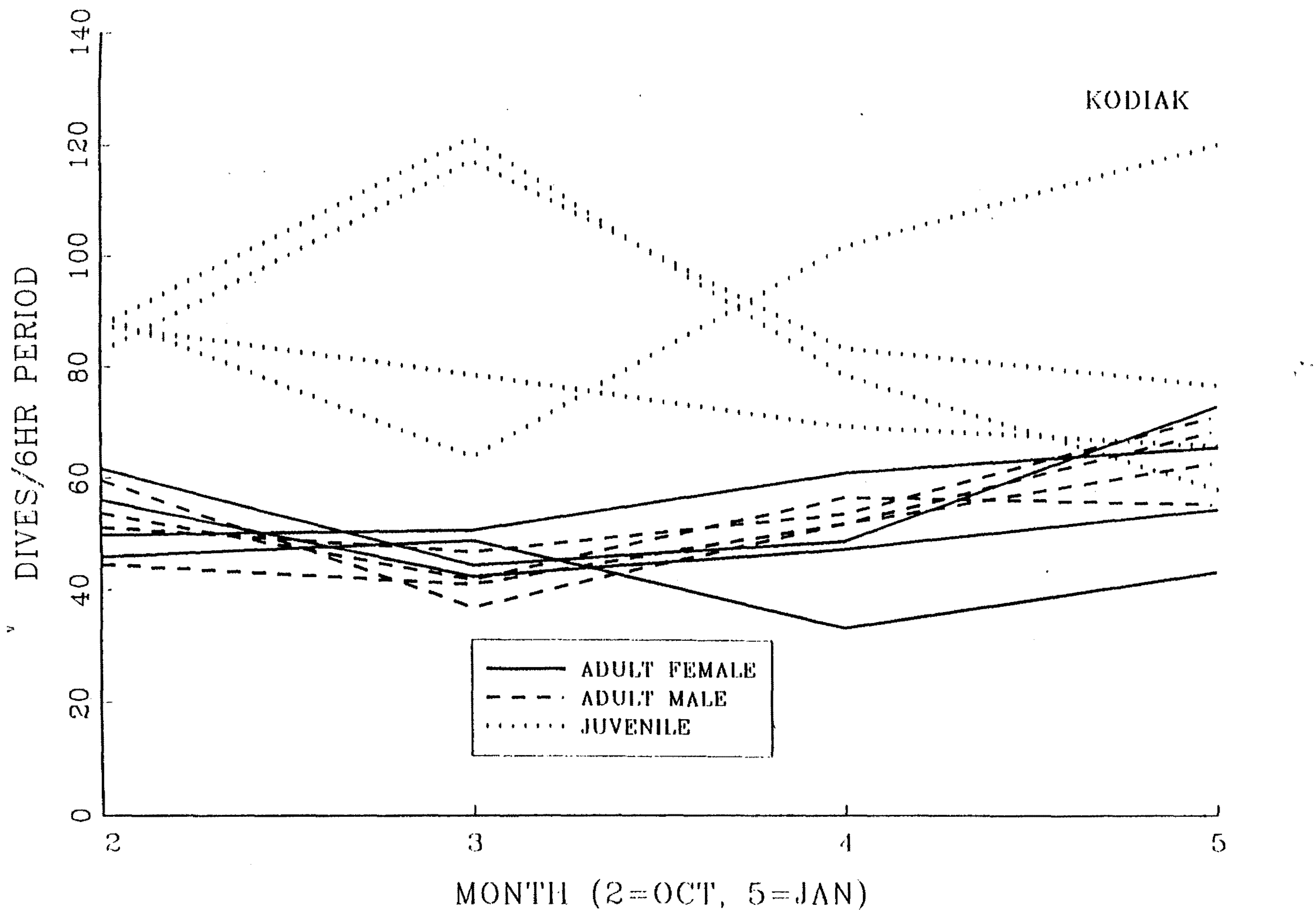


Figure 13. Dive frequency (no. of dives/6-hr period) by month for 10 SDR-tagged harbor seals in the Kodiak Island area, April 1993 - July 1995 (n=5 adult females, 3 adult males, 2 juveniles). The four lines per sex and age class represent different times of day.

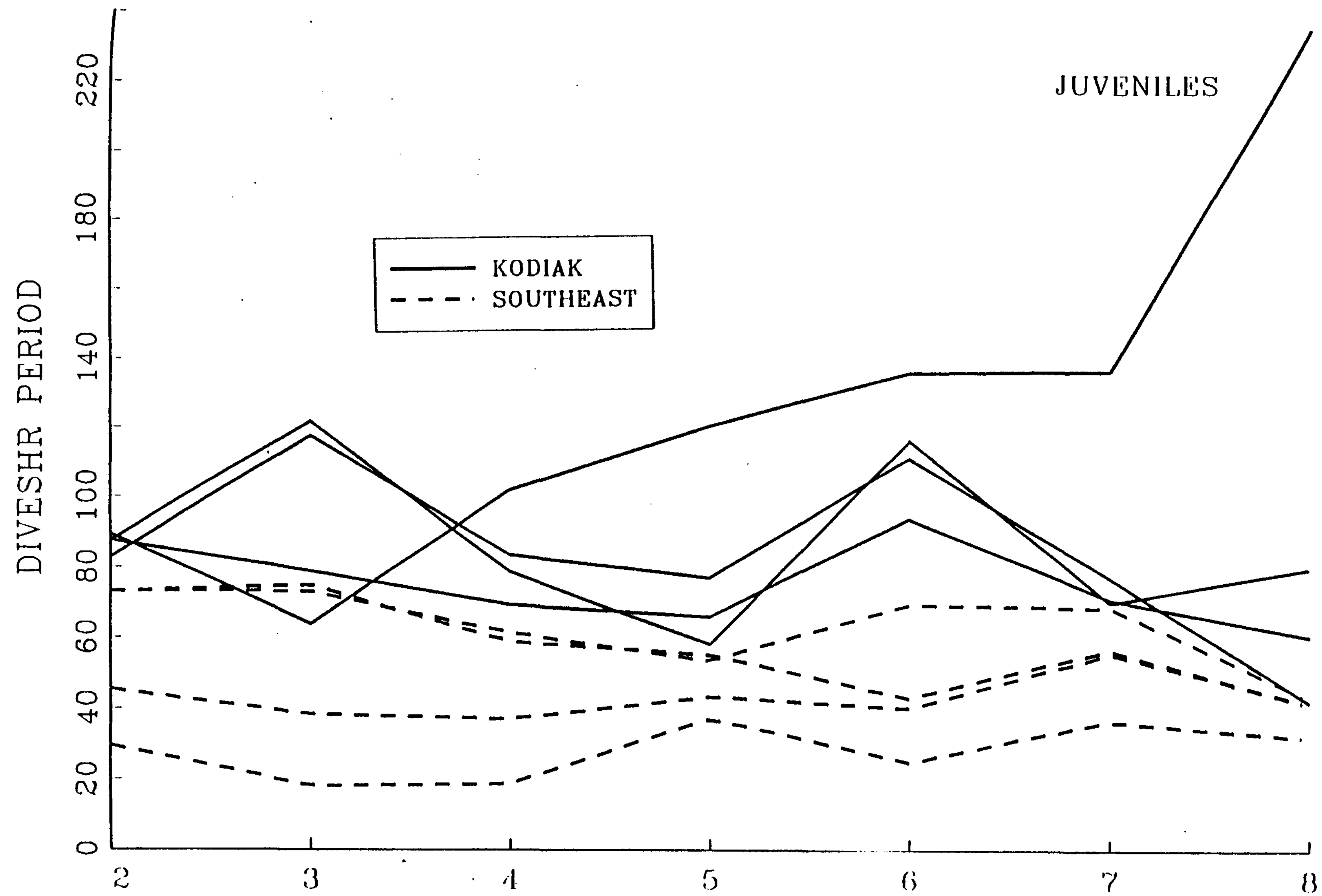


Figure 14. A comparison of dive frequency (no. of dives/6-hr period) between juvenile SDR-tagged harbor seals in Southeast Alaska and the Kodiak Island area, April 1993 - July 1995 (n=3 in Southeast Alaska, n=2 in Kodiak). The four lines per area represent different times of day.

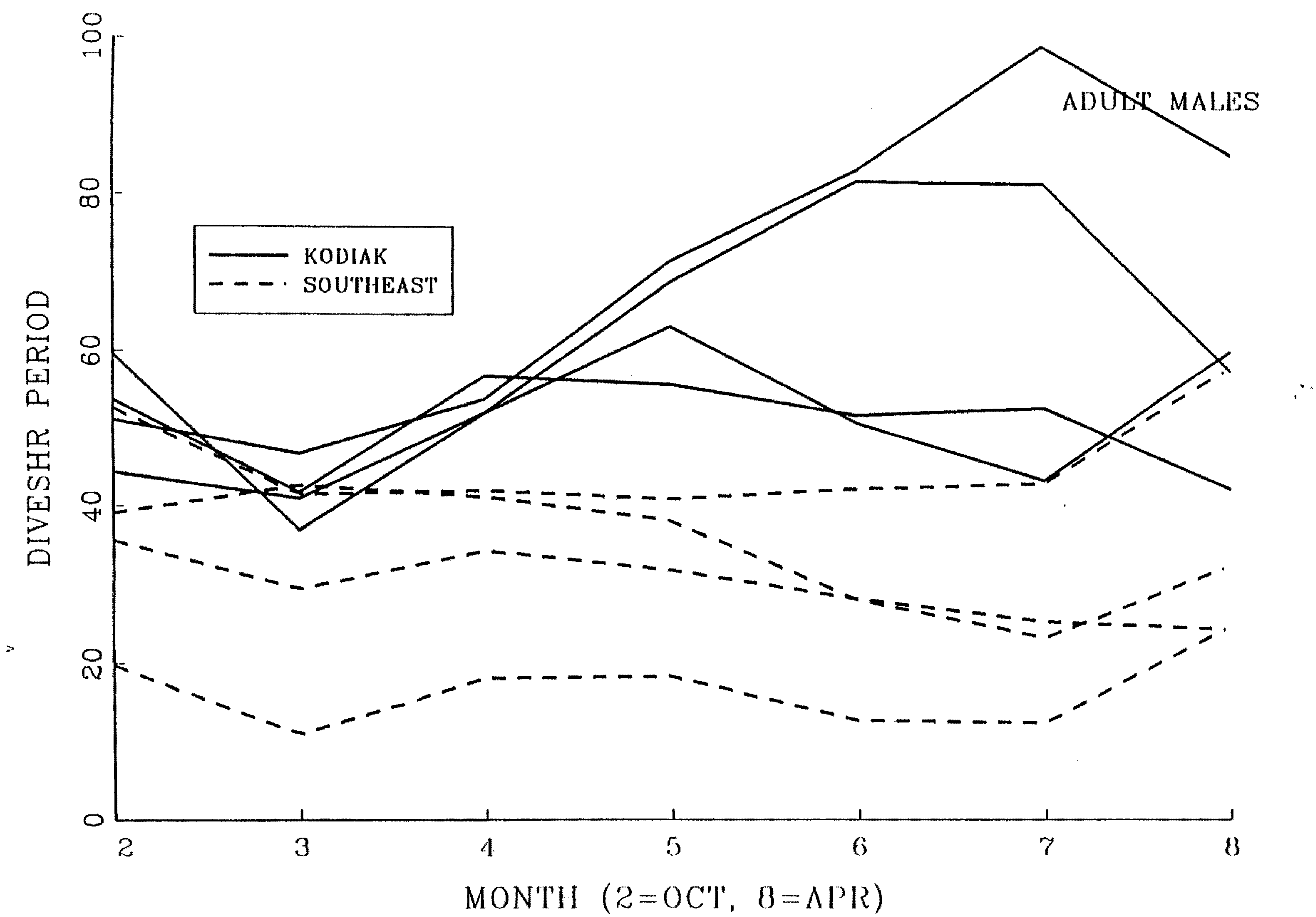


Figure 15. A comparison of dive frequency (no. of dives/6-hr period) between adult male SDR-tagged harbor seals in Southeast Alaska and the Kodiak Island area, April 1993 - July 1995 (n=10 in Southeast Alaska, n=3 in Kodiak). The four lines per area represent different times of day.

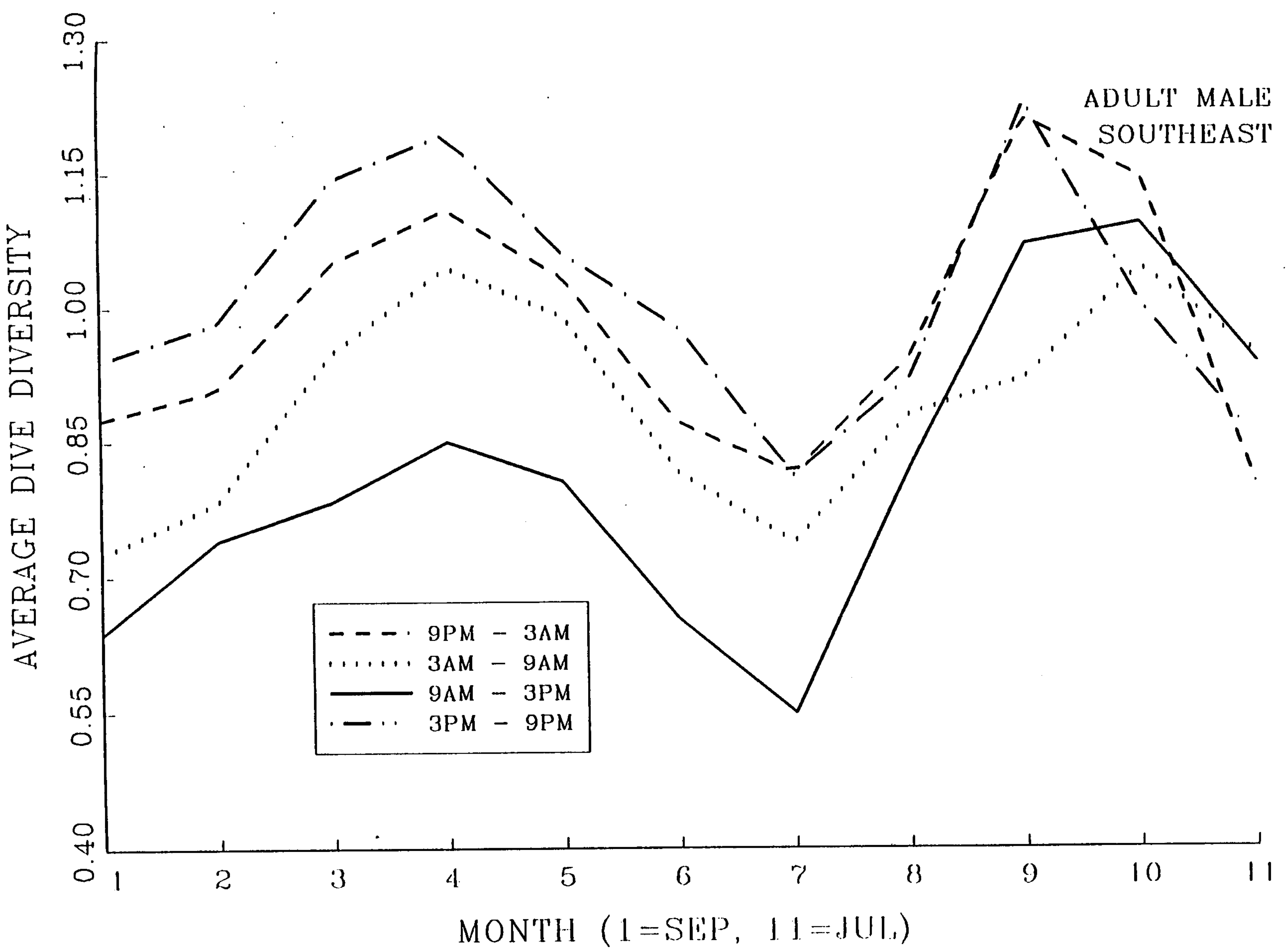


Figure 16a. Average dive diversity by month and time of day for 10 adult male SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995.

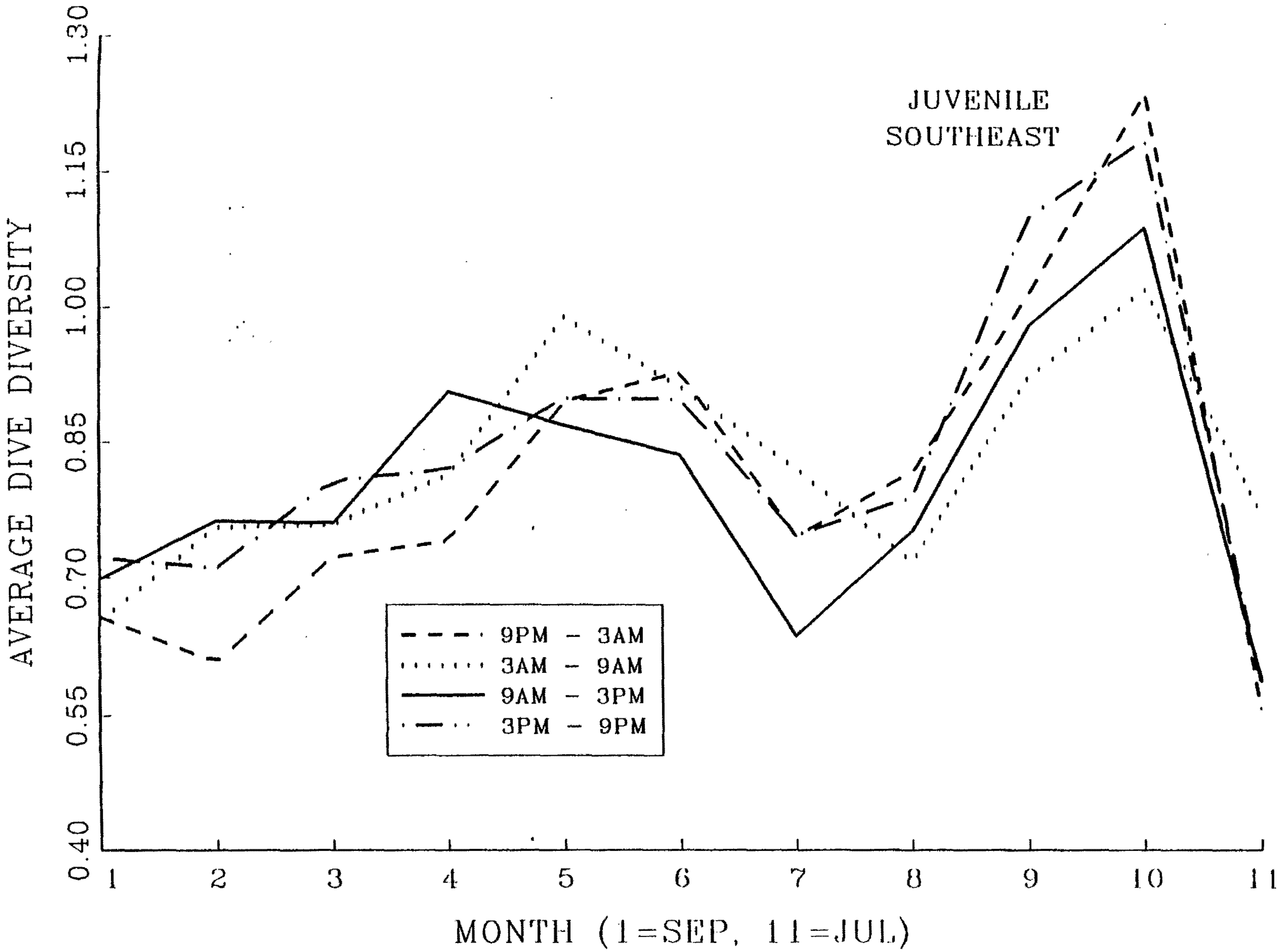


Figure 16b. Average dive diversity by month and time of day for 3 juvenile SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995.

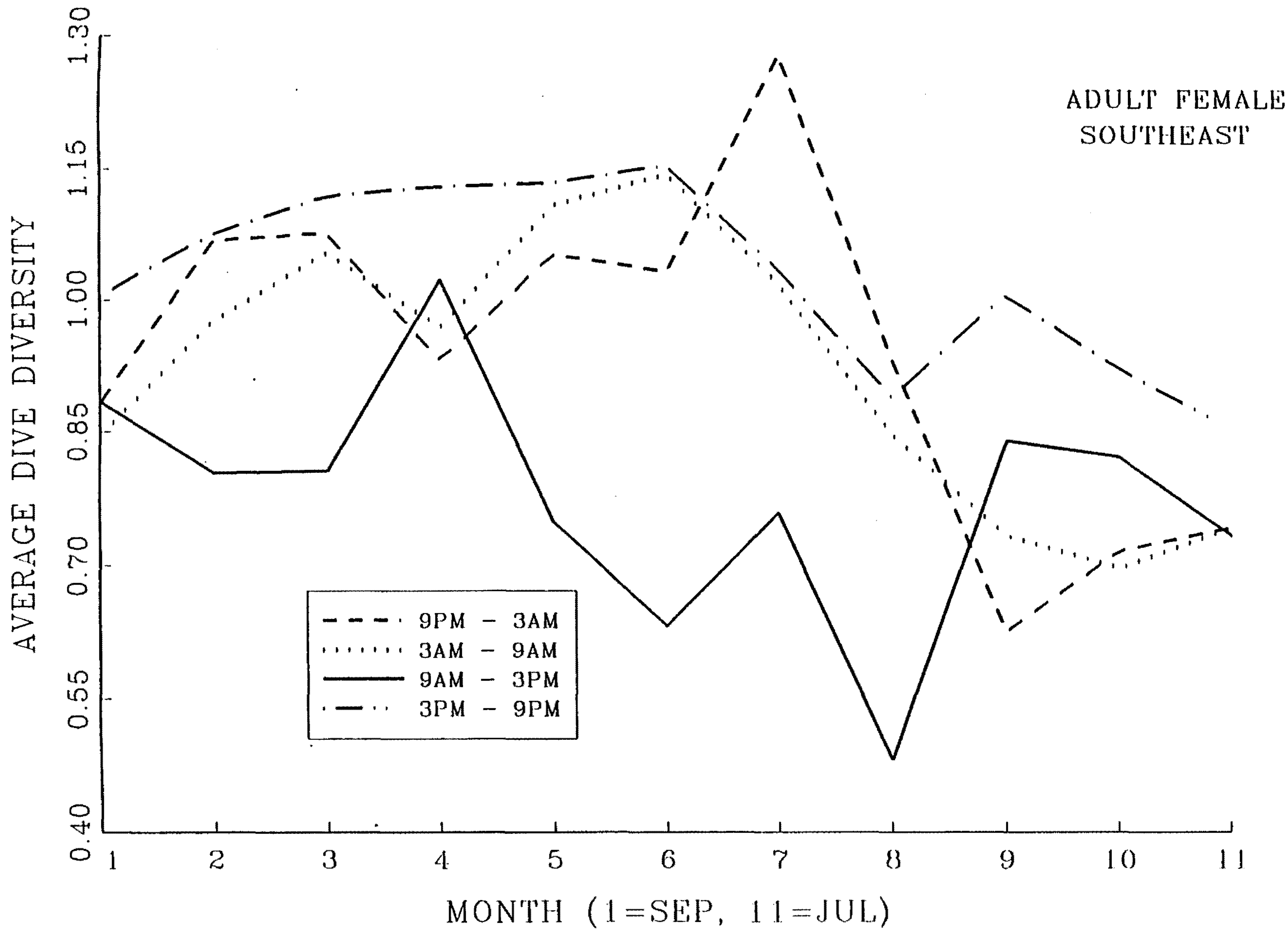


Figure 16c. Average dive diversity by month and time of day for 4 adult female SDR-tagged harbor seals in Southeast Alaska, April 1993 - July 1995.

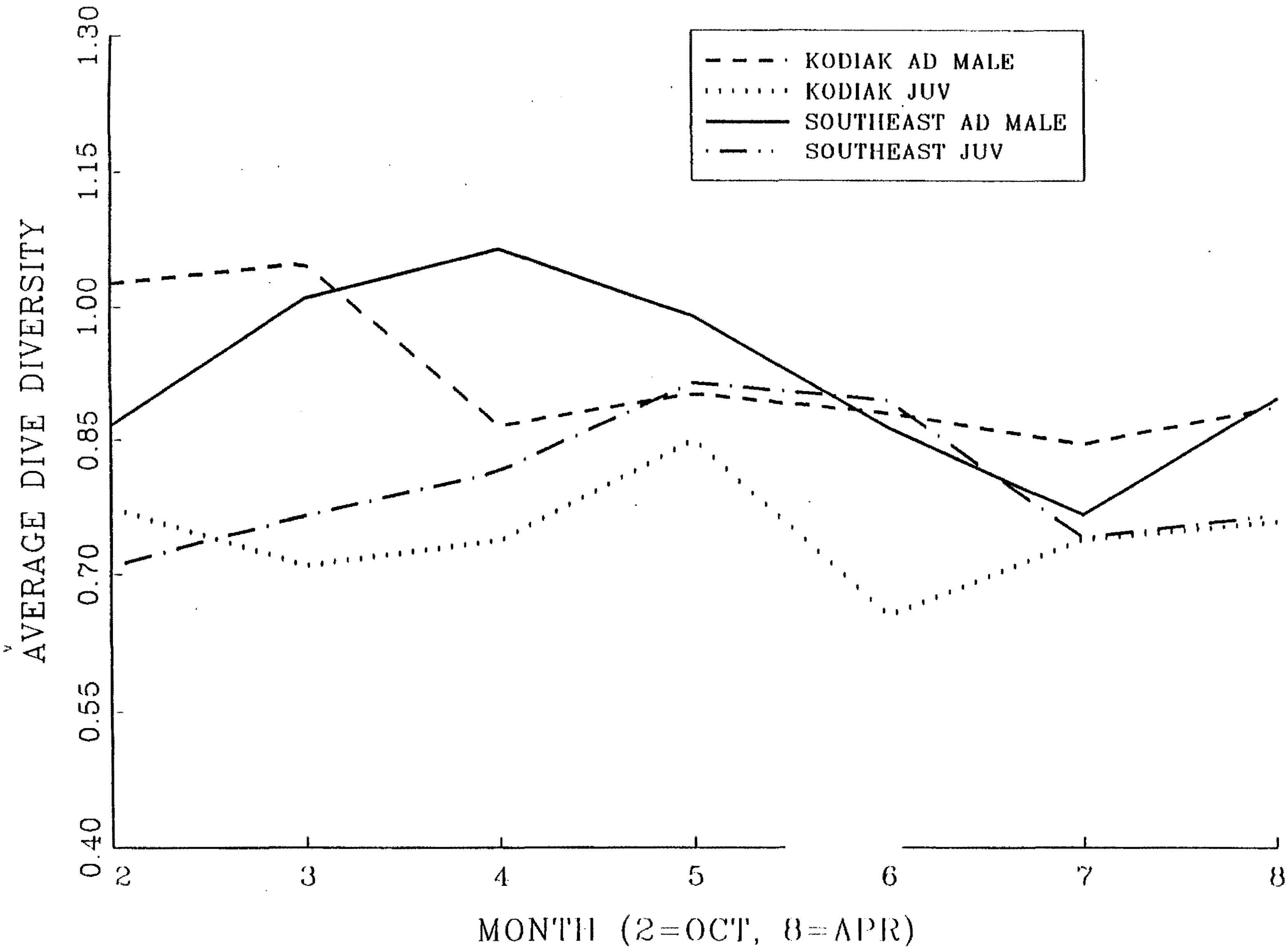


Figure 17. A comparison of average dive diversity between juvenile and adult male SDR-tagged harbor seals in Southeast Alaska and the Kodiak Island area, April 1993 - July 1995 (adult males:n=10 in Southeast Alaska, n=3 in Kodiak; juveniles: n=3 in Southeast Alaska, n=2 in Kodiak).

APPENDIX I

MOVEMENTS OF TAGGED HARBOR SEALS IN SOUTHEAST ALASKA AND KODIAK

Table 1A. Movements of SDR tagged harbor seals in Southeast Alaska and Kodiak Island during spring and fall 1993-94.

Spring 1993 - Southeast

SDR 3086 - Seal ID PV93SE2 - Adult Female
Gambier Bay; 4/5 - 5/22, 5/31 - 6/3
Pybus Bay; 5/23-31, 6/4 - 7/21

SDR 3087 - Seal ID PV93SE3 - Adult Male
Sail Island; 4/10 - 5/26, 6/3 -13, 6/20-26, 7/3-6, 7/10-19, 7/23 - 8/25
Tracy Arm Head; 5/28 - 6/1, 6/15-20, 7/8-10
Tracy Arm Mouth; 6/28-29, 7/19-21

SDR 3088 - Seal ID PV93SE4 - Subadult Male
Brothers Islands; 4/9 - 6/22, 7/14-20
Farragut Bay; 6/26-28
Thomas Bay; 6/30
Leconte Glacier; 7/1-11

SDR 3089 - Seal ID PV93SE9 - Adult Male
Frederick Sound; 4/10 - 8/14

SDR 3090 - Seal ID PV93SE7 - Adult Male
Brothers Island; 4/10 - 6/7, 7/26-29
Kake Area; 6/8 - 7/24

Fall 1993 - Southeast

SDR 2085 - Seal ID PV93SE16 - Adult Male
Gambier Bay; 9/18, 9/20-25, 10/25 - 11/27, 12/12 - 1/17, 2/4-17, 3/31 - 4/9
Seymour Canal; 9/19
Stephens Passage/Glass Peninsula; 9/26, 10/24, 12/10 -11, 1/18, 2/3, 3/30
Shelter Island; 9/29 - 10/4
Berners Bay; 10/5 - 10/7
Tracy Arm; 11/29 - 11/30, 12/8 - 9
Taku River; 12/3, 2/6 - 3/28

SDR 2086 - Seal ID PV93SE20 - Subadult Male
Gambier Bay; 9/18 - 1/5, 1/9 - 2/22, 3/4 - 4/21
Holkham Bay;1/7-8, 2/23 - 3/3

Table 1A (cont'd). Movements of SDR tagged harbor seals in Southeast Alaska and Kodiak Island during spring and fall 1993-94.

Fall 1993 - Southeast (cont'd)

SDR 2087 - Seal ID PV93SE18 - Adult Male
Gambier Bay; 9/18 - 10/5

SDR 2089 - Seal ID PV93SE10 - Adult Male
Gambier Bay; 9/14 - 10/1

SDR 2090 - Seal ID PV93SE15 - Adult Male
Gambier Bay; 9/18 - 1/18, 1/29 - 5/11
Port Houghton; 1/19-25
Endicott Arm; 1/26

SDR 2094 - Seal ID PV93SE19 - Subadult Female
Gambier Bay; 9/18 - 10/7, 10/16 - 3/11
Cape Fanshaw, Pt. Houghton; 10/8-15, 3/12
Stikine River; 3/13 - 4/3
Leconte Glacier; 4/4 - 4/27

Fall 1994 - Southeast

SDR 5039 - Seal ID PV94SE5 - Adult Female
Gambier Bay; 9/13-14, 9/21 - 11/4, 11/20 - 1/3,
Seymour Canal; 9/15-16, 11/15
Holkham Bay; 9/17, 1/31
Endicott Arm and Glacier; 9/18-20, 2/1-3
Port Snettisham; 11/16-17
Stephens Passage and Glass Peninsula; 11/18-19, 1/4
Auke Bay; 1/5-7
Berner's Bay; 1/8, 1/16
Chilkat Peninsula (Haines); 1/9-15
Douglas Island; 1/17-30

SDR 5045 - Seal ID PV94SE7 - Adult Male
Gambier Bay; 9/13 - 7/14

SDR 5047 - Seal ID PV94SE2 - Adult Female
Gambier Bay; 9/13 - 6/7

Table 1A (cont'd). Movements of SDR tagged harbor seals in Southeast Alaska and Kodiak Island during spring and fall 1993 -94.

<u>**Fall 1994 - Southeast (cont'd)**</u>

<u>SDR 5049 - Seal ID PV94SE3 - Adult Male</u>
Gambier Bay; 9/13 - 5/1

<u>SDR 5050 - Seal ID PV94SE8 - Adult Female</u>
Gambier Bay; 9/13-20, 11/6, 11/16, 12/4 - 1/1
Eliza Harbor; 9/21, 11/22-26
SW Tip of Admiralty I.; 9/22, 11/5
Hood Bay / Chatham Strait; 9/23 - 11/4
Seymour Canal; 11/7-14, 1/2 - 5/11
Stephens Passage; 11/15
Pybus Bay; 11/17-21, 11/27 - 12/3

<u>SDR 5051 - Seal ID PV94SE9 - Adult Male</u>
Gambier Bay; 9/13 - 4/15

<u>**Spring 1993 - Kodiak**</u>

<u>SDR 5044 - Seal ID PV93KO1 - Adult Female</u>
Sitkinak Island; 4/23 - 7/25

<u>SDR 5045 - Seal ID PV93KO2 - Adult Female</u>
Sitkinak Island; 4/25 - 7/20

<u>SDR 5046 - Seal ID PV93KO3 - Adult Female</u>
Sitkinak Island; 4/26 - 7/12

<u>SDR 5047 - Seal ID PV93KO4 - Adult Female</u>
Aiaktalik Island; 4/27 - 5/3, 5/16 - 6/15
Ugak Island; 5/5-11

Table 1A (cont'd). Movements of SDR tagged harbor seals in Southeast Alaska and Kodiak Island during spring and fall 1993-94.

Fall 1993 - Kodiak

SDR 5048 - Seal ID PV93KO4 - Adult Female
Tugidak Island; 10/5-20, 10/26-30, 11/3-9
Sitkinak Island; 10/22-25
Alitak; 11/1-2, 11/11-18

Fall 1994 - Kodiak

SDR 5041 - Seal ID PV94KO4 - Subadult Female
Ugak Bay; 10/7-8
Outer Kiliuda Bay / N. Sitkalidak I; 10/9, 10/15
S. Sitkalidak I.; 10/10
Gesse Islands; 10/11-13
Kiliuda Bay; 10/16-19
Kiliuda Bay (head); 10/22-26
Outer Kiliuda Bay; 10/26 - 1/19

SDR 5042 - Seal ID PV94KO1 - Adult Male
Ugak Bay; 10/6 - 4/21

SDR 5043 - Seal ID PV94KO2 - Adult Male
Ugak Bay; 10/5 - 7/5

SDR 5044 - Seal ID PV94KO9 - Subadult Female
Kiliuda Bay; 10/8-9, 10/11
Ugak Bay (mouth) / Ugak I.; 10/10, 10/13 - 12/14, 1/12-26, 2/8 - 3/10, 3/14 - 6/23
Sitkalidak I.; 1/6, 2/7
Cape Chiniak; 1/7, 1/10
Ugak Bay (head); 3/13

SDR 5046 - Seal ID PV94KO8 - Adult Male
Kiliuda Bay (head); 10/8-21, 11/18 - 5/18, 5/29
Kiliuda Bay (mouth) / Sitkalidak I.;10/26 - 11/18, 5/19-28, 5/30 - 6/2

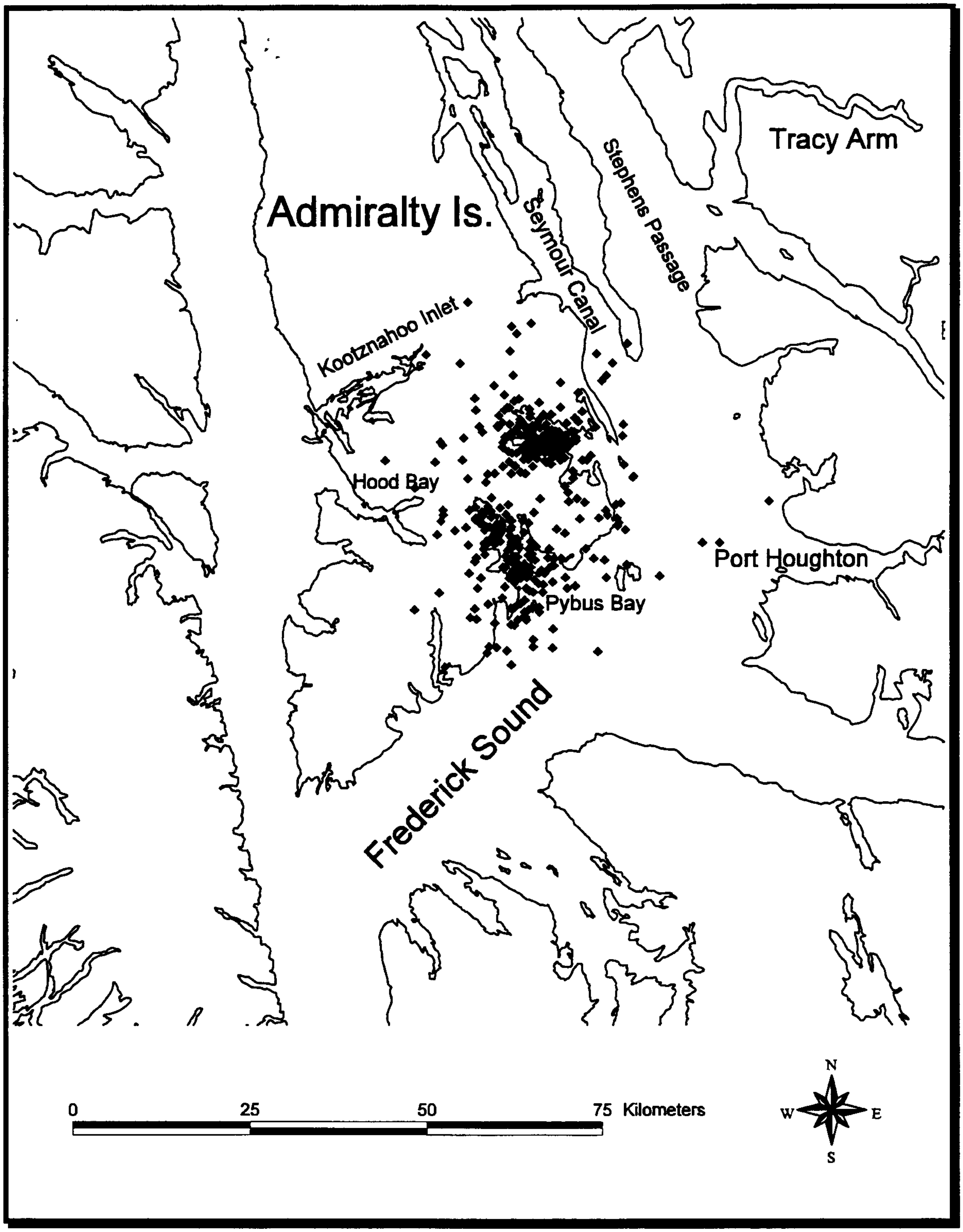


Figure 1A. Adult Female. SDR 3086. Seal ID PV93SE2. April 5, 1993 through July 21, 1993. Capture Location - Gambier Bay.

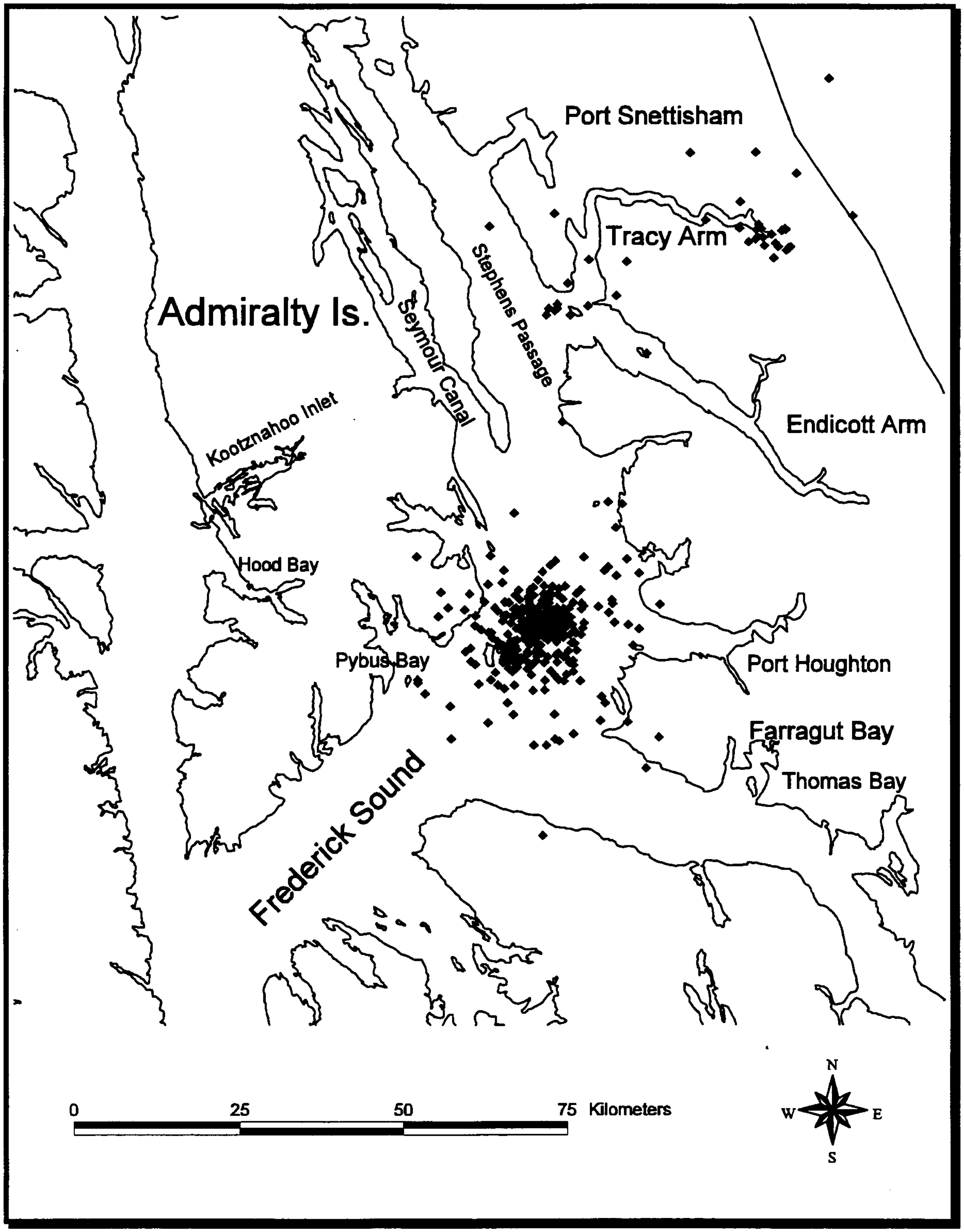


Figure 2A. Adult Male. SDR 3087. Seal ID PV93SE3. April 10, 1993 through August 25, 1993. Capture Location - Sail I.

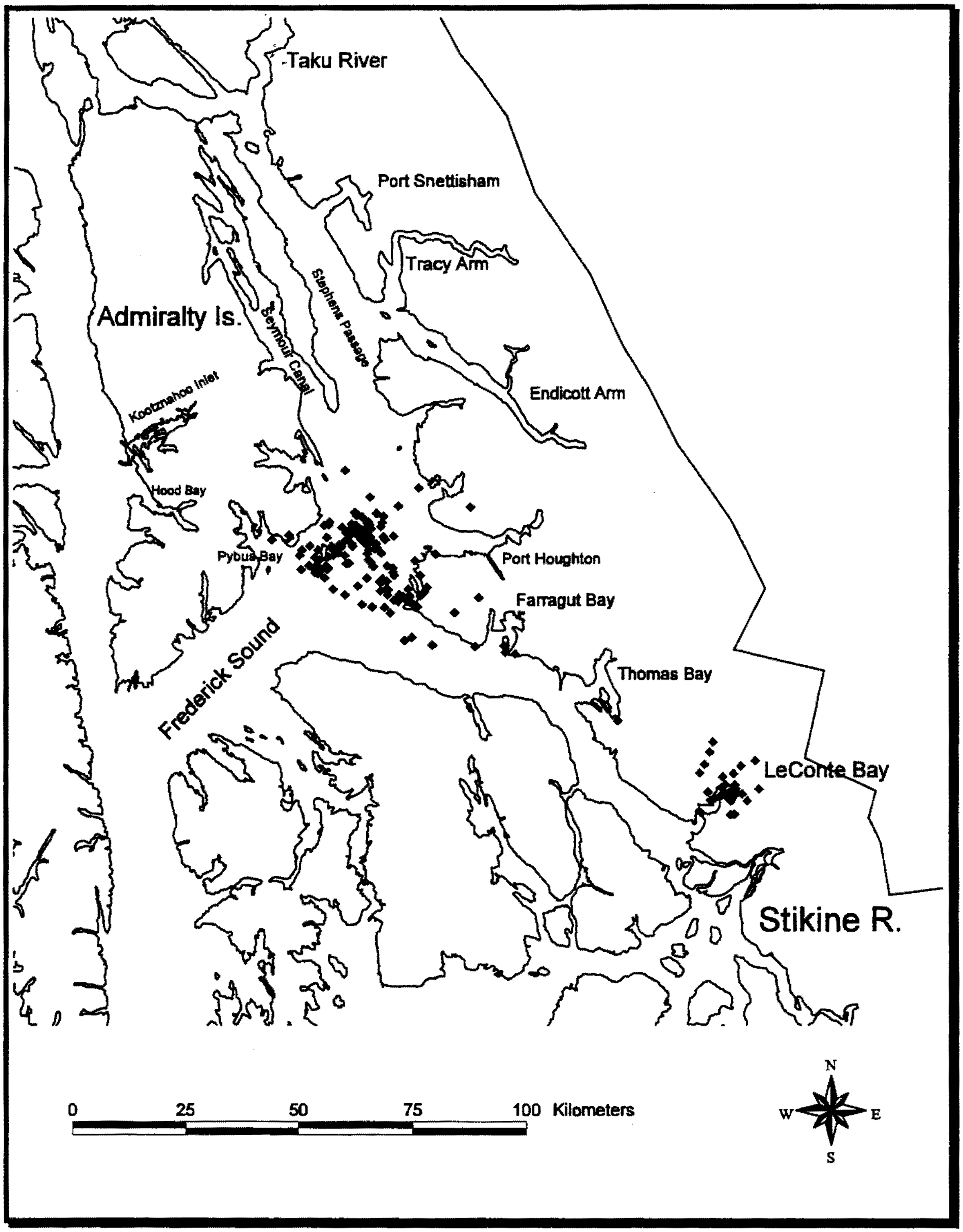


Figure 3A. Subadult Male. SDR 3088. Seal ID PV93SE4. April 9, 1993 through July 20, 1993. Capture Location - SW Brothers I.

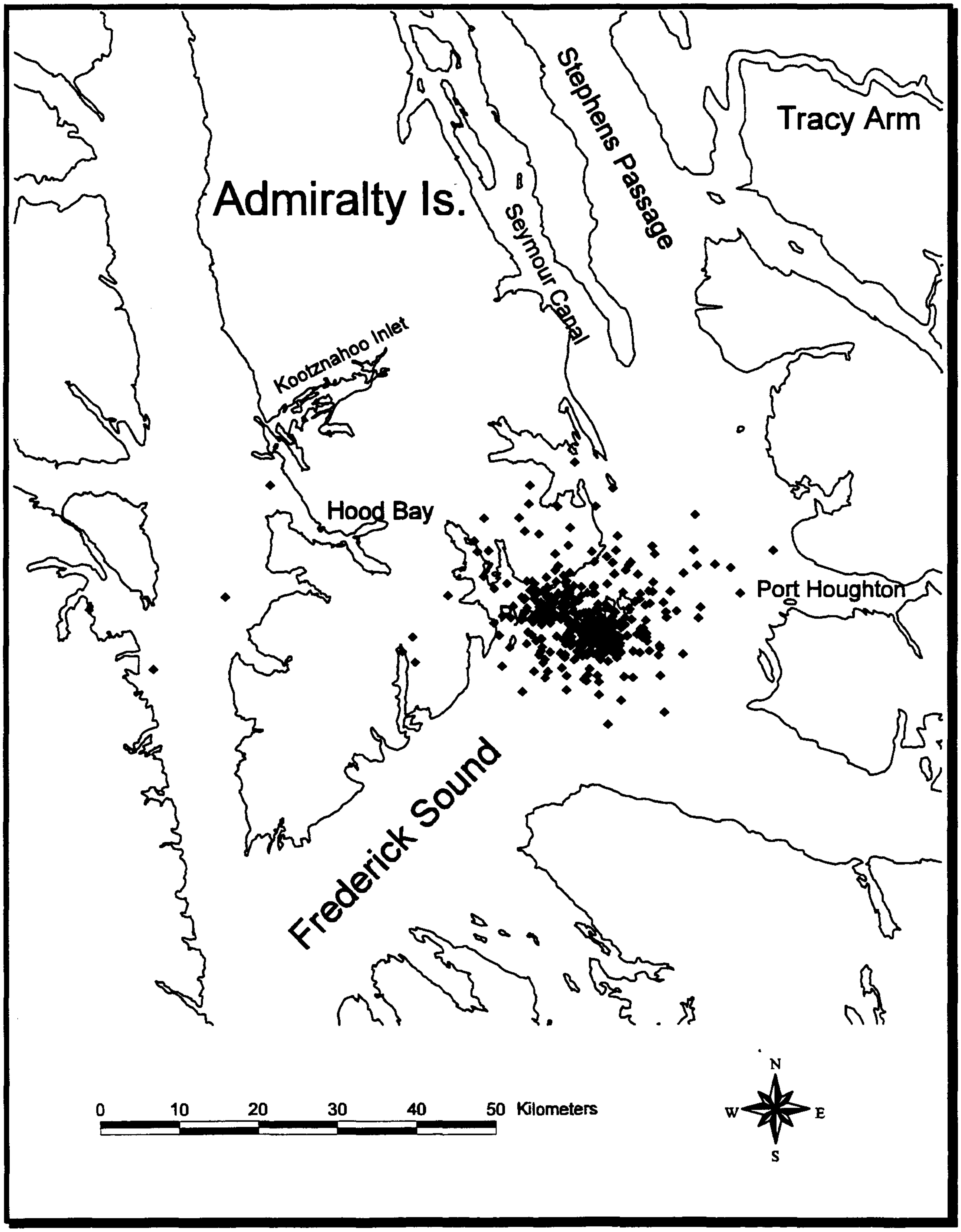


Figure 4A. Adult Male. SDR 3089. Seal ID PV93SE9. April 10, 1993 through August 14, 1993. Capture Location - SW Brothers I.

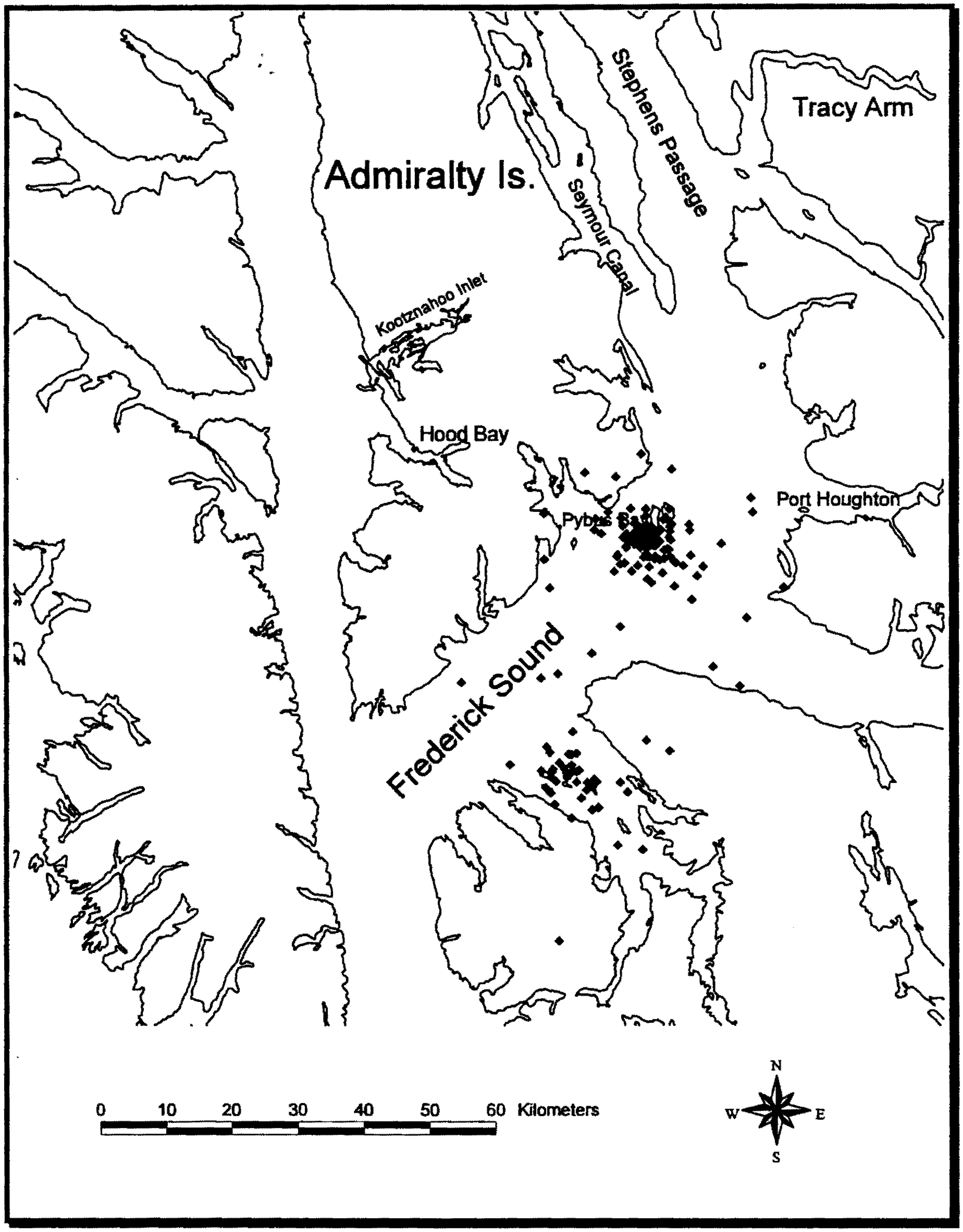


Figure 5A. Adult Male. SDR 3090. Seal ID PV93SE7. April 10, 1993 through July 29, 1993. Capture Location - SW Brothers I.

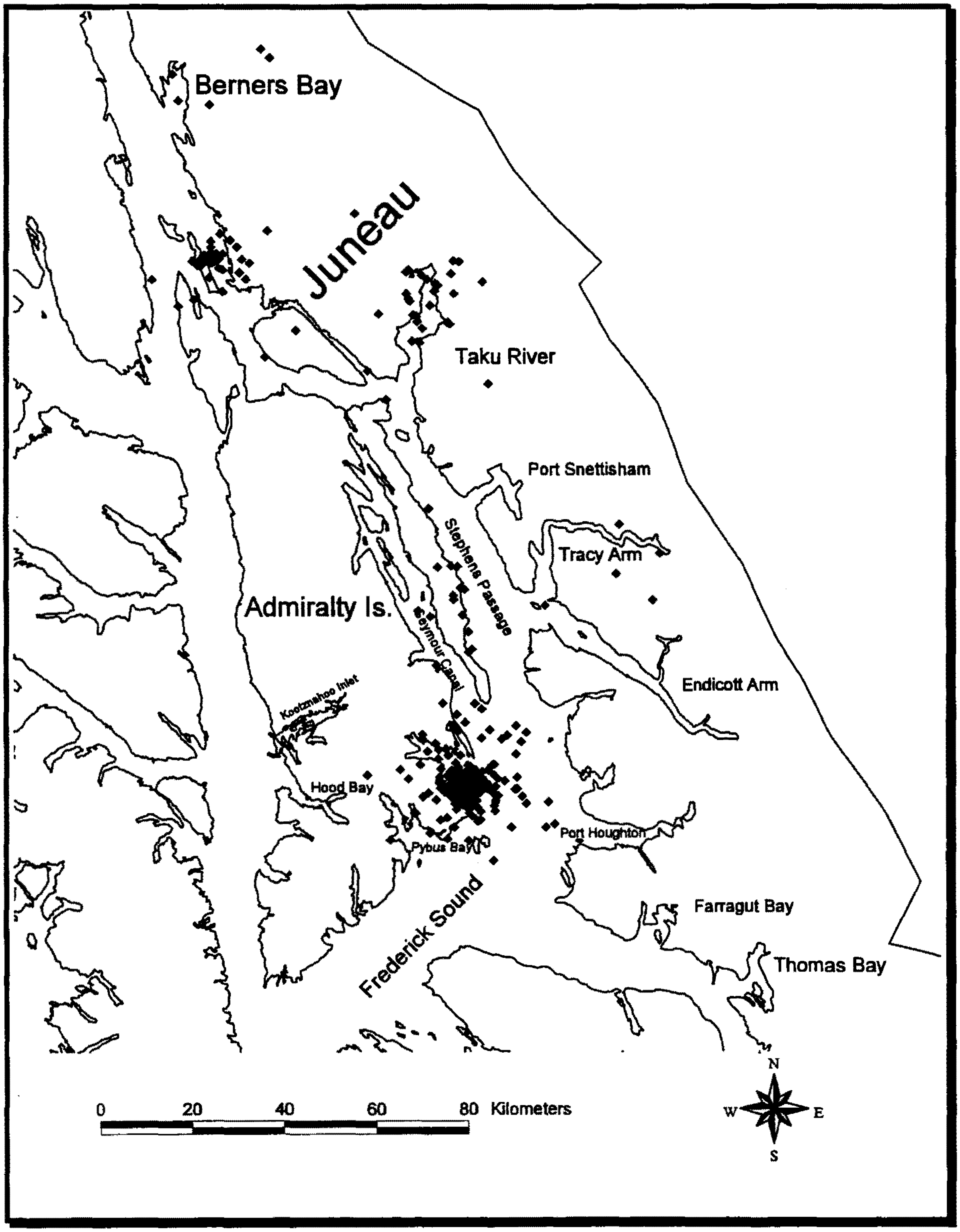


Figure 6A. Adult Male. SDR 2085. Seal ID PV93SE16. Sept. 18, 1994 through April 9, 1995. Capture Location - Price I.

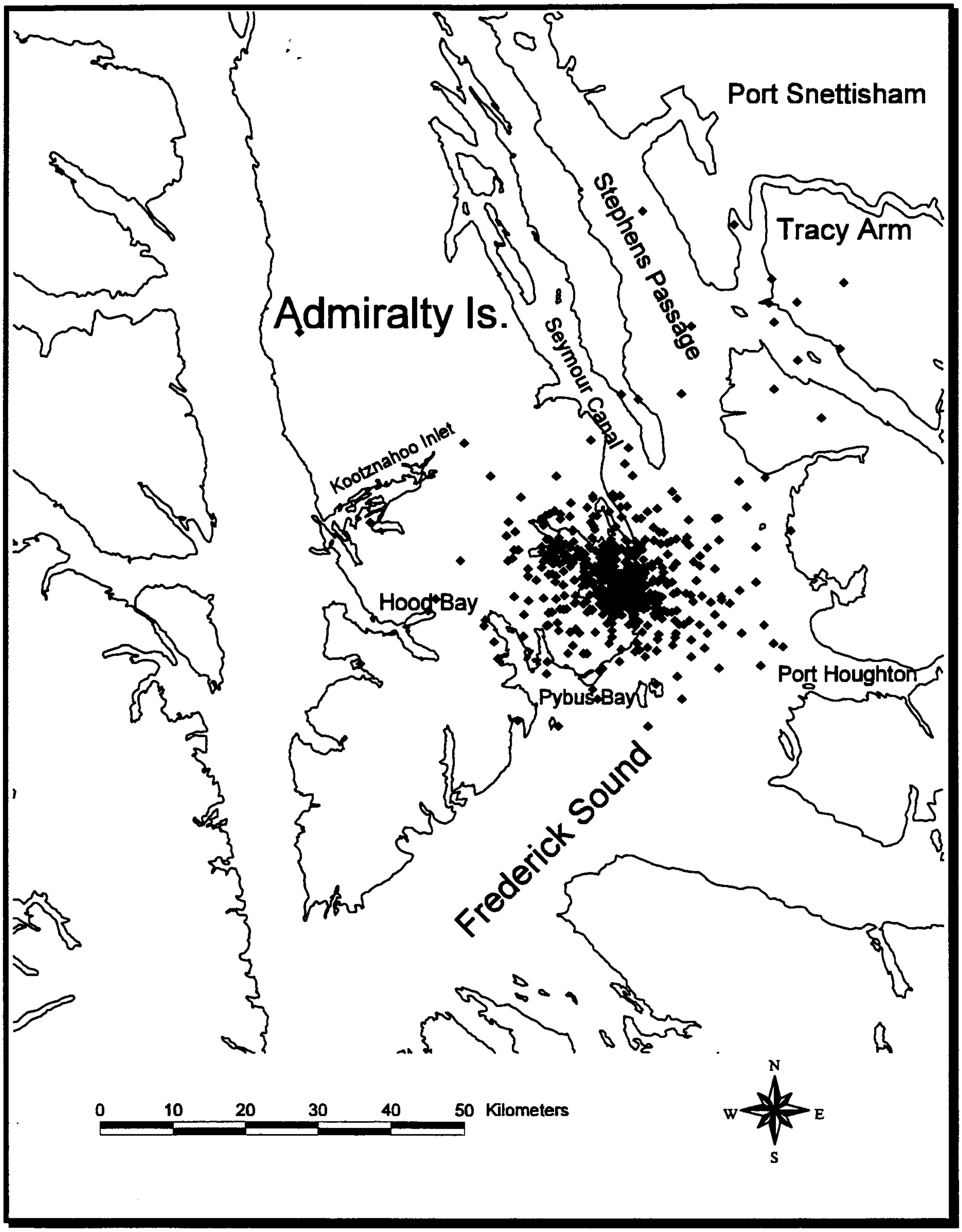


Figure 7A. Adult Male. SDR 2086. Seal ID PV93SE20. Sept. 18, 1993 through April 21, 1994. Capture Location - Price I.

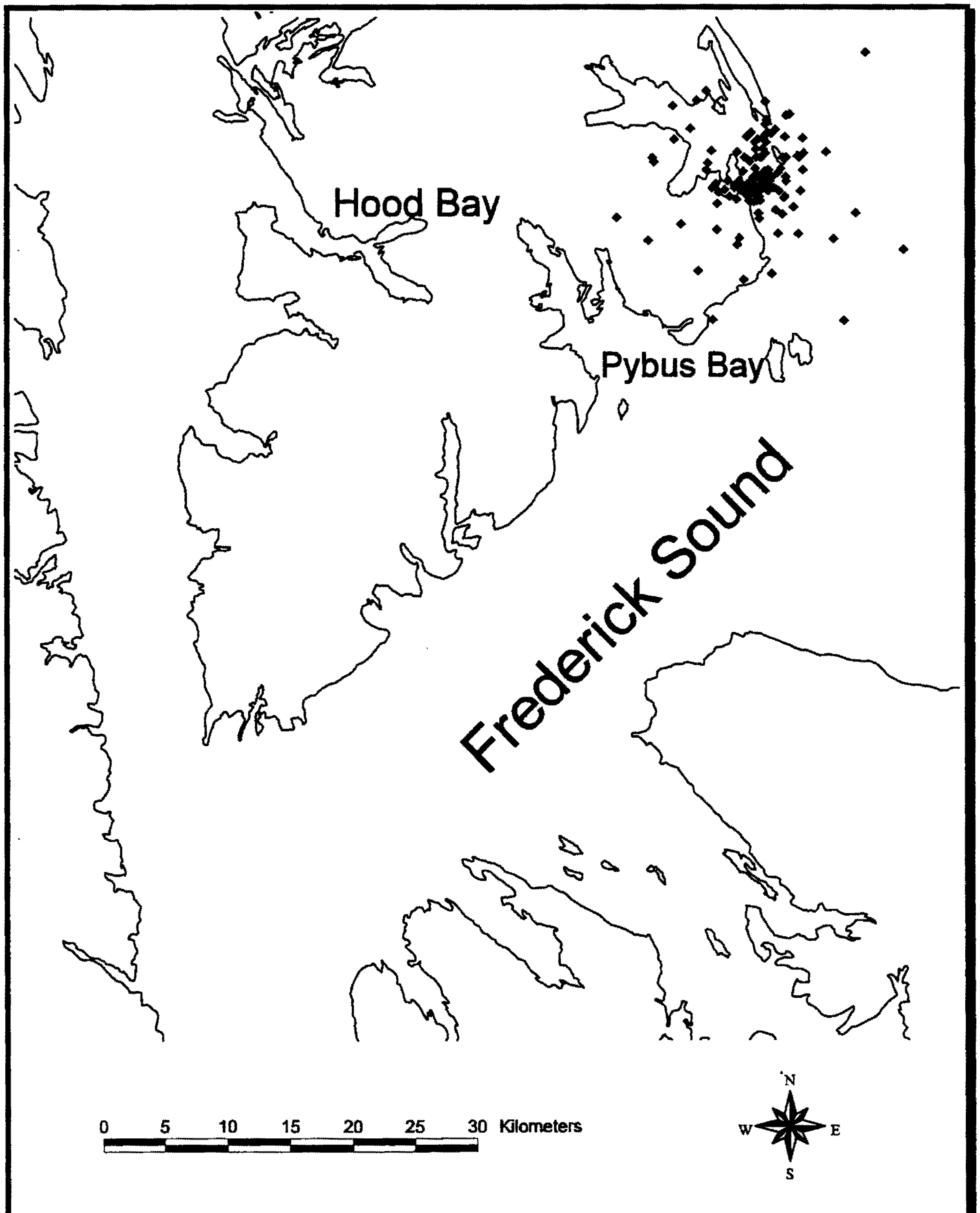


Figure 8A. Adult Male. SDR 2087. Seal ID PV93SE18. Sept. 18, 1993 through Oct. 5, 1993. Capture Location - Price I.

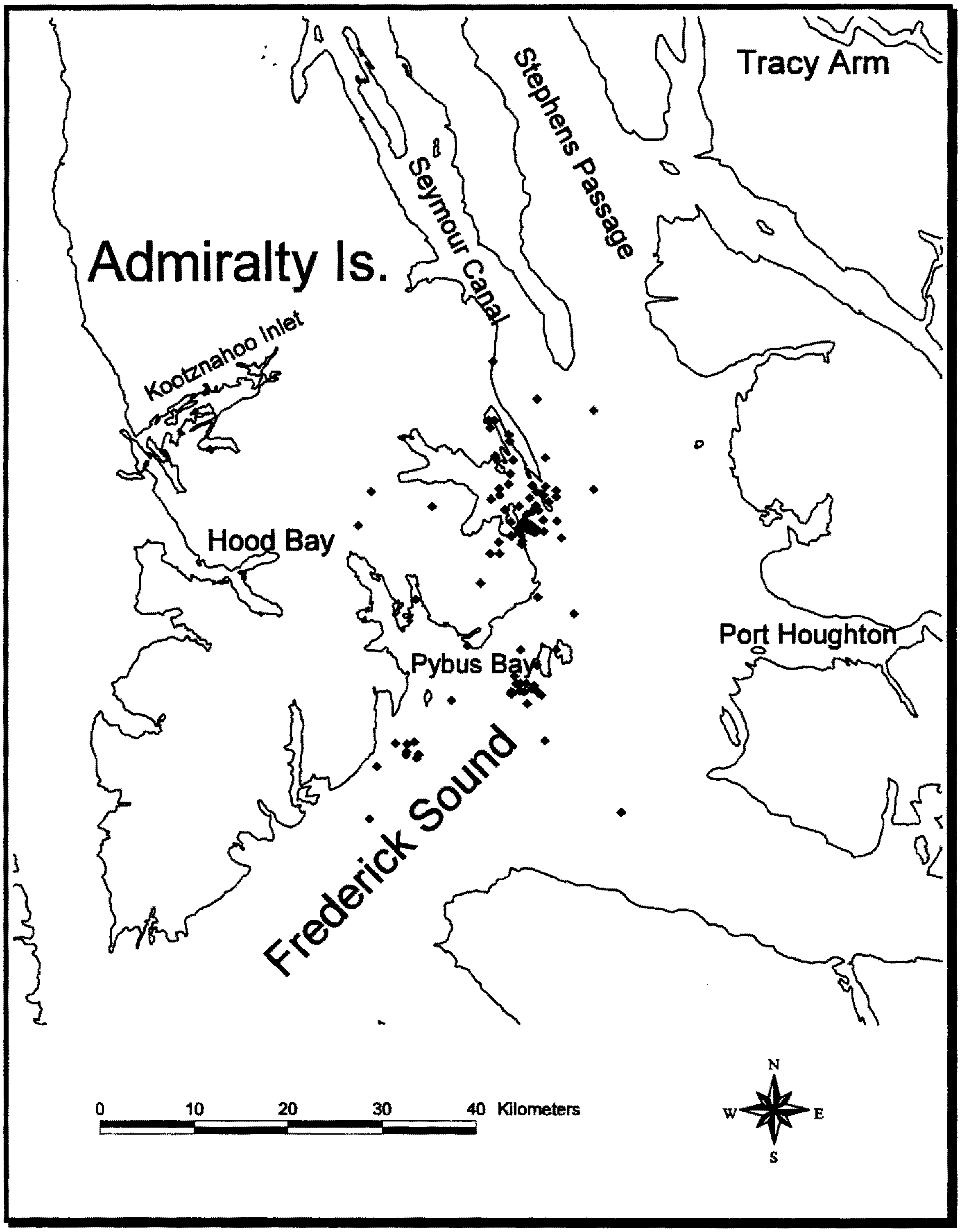


Figure 9A. Adult Male. SDR 2089. Seal ID PV93SE10. Sept. 14, 1993 through October 1, 1993. Capture Location - Price I.

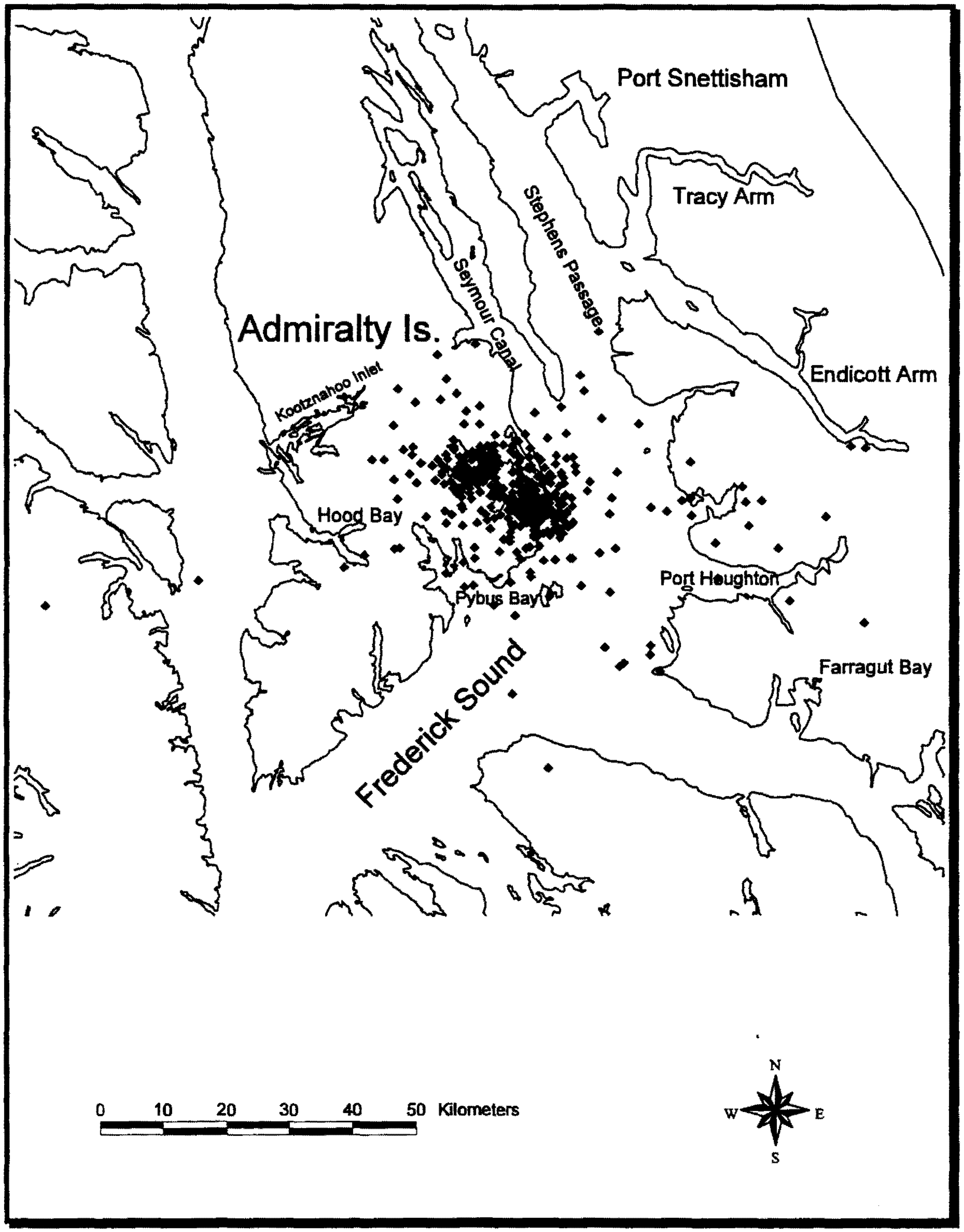


Figure 10A. Adult Male. SDR 2090. Seal ID PV93SE15. Sept. 18, 1993 through May 11, 1994. Capture Location - Price I.

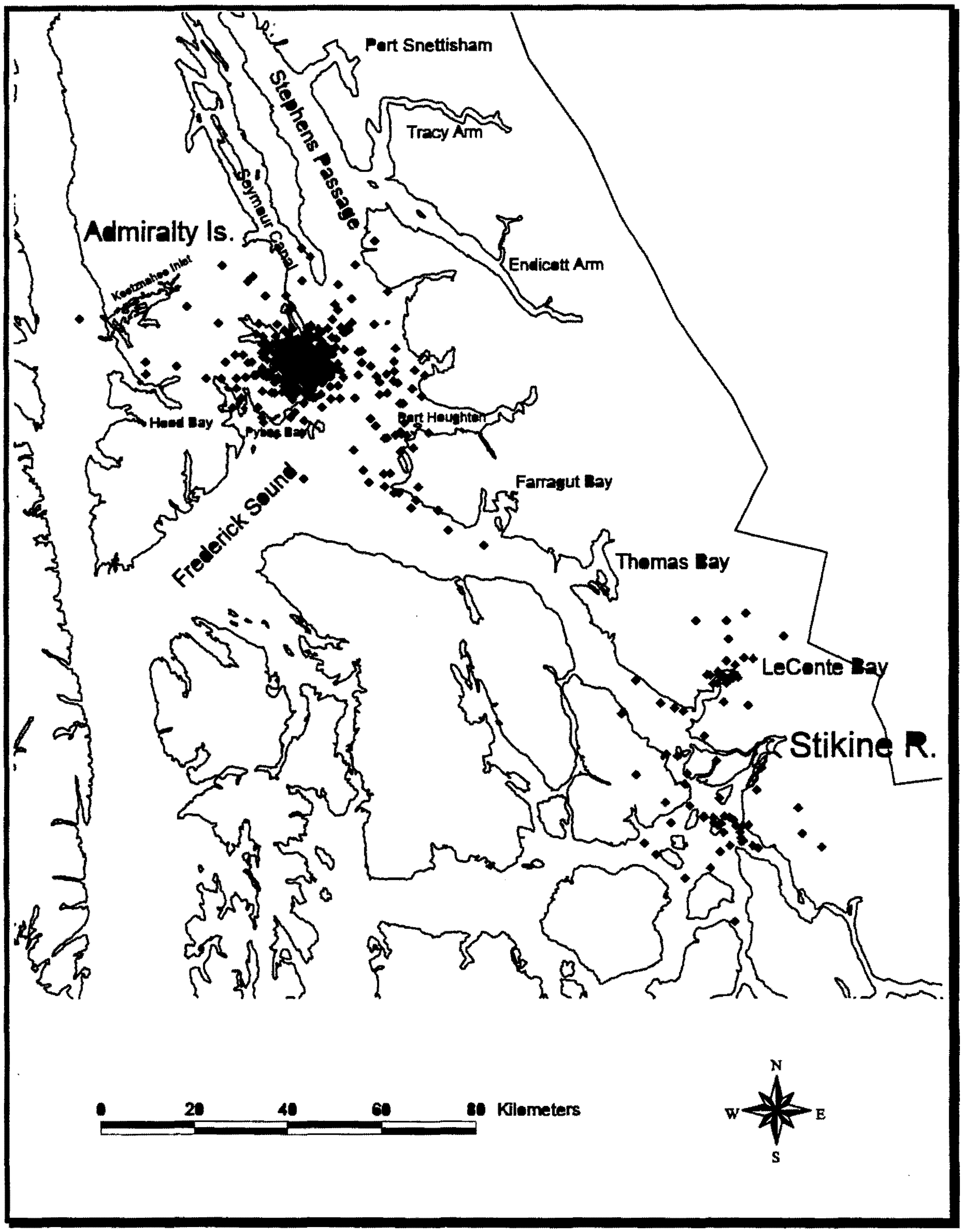


Figure 11A. Subadult Female. SDR 2094. Seal ID PV93SE19. Sept. 18, 1993 through April 27, 1994. Capture Location - Price Island.

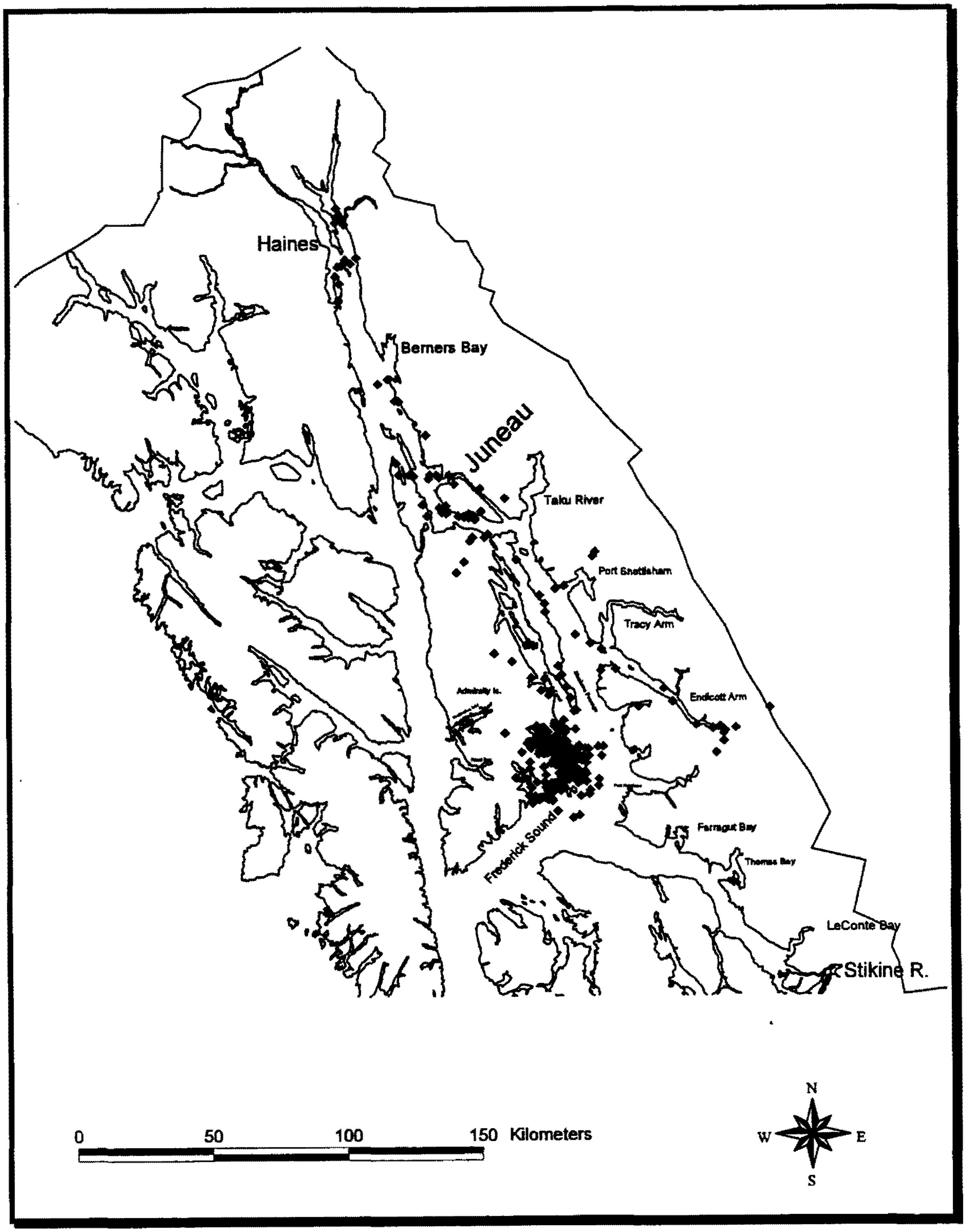


Figure 12A. Adult Female . SDR 5039. Seal ID PV94SE5. Sept. 13, 1994 through Feb. 3, 1995. Capture Location - Price I.

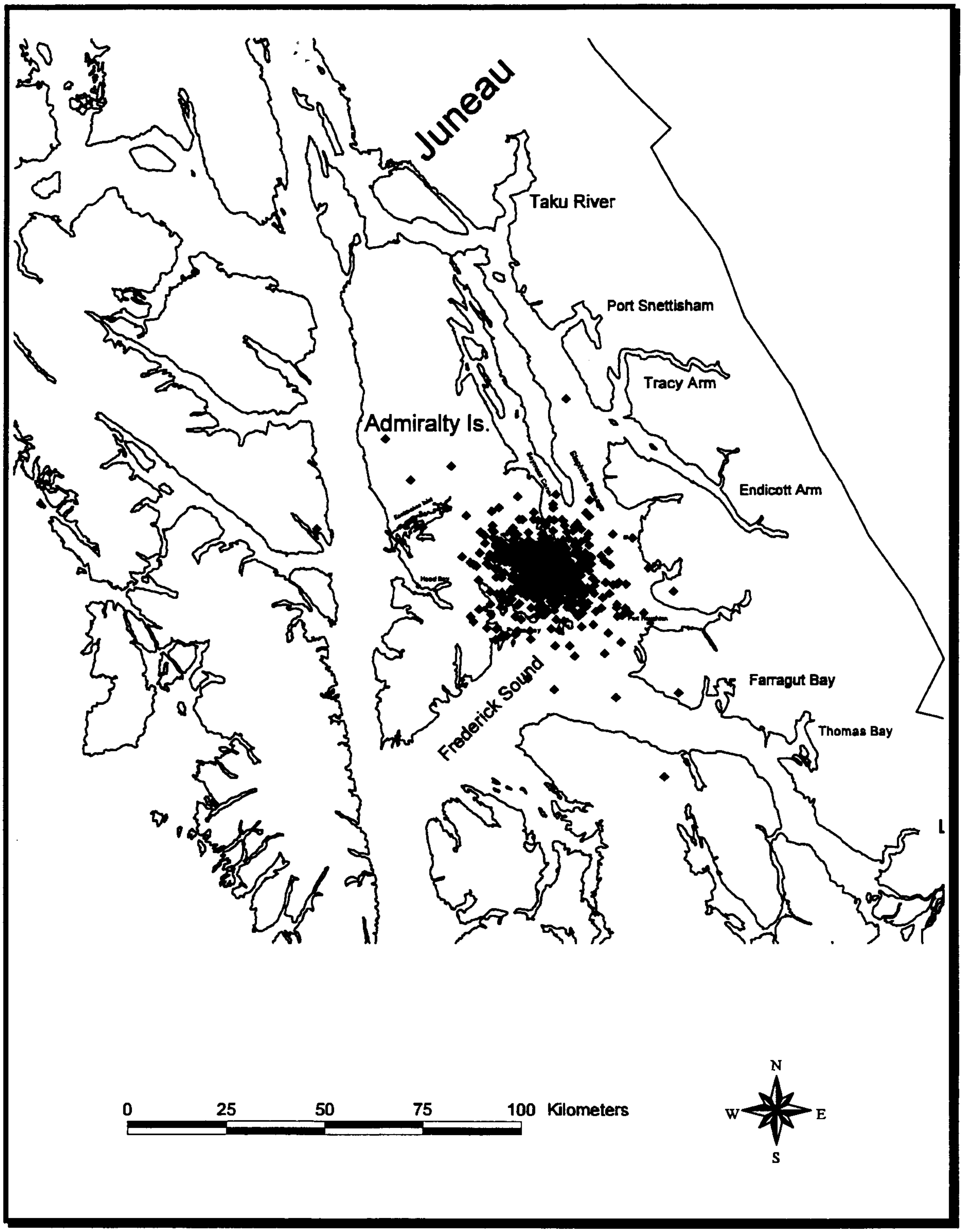


Figure 13A. Adult Male. SDR 5045. Seal ID PV94SE7. Sept. 13, 1994 through July 14, 1995. Capture Location - Price I.

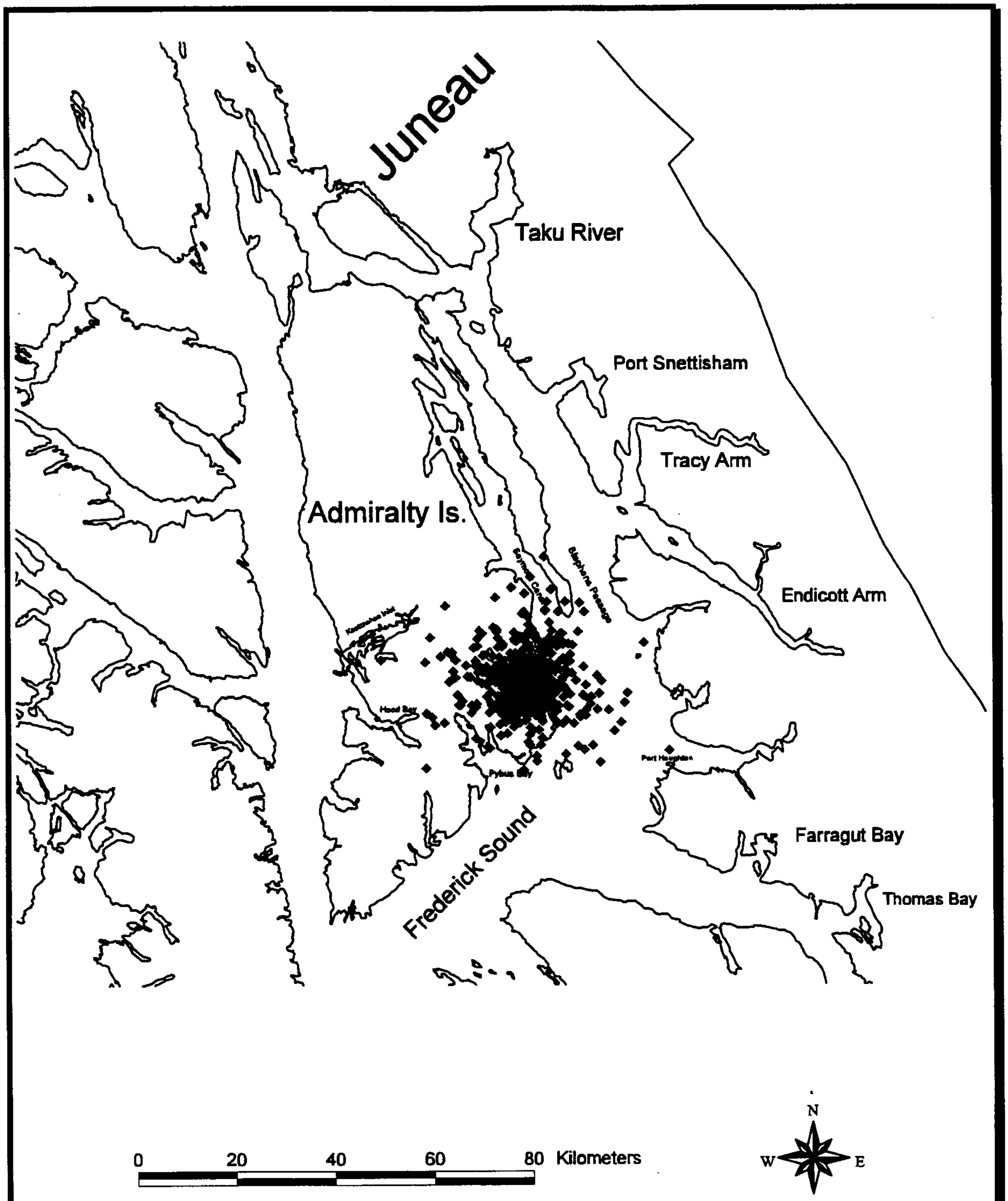


Figure 14A. Adult Female. SDR 5047. Seal ID PV94SE2. Sept. 13, 1994 through June 7, 1995. Capture Location - Price I.

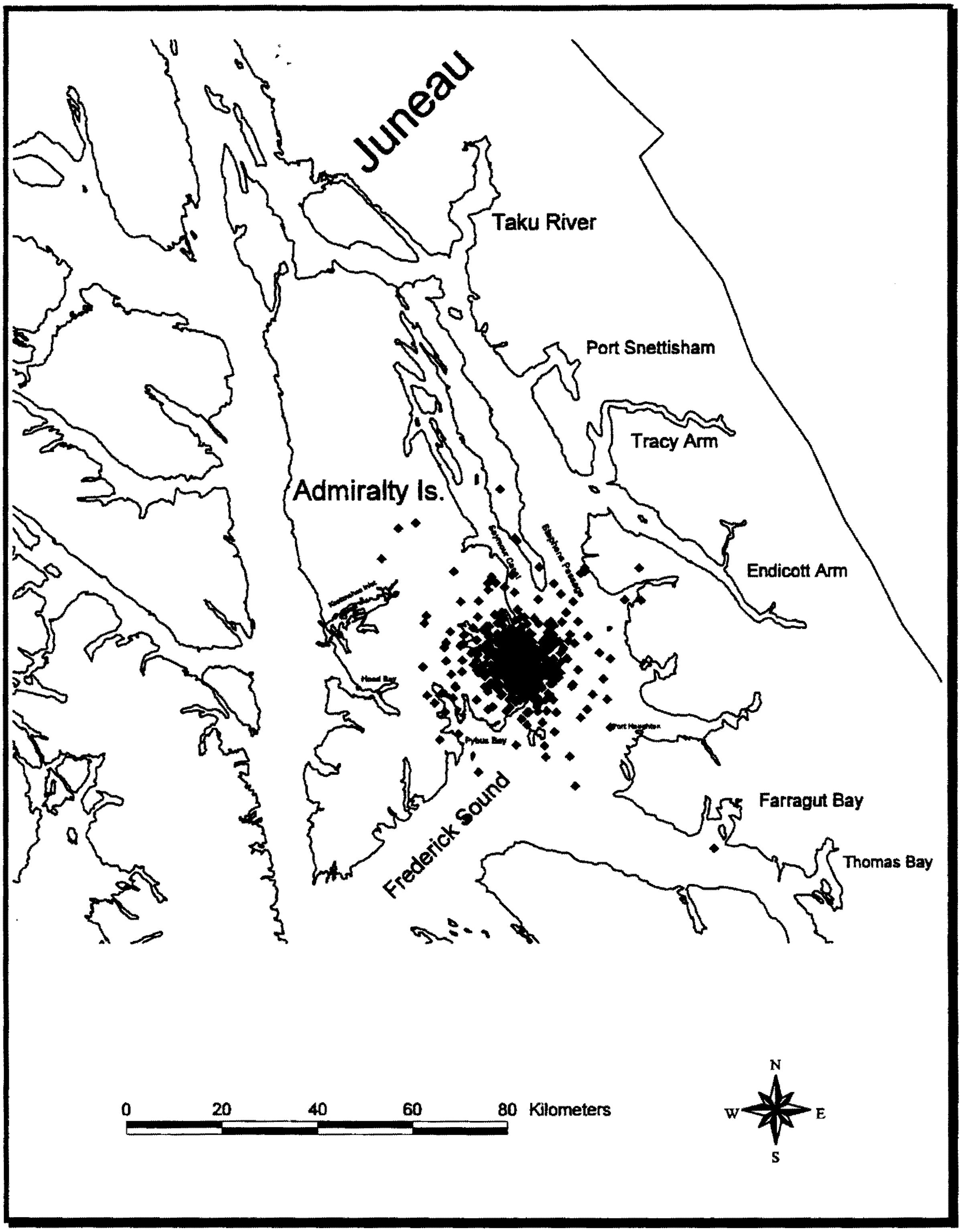


Figure 15A. Adult Male. SDR 5049. Seal ID PV94SE3. Sept. 13, 1994 through May 1, 1995. Capture Location - Price I.

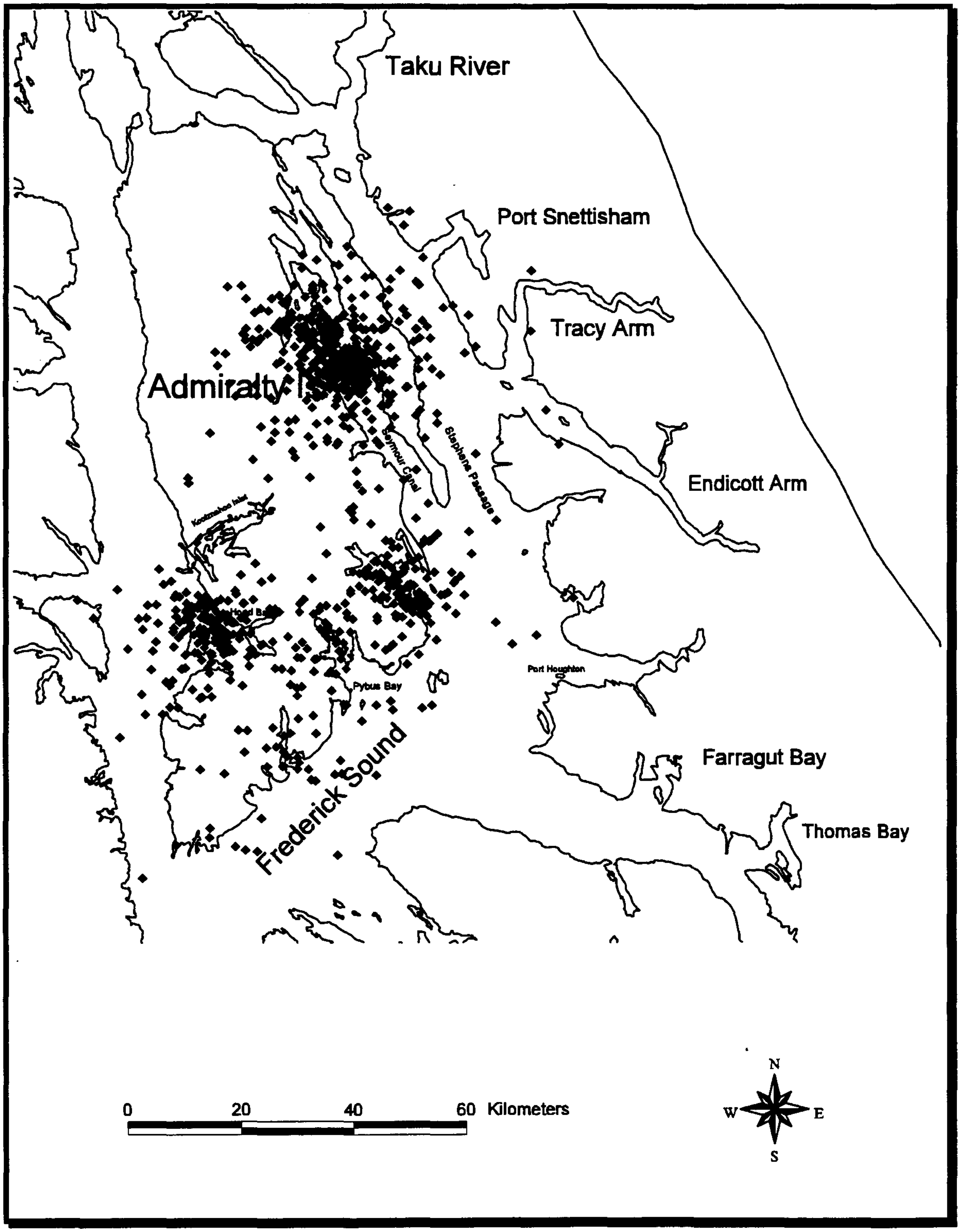


Figure 16A. Adult Female. SDR 5050. Seal ID PV94SE8. Sept. 13, 1994 through May 11, 1995. Capture Location - Price I.

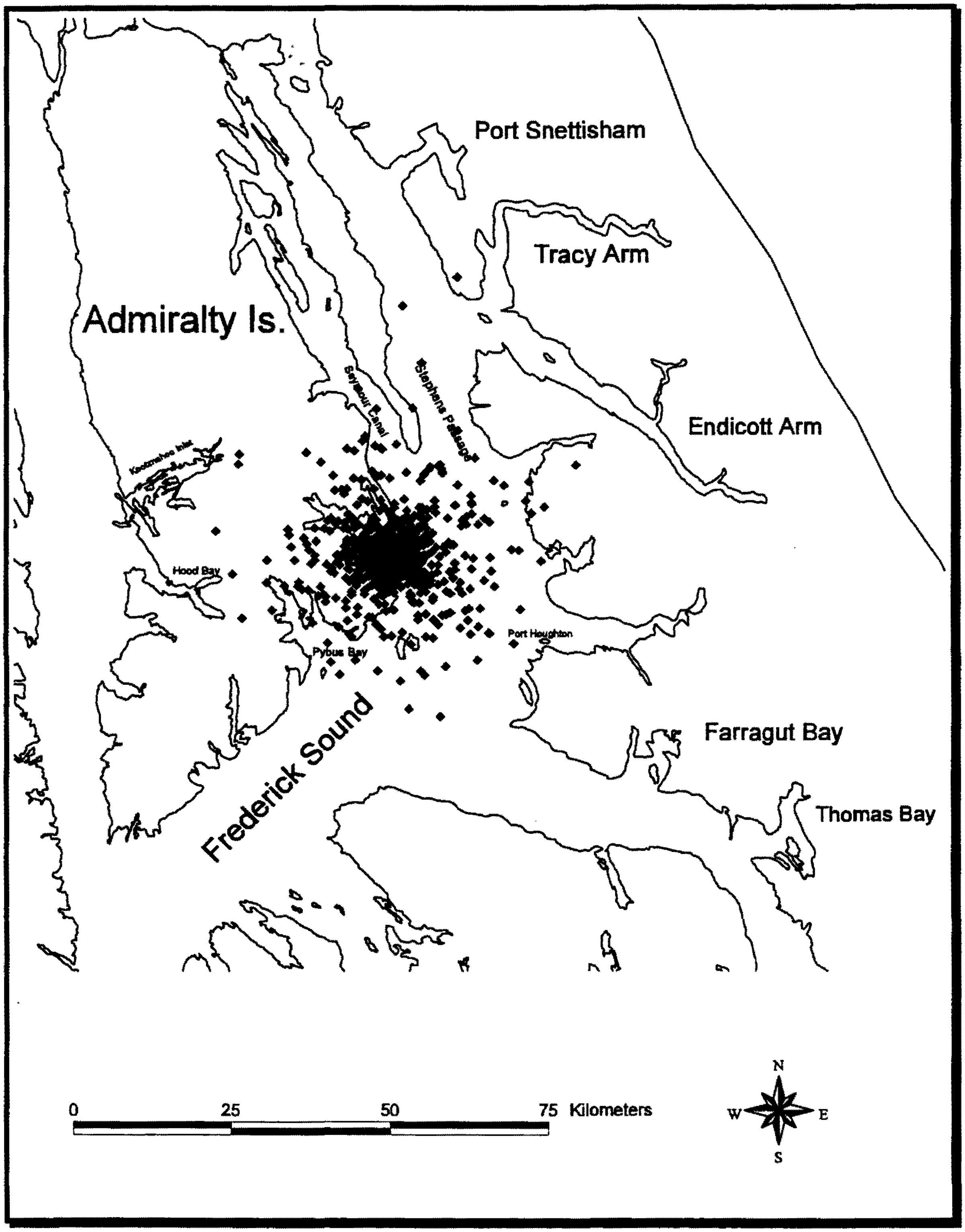


Figure 17A. Adult Male. SDR 5051. Seal ID PV94SE9. Sept. 13, 1994 through April 13, 1995. Capture location - Price I.

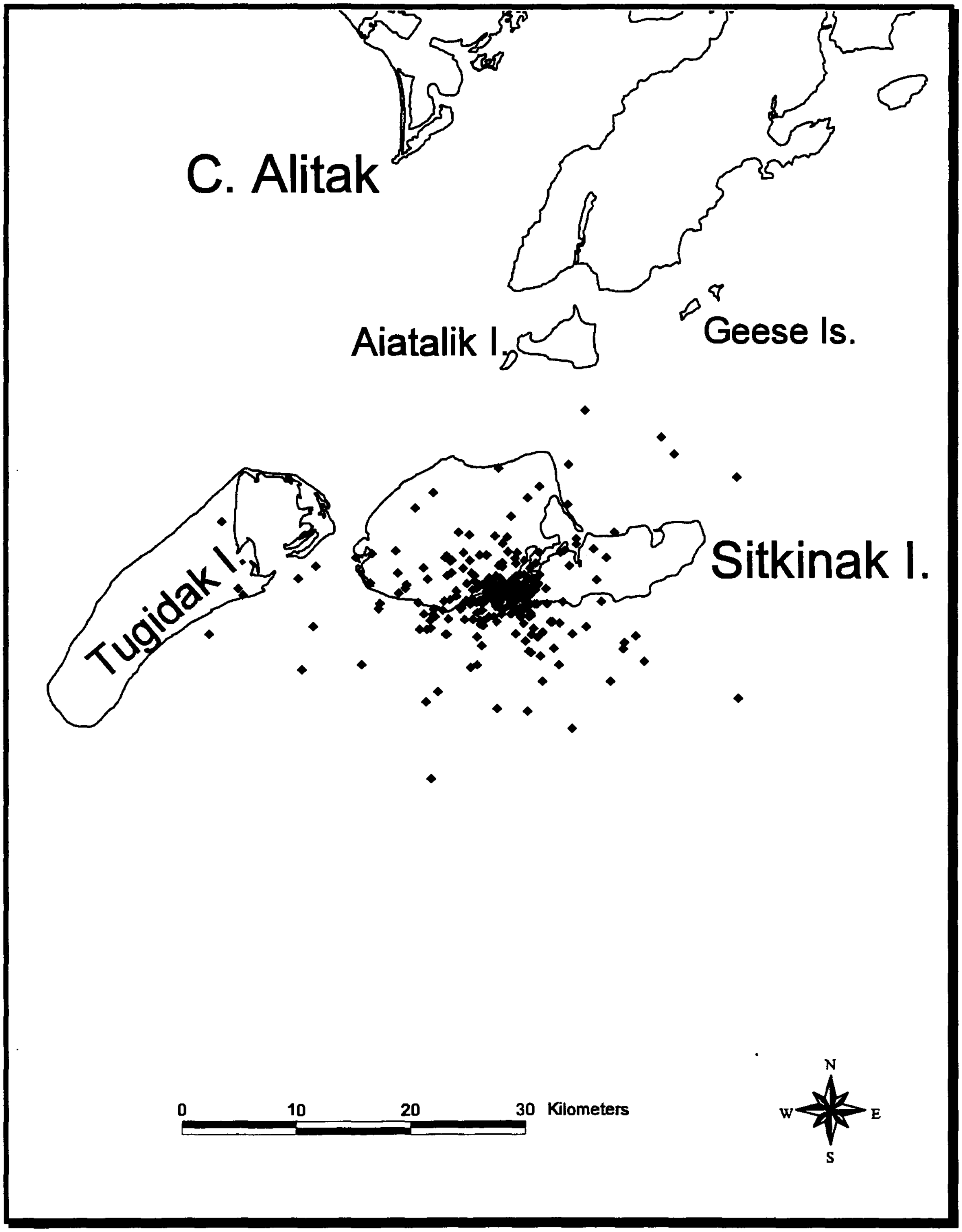


Figure 18A. Adult Female. SDR 5044. Seal ID PV93KO1. April 23, 1993 through July 25, 1993. Capture Location - Sitkinak I.

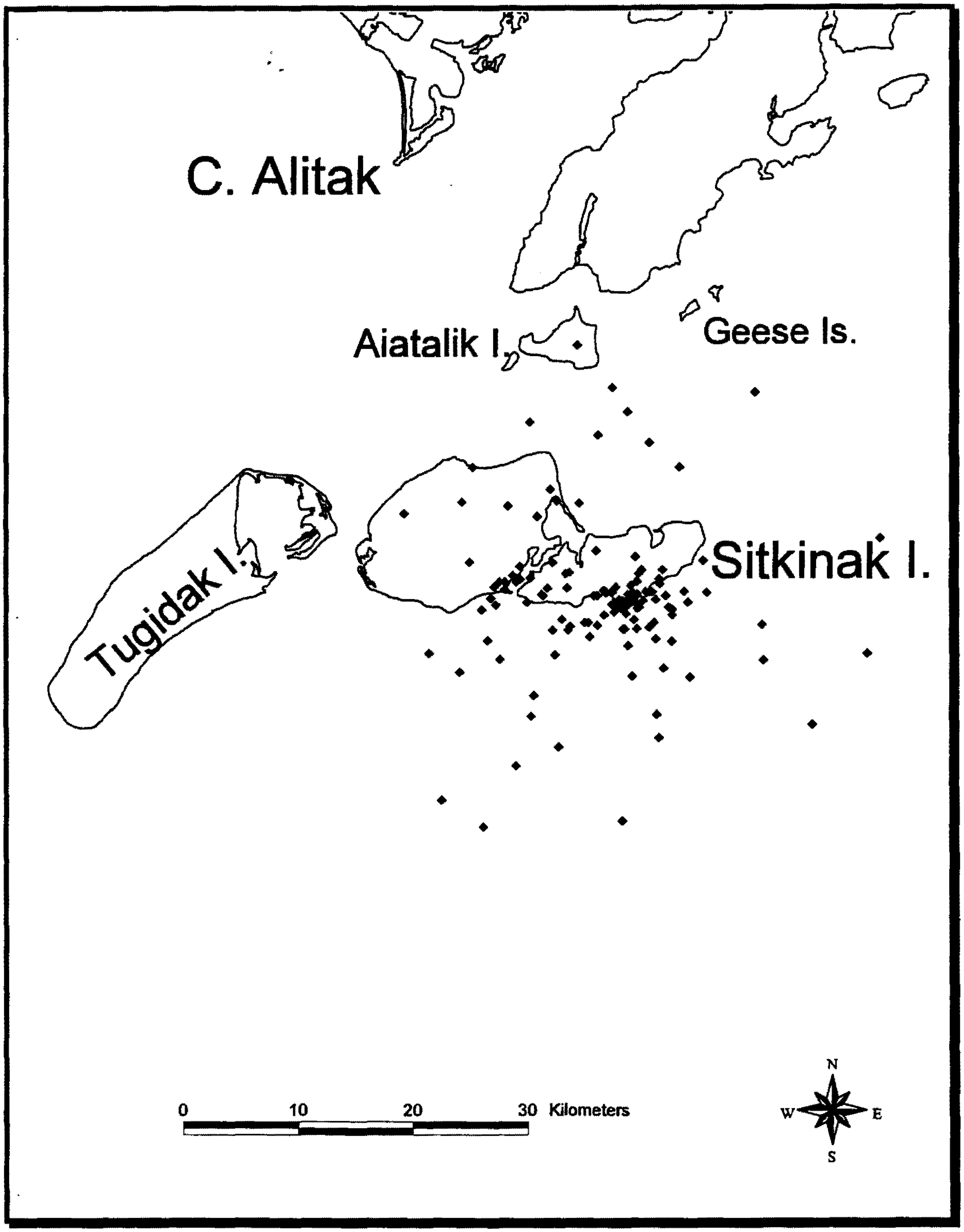


Figure 19A. Adult Female. SDR 5045. Seal ID PV93KO2. April 25, 1993 through July 20, 1993. Capture Location - Sitkinak I.

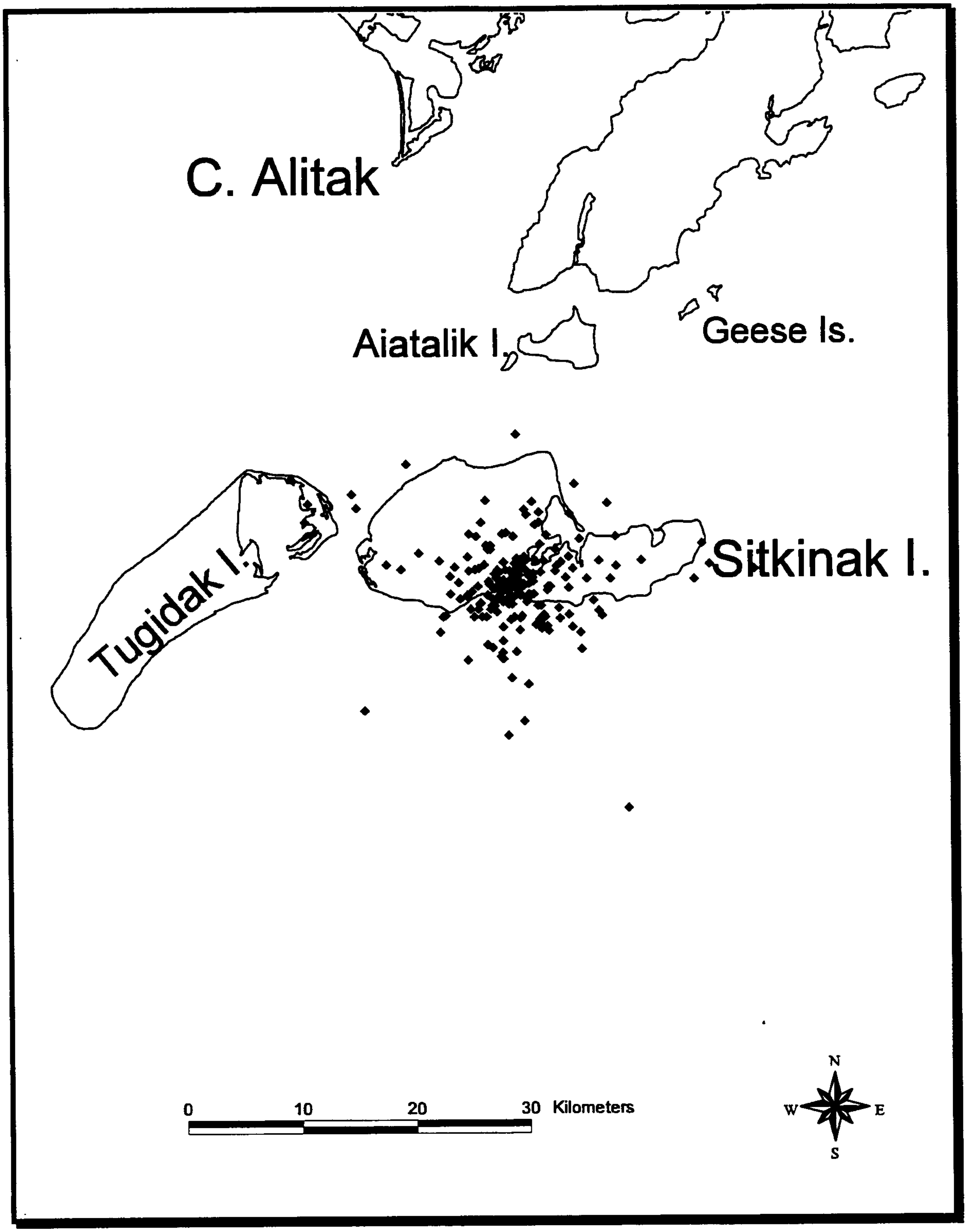


Figure 20A. Adult Female. SDR 5046. Seal ID PV93SE3. April 26, 1993 through July 12, 1993. Capture Location - Sitkinak I.

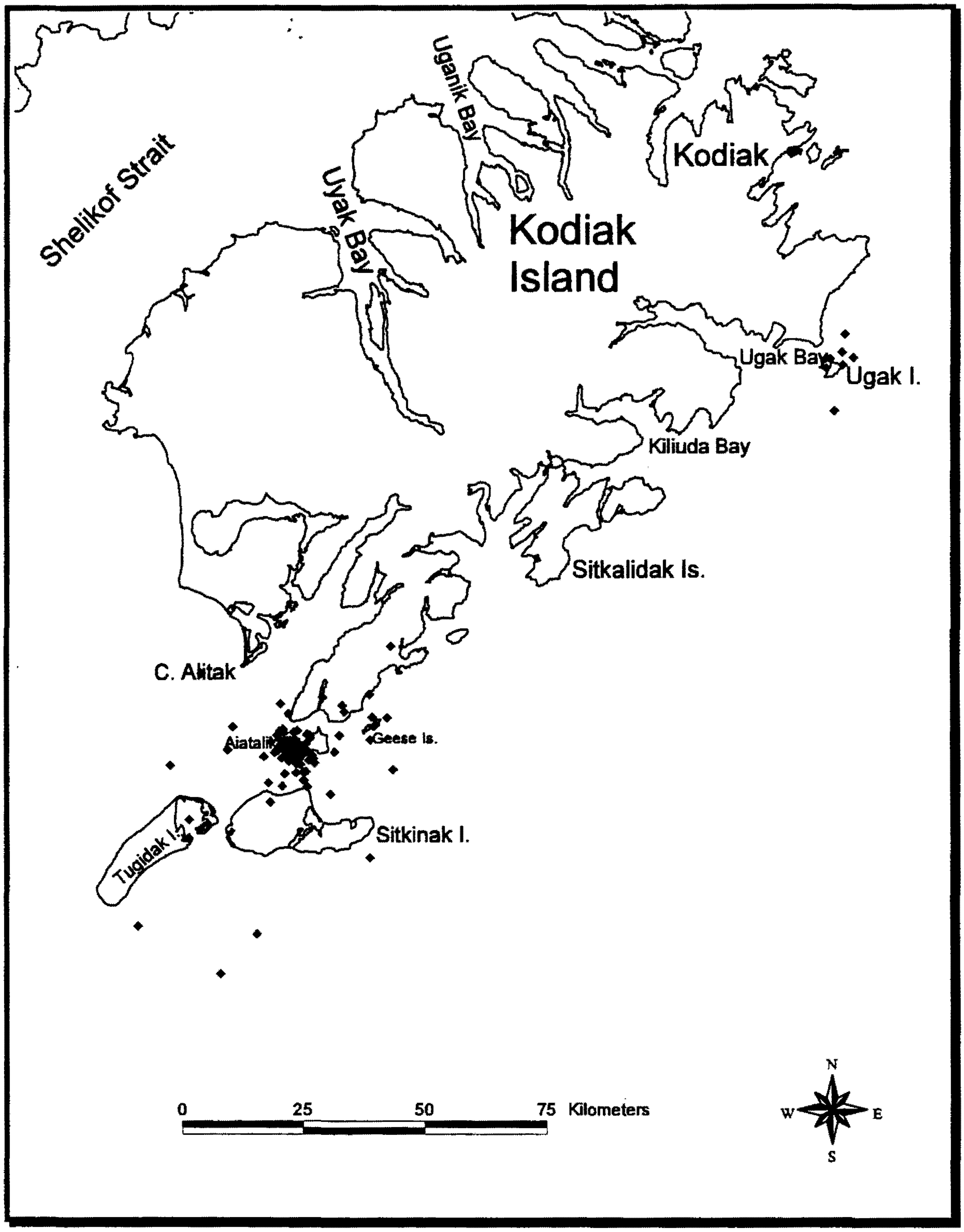


Figure 21A. Adult Female. SDR 5047. Seal ID PV93KO4. April 27, 1993 through June 15, 1993. Capture Location - Sitkinak Island.

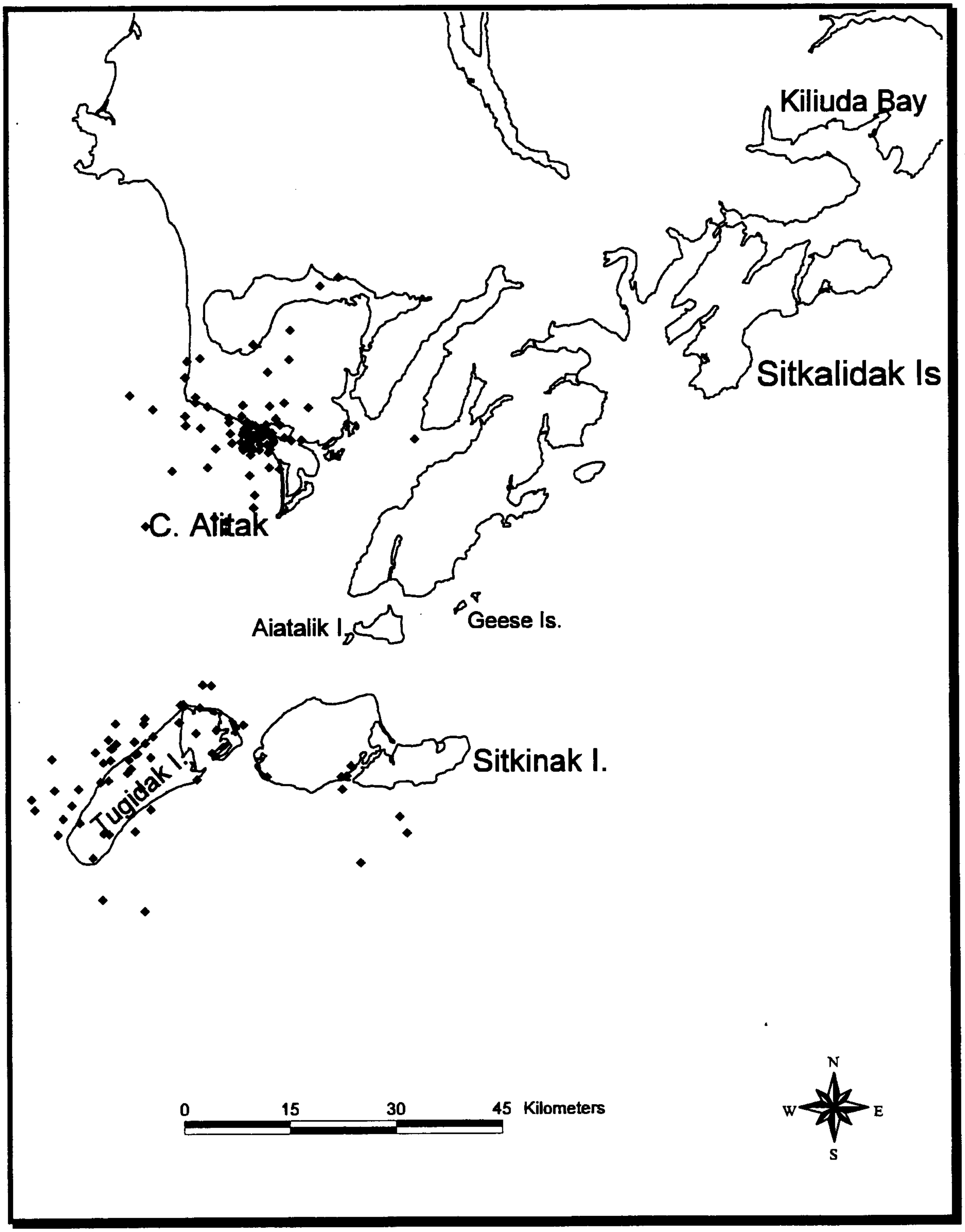


Figure 22A. Adult Female. SDR 5048. Seal ID PV93KO5. Oct. 5, 1993 through January 18, 1994. Capture Location - Sitkinak Island

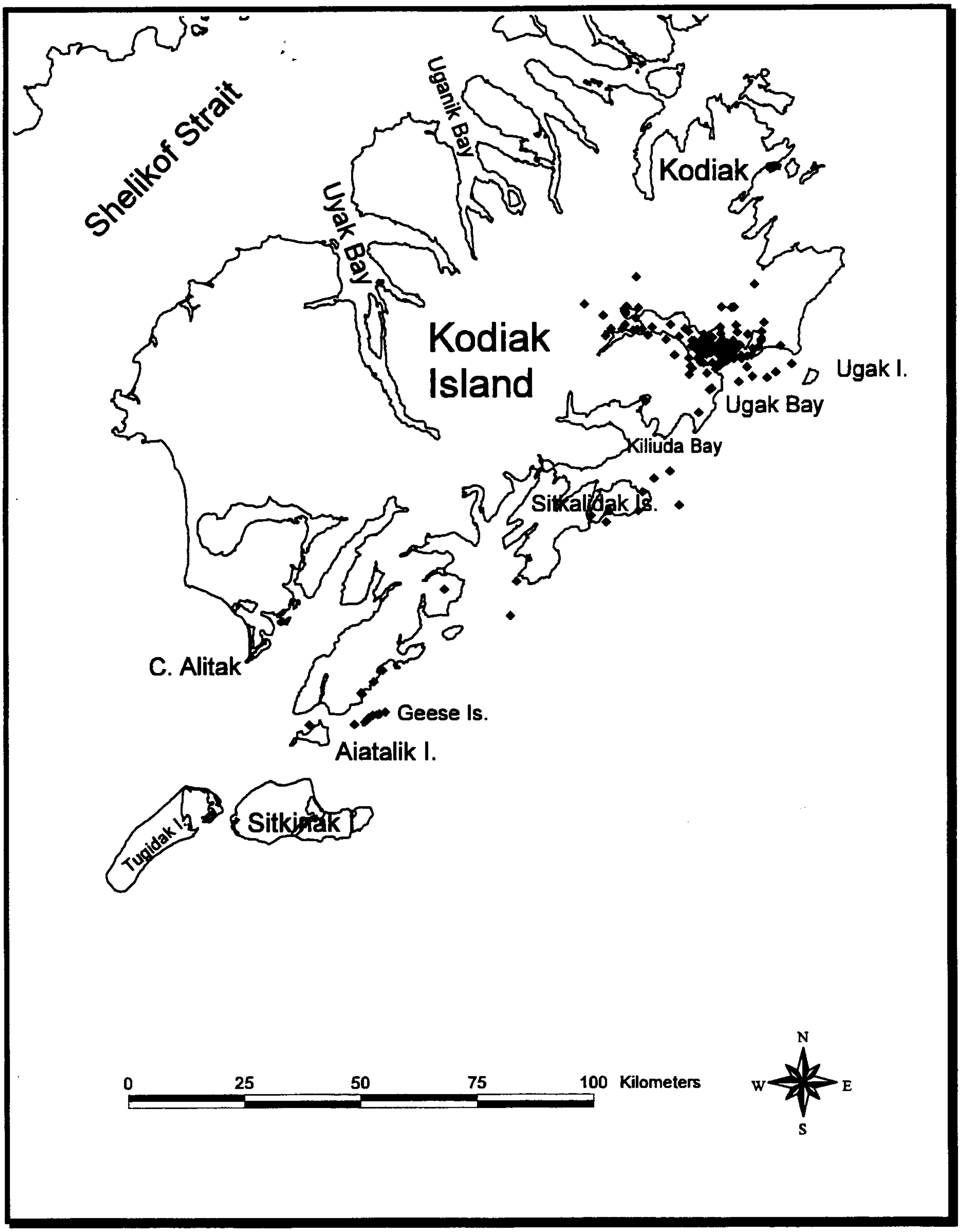


Figure 23A. Subadult Female. SDR 5041. Seal ID PV94KO4. Oct. 7, 1994 through January 19, 1995. Capture Location - Ugak Bay

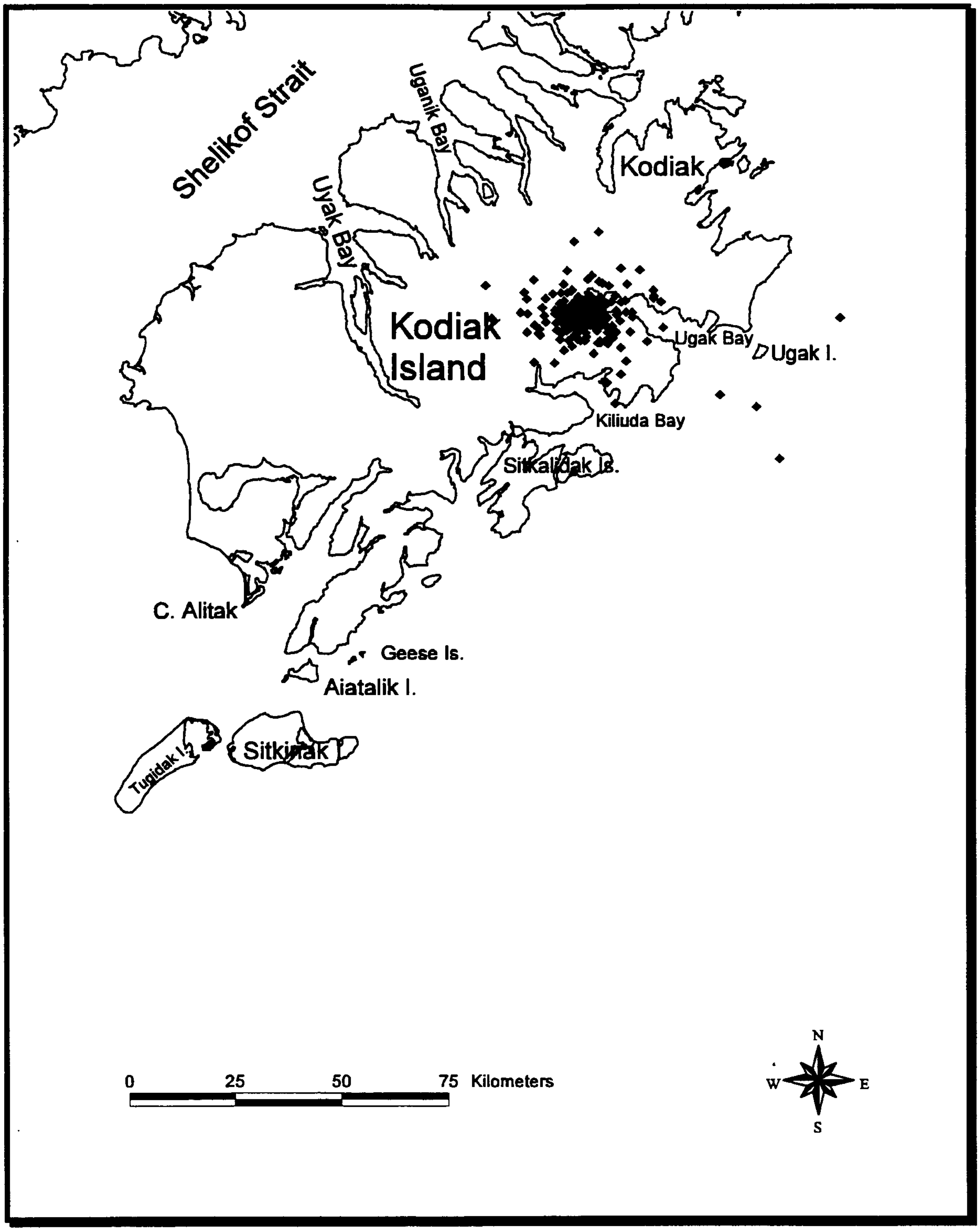


Figure 24A. Adult Male. SDR 5042. Seal ID PV94KO1. Oct. 6, 1994 through April 21, 1995. Capture Location - Ugak Bay.

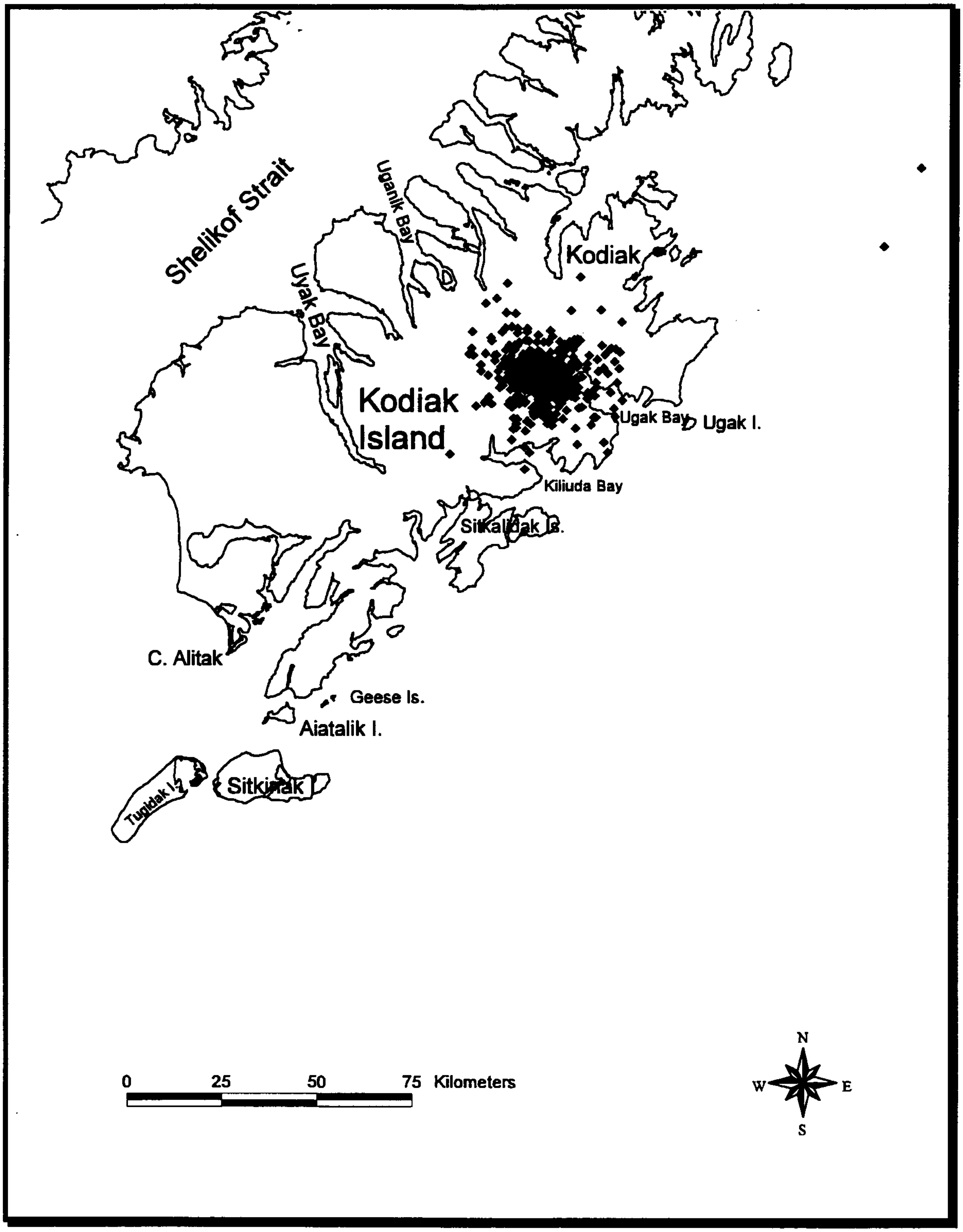


Figure 25A. Adult Male. SDR 5043. Seal ID. PV94KO2. Oct. 5, 1994 through July 5, 1995. Capture Location - Ugak Bay.

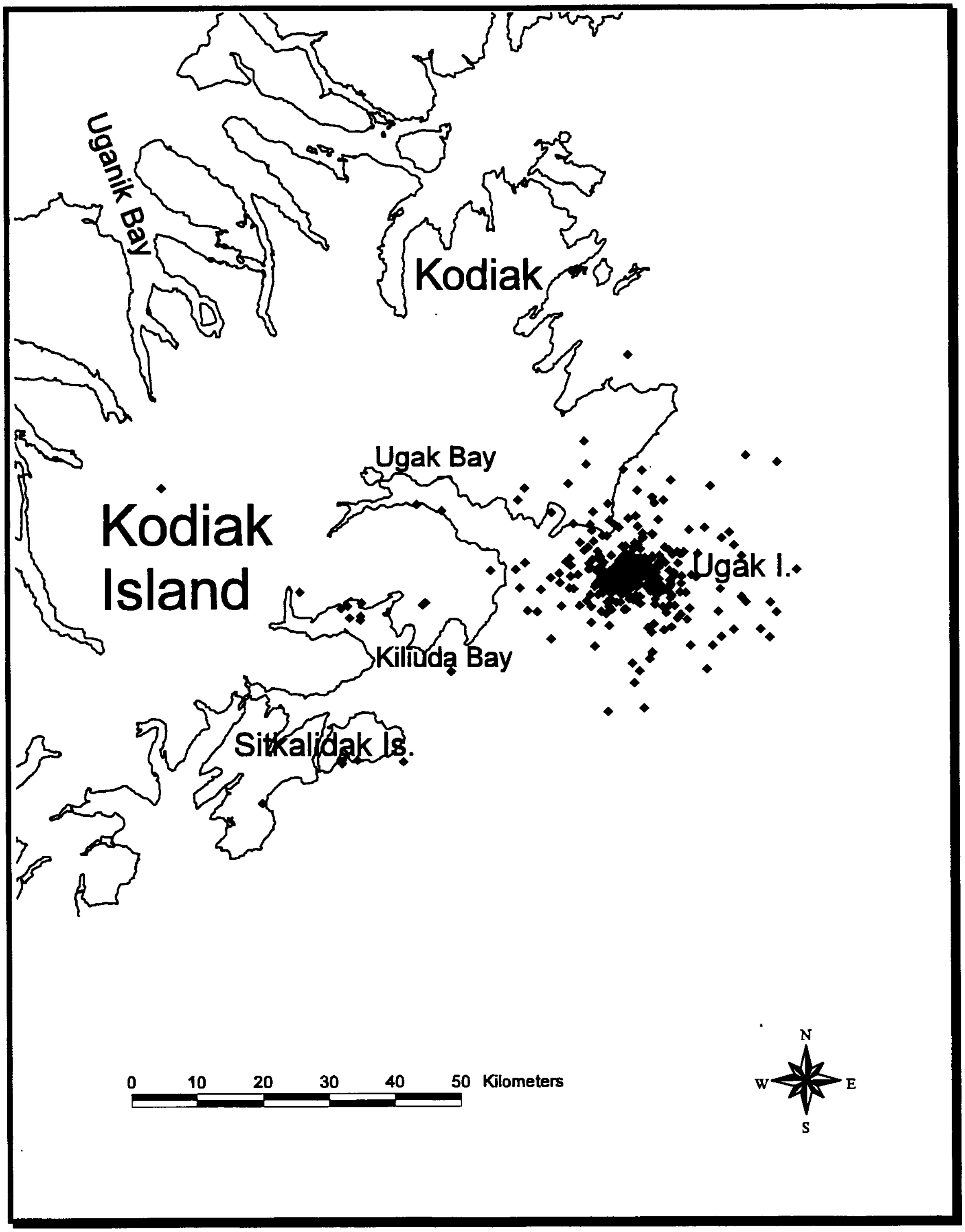


Figure 26A. Subadult Female. SDR 5044. Seal ID PV94KO9. Oct. 8, 1994 through June 23, 1995. Capture Location - Kiliuda Bay.

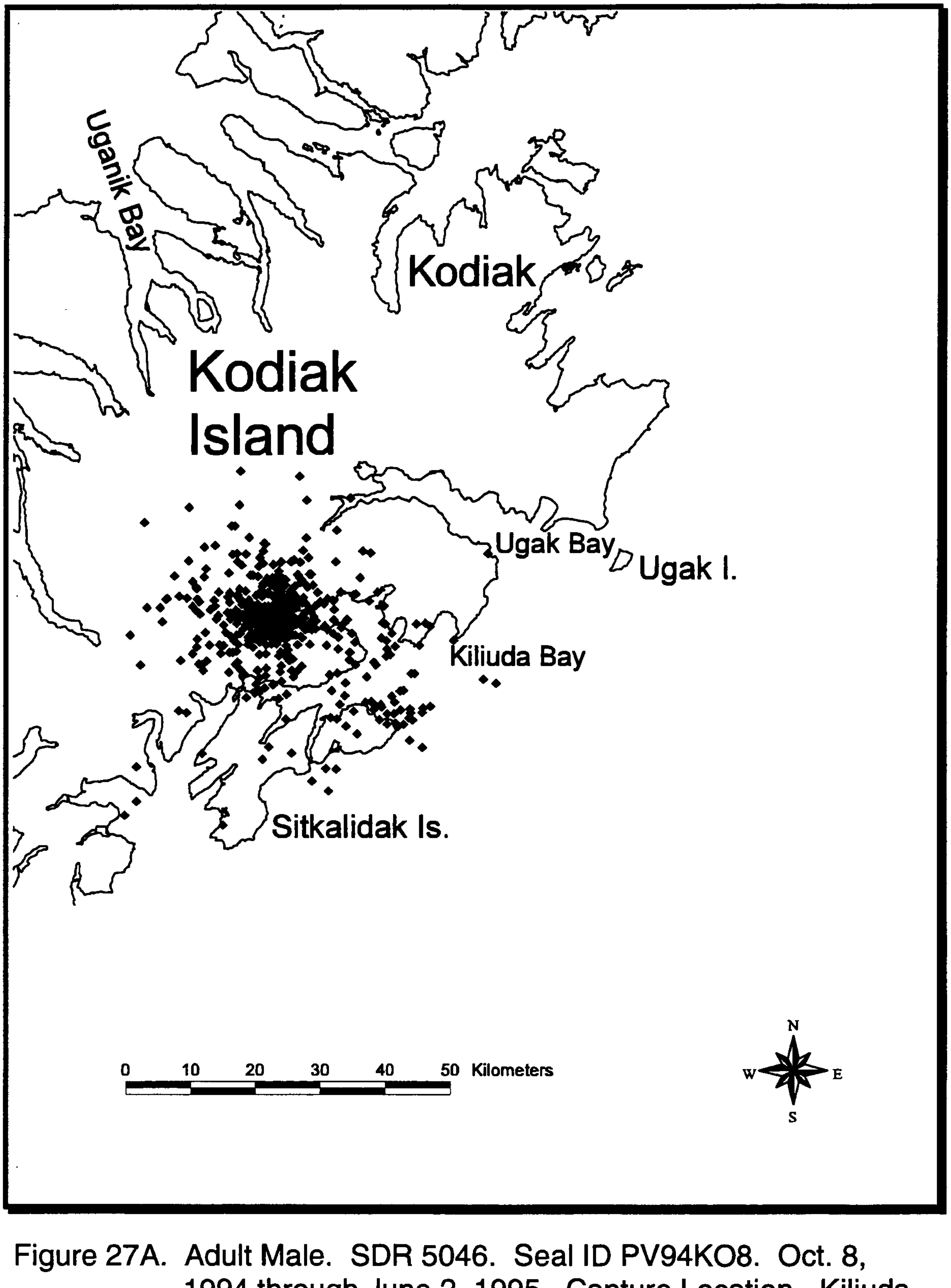


Figure 27A. Adult Male. SDR 5046. Seal ID PV94KO8. Oct. 8, 1994 through June 2, 1995. Capture Location - Kiliuda Bay.

CHAPTER THREE

OBJECTIVE 4

Determine the health status of harbor seals in Southeast Alaska and the Kodiak Archipelago, and the prevalence of infectious diseases

DISEASE STUDIES OF ALASKA HARBOR SEALS

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INTRODUCTION

Infectious diseases have caused significant mortality to harbor seals (*Phoca vitulina*) in some areas (e.g., Borst et al. 1986, Geraci et al. 1982, Heide-Jørgensen et al. 1992). There is no evidence that harbor seals in Alaska have been significantly affected by infectious diseases. Nonetheless, it has been difficult to conclude with certainty that disease has not been one of the factors causing ongoing population declines in some parts of the state (Sease 1992, Hoover-Miller 1994). For that reason, one of the objectives of this project has been to compare the prevalence of some infectious diseases in harbor seals in regions with different population trends.

The Alaska Department of Fish and Game (ADF&G) has coordinated testing of Alaskan harbor seals for exposure to several disease agents. Lewis (1995) reported preliminary results of testing for exposure to the viral agents phocine distemper virus (PDV), phocid herpesvirus (PhHV), caliciviruses, and *Chlamydia psittaci*. At that time we were awaiting results of additional samples that had been sent to be tested for PDV and PhHV. Recently we have made arrangements to test harbor seal serum for exposure to influenza virus, the bacterial genus *Brucella*, and the protozoan *Toxoplasma gondii*. Also, additional samples have been sent to another laboratory for calicivirus testing.

This report presents preliminary results of all serologic testing of harbor seal serum provided by ADF&G. Final analysis and reporting of results will be done in the future in collaboration with appropriate experts (e.g., Osterhaus et al. in prep., Zarnke et al., in prep.).

METHODS

Since 1978, ADF&G biologists have routinely collected blood from Alaskan marine mammals. Blood was taken from the extradural intervertebral vein of seals that were either collected for biological studies (Pitcher and Calkins 1979, Frost and Lowry 1994) or that were captured and released (Frost et al. 1996, Lewis 1995). Blood was allowed to clot, and was then centrifuged to separate serum. Serum was transferred by pipette to sterile storage vials. Samples were frozen as soon as possible at -12°C, and archived at ADF&G offices in Anchorage and Fairbanks at -40° to -46°C. Some additional sera have been provided by researchers from the National Marine Fisheries Service and the University of Alaska.

Testing for *Chlamydial* isolation was conducted by swabbing rectal and genital openings and inoculating agar plates with the swabs. The plates were incubated at 37° C until sufficient growth occurred and then refrigerated. Plates were then transported to a laboratory in Colorado where bacteria were replated, grown and subsequently isolated and identified.

Serum samples were shipped frozen to various laboratories for analysis (Table 1). Serum neutralization assays were used to test for exposure to PhHV, PDV, and caliciviruses (bovine calicivirus and 9 serotypes of San Miguel sea lion virus (SMSV)). For PhHV the viral challenge used was 50-100 TCID50 of the 1984 Pieterburen strain of PhHV-1. For PDV the viral challenge dose was 10-30 TCID50 of PDV-1 from the eastern North Atlantic.

Enzyme-linked immuno-sorbant assays (ELISA) were used to test for exposure to *Brucella* spp.. For *C. psittaci*, serum was tested using a complement fixation method and swabs were tested using ELISA. *T. gondii* exposure was tested using a modified agglutination test. Influenza testing was done by immunodiffusion assay.

RESULTS AND DISCUSSION

Phocid herpesvirus

Sera from 324 harbor seals were tested for PhHV (Table 2). Seventy-eight percent of the samples had titers ranging from 5 to 540, and the remainder had no detectable levels of antibody. Most of the samples that tested positive had relatively low titers of less than 180. Zarnke et al. (in prep.) suggest using a threshold titer of 20 for assessing positive exposure to PhHV. Based on that criterion, the prevalence of PhHV exposure in harbor seals ranged from 0% to 100% for the individual areas/years sampled, with an overall average of 64%.

Based on an analysis of 1,125 samples from nine marine mammal species sampled in Alaska and eastern Russia, Zarnke et al. (in prep.) concluded that exposure to PhHV-1 or a closely related virus has been common, geographically widespread, and long term. The lack of documented epizootics suggests that PhHV-1 has not been highly pathogenic in marine mammals of the region.

PhHV was first isolated from harbor seal pups in a sanctuary in the Netherlands where they developed clinical signs of acute viral infection, including fever, nasal discharge, vomiting and diarrhea (Borst et al. 1986). Eleven of 23 affected seals died. The disease outbreak was apparently confined to the seal sanctuary, although later studies showed that PhHV or a related herpesvirus commonly infects pinnipeds worldwide (Vedder et al. 1987).

Phocine distemper virus

Sera from 264 harbor seals were tested for PDV (Table 3). In aggregate, 66% of the samples tested had no detectable levels of antibody while the remainder showed titers of 10 to 180.

To properly evaluate these results it is important to determine the appropriate threshold titer for assessing positive exposure to PDV. The test procedure used normally identifies positive sera using a threshold titer of 20 (Visser et al. 1990). Because PDV has not been isolated from Alaskan waters it may be more appropriate to use a higher threshold titer of 100 for assessing prevalence in this region (Osterhaus et al. in prep.). Using a threshold titer of 100, the prevalence of PDV exposure in harbor seals ranged from 0% to 20% for the individual areas/years sampled with an overall average of 3%.

Osterhaus et al. (in prep) tested 1,099 sera from eight species of marine mammals sampled in Alaska and eastern Russia for exposure to PDV. All species showed evidence of having been exposed to PDV, but mostly with low prevalence and low titers. Exposure over a long time at a low prevalence suggests that the virus has been enzootic in the region for many years.

Morbillivirus infection in pinnipeds causes symptoms similar to canine distemper virus in dogs: fever, nasal discharge, gastrointestinal problems, cutaneous lesions, and central nervous system effects (Visser et al. 1991). Serious disease outbreaks caused by two different morbilliviruses occurred in seals in Siberia (Lake Baikal) in 1987 and in northwestern Europe in 1988 (Visser et al. 1990). The European seal epizootic, which resulted in the death of more than 18,000 harbor seals, was particularly well studied (reviewed in Heide-Jørgensen et al. 1992). Exposure to PDV has also been documented for harbor seals in eastern Canada (Ross et al. 1992) and New York (Duignan et al. 1993).

It is possible that some previously documented seal epizootics associated with pneumonia may have been due to PDV (Visser et al. 1991).

Brucella spp.

Sera from 131 harbor seals were tested for *Brucella* spp. (Table 4). Samples shown in the table as positive are those reported by the laboratory as "strong positive" which very likely indicates that animals were infected (MacMillan, pers. commun.). Thirty-four animals which were reported by the laboratory as "weak positive" are included in this report as negative. With those assumptions, prevalences ranged from 0% to 44%, with an average for all samples of 27%.

Brucella spp. have been isolated from several marine mammal species, including harbor seals, in the North Atlantic (MacMillan, pers. commun.). Similarly, in the North Pacific there is serologic evidence of exposure in ringed (*Phoca hispida*), spotted (*P. largha*), and ribbon (*P. fasciata*) seals, and Pacific walrus (*Odobenus rosmarus divergens*) (Zarnke, unpubl. data). Possible effects of *Brucella* spp. on marine mammals are unknown. The most typical result of brucellosis in other species is abortion (Witter 1981). A *Brucella* sp. was isolated from an aborted bottlenosed dolphin (*Tursiops truncatus*) fetus from the coast of California (Ewalt et al. 1994).

Toxoplasma gondii

Sera from 128 harbor seals were tested for exposure to *T. gondii* (Table 5). No serologic evidence of exposure was found in about 80% of the samples. Low titers were found in a few animals, but none of the sera reacted at a serum dilution of 1:500.

T. gondii has been found in several species of pinnipeds including harbor seals, with infected animals showing necrosis of organs such as heart, brain, liver, lung, lymph nodes, and stomach (Haebler and Moeller 1993). Van Pelt and Dietrich (1973) described *T. gondii* infection of a harbor seal pup that was captured shortly after birth in Cold Bay, AK, and that died 23 days later. They postulated that the pup had become infected through the placenta.

Influenza

Sera from 139 harbor seals were tested for exposure to influenza virus, as follows: Bering Sea--21; Prince William Sound--91; Kodiak--13, and Southeast Alaska (SE)--14. All samples were negative.

These results suggest that Alaskan harbor seals have not been exposed to influenza. One ringed seal sample from Alaska tested strongly positive for influenza A (Olsen, pers. commun.), which demonstrates that some seals in the Pacific have.been exposed to this virus.

Influenza caused the deaths of more than 400 harbor seals along the New England coast in 1979-1980 (Geraci et al. 1982). Clinical symptoms included weakness, lack of coordination, and respiratory distress, and death was caused by pneumonia. Influenza virus was again isolated from seals that died in this region in 1991-1992 (Callan et al. 1995). Disease outbreaks reported in other species and areas may have been caused by influenza, but could also have been due to morbillivirus (Visser et al. 1991).

Chlamydia psittaci

Serum tests for exposure to *C. psittaci* were done on 23 samples, 19 from southeast Alaska and 4 from Kodiak. Results were in most cases negative or showed very low titers, with the exception of one seal from Kodiak (titer 20) and one from southeast Alaska (titer 80) (Table 6). Results from ELISA tests done on swabs were negative for all sites except rectum where 15 of 25 animals showed evidence of exposure (Table 6).

These results show evidence that harbor seals have been exposed to *C. psittaci*, but none of the serum titers were very high. This could be interpreted as current or recent low-level immune response, or that seals were strongly infected in the past and their immunity is now waning. A comparison of results from serum and swabs (Table 7) suggests that many false positives were obtained from ELISA tests of rectal swabs, and serum tests should be given priority in evaluating exposure.

There is little information available on *C. psittaci* in marine mammals. Serum from Pribilof fur seals (*Callorhinus ursinus*), showed some immune response to chlamydial antigen (Eddie et al. 1966). Calkins and Goodwin (1988) reported that 53 of 109 Steller sea lions (*Eumetopias jubatus*) tested for *C. psittaci* had titers of 16 or greater, and 25 had titers of 128 or greater. Spraker and Bradley (1996) reported that 22 of 41 Steller sea lions sampled during 1992-1994 tested positive. Effects of *C. psittaci* on seals have not been documented, but in other animals it is known to cause abortion, stillbirths, and production of weak young (Shewen 1980).

Caliciviruses

Twenty-two samples (17 from southeast Alaska and 5 from Prince William Sound) have been tested for caliciviruses. All tests were negative. Additional samples have been sent to a different laboratory for analysis, but results are not yet available.

SMSV has been implicated in abortions of California sea lions (*Zalophus californianus*) and also caused formation of vesicular lesions on the flippers (Visser et al. 1991). Thirteen different serotypes have been identified from pinnipeds, all of which cause similar symptoms. It appears to be a widely transmissible calicivirus prevalent in the North Pacific. In addition to California sea lions, Smith and Boyt (1990) cite serologic evidence of exposure in Steller sea lions (*Eumetopias jubatus*), northern fur seals (*Callorhinus ursinus*), northern elephant seals (*Mirounga angustirostris*), and walrus, but apparently there is no record of calicivirus exposure in harbor seals (Visser et al. 1991). Steller sea lions in Alaska continue to show serologic evidence of exposure to six serotypes of SMSV (Spraker and Bradley 1996).

CONCLUSIONS

This study reports preliminary results from disease testing of more than 300 harbor seals sampled in Alaska during 1978-1994. Seven potential disease-causing agents were included in the tests.

Alaskan harbor seals have apparently been exposed to phocid herpesvirus, phocine distemper virus, *Brucella* spp., *Toxoplasma gondii*, and *Chlamydia psittaci* (Table 8). There is no evidence of exposure to influenza or calicivirus.

The possible significance of exposure to these disease agents is unclear. In most cases titers are low which could be indicative of mild exposure, weak immune reaction, or waning antibody response. Although some of these diseases are known to cause mortalities or to have reproductive effects, symptoms of disease have not been documented in Alaskan harbor seals. While these data have not yet been completely analyzed, there are no obvious differences in disease exposure between southeast Alaska and other parts of the state. Therefore, the data collected to date do not support the hypothesis that disease has been an important factor in the decline of seal numbers in some areas of Alaska.

ACKNOWLEDGMENTS

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Table 1. Serological analyses that have been or are being conducted on harbor seal specimens provided by ADF&G.

Disease Agent	Principal Investigator	Testing Institution
Phocid herpesvirus	A. Osterhaus	Erasmus University, The Netherlands
Phocine distemper virus	A. Osterhaus	Erasmus University, The Netherlands
Brucella spp.	A. MacMillan	Centre for Brucellosis Research, U.K.
Toxoplasma gondii	J. Dubey	U.S. Dept. of Agriculture, Maryland
Influenza	C. Olsen	University of Wisconsin
Chlamydia psittaci	T. Spraker	U.S. Dept. of Agriculture, Iowa
Caliciviruses	T. Spraker	U.S. Dept. of Agriculture, Iowa
Caliciviruses	N. Ferris	Institute of Animal Health, U.K.

Table 2. Results of testing for phocid herpesvirus in Alaskan harbor seals.

Location/year	Titer neg.	5	10	20+	Titer neg.	20	60	180	540
Bering Sea									
1979 (n=15)	0	0	1	14	--	--	--	--	--
1981 (n=27)	0	0	4	23	--	--	--	--	--
1985 (n=24)	12	10	2	0	--	--	--	--	--
Gulf of Alaska									
1978 (n=70)	4	0	11	55	--	--	--	--	--
1989 (n=6)	1	0	2	3	--	--	--	--	--
1993 (n=5)	--	--	--	--	1	1	3	0	0
1994 (n=10)	--	--	--	--	4	3	2	0	1
Prince William Sound									
1989 (n=14)	1	0	6	7	--	--	--	--	--
1990 (n=7)	2	0	3	2	--	--	--	--	--
1991 (n=8)	--	--	--	--	2	3	1	2	0
1992 (n=8)	--	--	--	--	1	5	1	1	0
1993 (n=27)	--	--	--	--	12	7	8	0	0
1994 (n=38)	--	--	--	--	16	14	6	2	0
Southeast Alaska									
1990 (n=2)	--	--	--	--	0	0	1	1	0
1993 (n=18)	--	--	--	--	6	10	2	0	0
1994 (n=45)	--	--	--	--	12	24	5	1	0

Table 3. Results of testing for phocine distemper virus in Alaskan harbor seals.

Location/year	Titer neg.	10	30	100	Titer neg.	20	60	180
Bering Sea								
1979 (n=15)	12	1	1	1	--	--	--	--
Gulf of Alaska								
1978 (n=71)	55	4	9	3	--	--	--	--
1989 (n=6)	6	0	0	0	--	--	--	--
1993 (n=5)	--	--	--	--	2	1	1	1
1994 (n=10)	--	--	--	--	5	1	3	1
Prince William Sound								
1990 (n=7)	7	0	0	0	--	--	--	--
1991 (n=8)	--	--	--	--	4	0	4	0
1992 (n=8)	--	--	--	--	4	1	3	0
1993 (n=27)	--	--	--	--	11	8	8	0
1994 (n=34)	--	--	--	--	24	0	9	1
Southeast Alaska								
1990 (n=2)	--	--	--	--	1	1	0	0
1993 (n=18)	--	--	--	--	9	3	5	1
1994 (n=42)	--	--	--	--	34	1	6	1

Table 4. Results of testing for *Brucella* spp. in Alaskan harbor seals.

Sample location	Year	Number positive (%)	Number negative[1]	Total sampled
Bering Sea	1985	7 (29)	17	24
Lower Cook Inlet	1978	0 (0)	9	9
Kodiak	1993	0 (0)	4	4
Prince William Sound	1989	2 (13)	13	15
Prince William Sound	1993	3 (27)	8	11
Prince William Sound	1994	8 (28)	21	29
Prince William Sound	1995	11 (44)	14	25
Southeast Alaska	1993	4 (29)	10	14
Overall		35 (27)	96	131

[1] Samples identified by the laboratory as "weak positive" are included as negative.

Table 5. Summary of result of testing for *Toxoplasma gondii* in Alaskan harbor seals.

Sample location	Year	Titer			Total
		negative	25	50	
Bering Sea	1985	17	2	3	22
Kodiak	1993	3	1	0	4
Prince William Sound	1989	14	0	1	15
Prince William Sound	1993	9	2	0	11
Prince William Sound	1994	27	1	1	29
Prince William Sound	1995	22	1	2	25
Southeast Alaska	1993	12	2	0	14
Overall		111	9	7	128

Table 6. Results of testing for *Chlamydia psittaci* in harbor seals from Alaska.

Location/Area	swabs						serum				
	vaginal		pharynx		rectal						
	neg	pos	neg	pos	neg	pos	neg	1:10	1:20	1:80	ns[1]
Gulf of Alaska											
1993 (Kodiak)	4	0	--	--	0	4	1	1	1	0	1
Prince William Sound											
1993	4	0	--	--	10	3	--	--	--	--	--
Southeast Alaska											
1993	3	0	4	0	0	8	10	4	0	1	4

[1] non-specific reaction

Table 7. Comparison of serum and tissue screening for the presence of *Chlamydia psittaci*.

Specimen	Serum	Rectal	Vaginal	Pharynx	Nasal	Eye
SE-1-93	Neg	Pos	--	Neg	--	--
SE-2-93	Neg	Pos	Neg	Neg	--	--
SE-3-93	1:10	Pos	--	--	Neg	Neg
SE-4-93	1:80	Neg	--	Neg	--	--
SE-5-93	1:10	Pos	Neg	--	--	--
SE-6-93	NS	Pos	Neg	--	--	--
SE-7-93	1:10	Pos	--	Neg	--	--
SE-8-93	Neg	Pos	--	--	--	--
SE-9-93	Neg	Pos	--	--	Neg	--
KOD-1-93	NS	Pos	Neg	--	--	--
KOD-2-93	1:10	Pos	Neg	--	--	--
KOD-3-93	1:20	Pos	Neg	--	--	--
KOD-4-93	Neg	Pos	Neg	--	--	--

Table 8. Summary of results of disease studies on Alaska harbor seals that have used specimens provided by ADF&G.

Disease Agent	Evidence of Exposure	Comment
Phocid herpesvirus	high prevalence	
Phocine distemper virus	low prevalence	low titers
Brucella spp.	moderate prevalence	
Toxoplasma gondii	low prevalence	
Influenza	none	
Chlamydia psittaci	moderate prevalence	low titers
Caliciviruses	none	additional testing underway

CHAPTER FOUR

OBJECTIVE 5

Provide support to studies by other investigators that will examine nutritional status, energetic requirements, and food habits of harbor seals.

HEMATOLOGY AND PLASMA CHEMISTRY VALUES FOR GULF OF ALASKA HARBOR SEALS, AND PRELIMINARY REGIONAL COMPARISONS 1993-95

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ABSTRACT

As part of a collaborative effort to understand factors affecting harbor seal populations in the Gulf of Alaska, we have collected blood samples from seals captured from Southeast Alaska (SE), Prince William Sound and Kodiak Island. These samples were analyzed for standard clinical chemistry and hematology values, and work continues on other hematological indicators of health. We generated reference ranges and mean values for clinical blood values of harbor seals within the Gulf of Alaska from a potential total sample size of 250 seals, which incorporated broader temporal and spatial ranges than had previously been reported for harbor seals. Several hematological values were significantly affected by age, gender, animal and sample handling, area and season. Consequently, this variation must be taken into account when regional and interannual comparisons are performed. Preliminary regional comparisons showed that some hematological values of seals from SE Alaska were different in magnitude and patterns of seasonal change as compared to seals sampled within Kodiak or Prince William Sound regions. While we currently do not understand the biological or health implications of these differences, there did not appear to be widespread indications of poor health or disease from any region.

INTRODUCTION

As part of a collaborative effort among the Alaska Department of Fish and Game, National Marine Fisheries Service, Texas A&M, Colorado State University and other University of Alaska researchers to understand factors affecting harbor seal populations in Alaska, we have been examining the health status and body condition of harbor seals sampled within the Gulf of Alaska since 1993. This research is part of a Ph.D. thesis by Brian Fadely, which is expected to be completed and available for public acquisition and citation by June 1997. This progress report focuses on aspects of blood chemistry and hematology, updating a previous report included in Lewis (1995). A summary of work in progress on body condition assessment utilizing non-lethal techniques can be found in Fadely and Castellini (1996).

Blood chemistry and hematology values can be indicative of health status, disease, or environmental conditions (Roletto 1993; Wolkers et al. 1994; Schumacher et al. 1995). This requires establishing a set of reference or 'normal' ranges for these blood values, and quantifying confounding sources of variation such as gender, age, and animal or sample handling techniques. Prior to the initiation of this project, reference ranges of clinical chemistry and hematology values were poorly known for harbor seals, limited to a few field studies with small sample sizes and single season data, or from captive seals (Bossart and Dierauf 1990).

This study was designed to collect data sufficient to establish clinical chemistry and hematology reference ranges for Gulf of Alaska harbor seals, and to determine the effects, if any, of gender, age, season, location, and handling techniques on these values. With these established, we can then perform interannual and interregional comparisons with a reduced likelihood of false inference, and an ability to calculate the statistical power of detecting differences.

Specifically, the goals for this project were to:

1. Collect clinical blood chemistry and hematological data from harbor seals throughout the Gulf of Alaska over several years and seasons to generate 'normal' reference ranges.
2. Determine whether factors such as gender, age, handling techniques, sample processing techniques, geographical location or season of capture account for variation within these reference ranges.
3. Review individual seal blood profiles within the framework provided by goals #1 and #2 to screen for outlying values and potential health problems.
4. Perform interregional and interannual comparisons based on findings of goals 1-3 and interpret results within medical and ecological contexts.

METHODS

Harbor seals were captured from three general geographic regions; Kodiak and Sitkinak Islands (grouped as Kodiak archipelago), Prince William Sound and SE Alaska. Captures were typically conducted during spring (March-May) or fall (September-October) months throughout 1993-95. Seals were live-captured by net-entanglement using techniques described elsewhere in this report, Frost and Lowry (1994) and Lewis (1995). After removal from the net, seals were transported to ship or shore, and were restrained manually or chemically by intramuscular injection with a ketamine/diazepam mixture. Weights were measured (±0.1 kg) with a hanging electronic load cell balance (Ohaus Model I-20W), and blood samples were collected prior to any other invasive procedures. Morphometric measurements were then completed and other procedures performed as detailed in Lewis (1995). Seals were categorized into age classes of pup, yearling, subadult or adult on the basis of size and time of year. Seals were held for variable periods to recover from drugging effects before being allowed to return to water.

Blood was sampled from the intervertebral extradural vein using 3.5 inch 18 or 20 G spinal needles (Monoject) into various blood collection tubes (Vacutainer). Typically up to 40 mL of blood was collected for serum, 25 mL for plasma, and 12 mL in EDTA tubes for complete blood counts (CBC) and hormone analyses. Blood samples from pups and some yearlings were taken by flipper venipuncture, using 1.5 inch 18 or 20 G needles drawing into blood collection tubes. In the field, blood hematocrit (% red blood cells by volume) was measured using a portable centrifuge (Compur M1100). Samples of whole blood were pipetted into Drabkin's reagent for later hemoglobin analysis. Blood was then centrifuged and plasma, serum, and whole blood samples were frozen in liquid nitrogen for later laboratory analyses. Blood smear slides were made for determination of differential leukocyte counts.

Standard panels that assay plasma sodium, potassium, chloride, phosphorus, blood urea nitrogen (BUN) creatinine, cholesterol, direct and total bilirubin, total protein, albumin, globulin, alkaline phosphatase, glucose, lactate dehydrogenase (LDH), gammaglobulin transferase (GGT), creatine phosphokinase (CPK), aspartate aminotransferase (AST) and alanine aminotransferase (ALT) were performed by automated machine analysis at the Fairbanks Memorial Hospital (FMH) using an Ektachem Analyzer. Hemoglobin was determined using standard kits from Sigma Chemical Co. and performed in our laboratory. Complete blood counts of white and red blood cells, platelet counts and differential white blood cell counts were performed by technicians at FMH from blood collected in EDTA collection tubes using a Coulter Model S-Plus-4 Counter, and from blood smears produced in the field. Some white blood cell counts were performed directly in the field using light microscopy by Dr. Terry Spraker. Mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin content (MCHC) were calculated from combinations of measured hematocrit, hemoglobin and red blood cell count (RBC) following Kerr (1989). Ratios of albumin to globulin (AG) and blood urea nitrogen to creatinine were calculated from measured values.

Reference ranges for blood chemistries and hematologies were calculated as being within two standard deviations of the mean (Kerr 1989). Some values (particularly proportional or count data) were arcsine or square-root transformed to improve the normality of their distributions before statistical calculations were performed (Zar 1984). Reference range calculations excluded samples that were lipemic, hemolytic, or collected posthumously, and included samples collected from Prince William Sound in 1991 and 1992 (Frost and Lowry 1994), from SE in August 1994, and Prince William Sound in July-August 1995. Individual blood profiles of chemical and hematological values were reviewed to locate statistical outliers. Seal profiles with significantly elevated or decreased values were compared to determine regional patterns by expressing the outlier count as a proportion of the total number of outlying values for that region, as a type of frequency of occurrence, for all years combined. At the time of this report we did not possess most of the leukocyte differential count data, so that portion of the analysis is incomplete.

The effect of individual, temporal and spatial factors on the variability in blood values was modeled by combining age class, gender, elapsed time from capture to blood sample, elapsed time of drug administration to blood sample, region, season as spring or fall, and year in a multiple regression analysis model against each blood parameter. Preliminary regional, seasonal and interannual comparisons were performed by grouping blood values within season (spring/fall), region (Kodiak, PWS, SE) and year. Samples that were collected posthumously, or that were lipemic or hemolytic were excluded.

RESULTS

A total of 254 harbor seals were captured from within the three regions during 1993-95 (Table 1), though not all data were necessarily collected for each seal. Summer samples were excluded for seasonal, regional and interannual comparisons in this report leaving a potential total sample size of 201. Mean plasma chemistry, erythrogram and leukogram values, and calculated reference ranges are summarized in Tables 2-4, respectively.

Individual, animal handling, regional and seasonal influences on variation were evident for many plasma chemistry and hematology values (Table 5). For example, some of the variation in plasma sodium was found to be accounted for by adult age class, a regional effect of SE Alaska, and a seasonal difference attributable to fall months (Table 5). Effects due to age were inseparable from effects of body mass because of a high degree of autocorrelation. There were no significant ($P>0.05$) effects of these parameters on BUN:Creatinine ratio, total or direct bilirubin, GGT, MCV or WBC. Changes in blood values attributable to seal handling were evident in the number of blood parameters (10) that showed a significant effect of the elapsed time between seal capture and blood collection (Table 5).

The effect of delays between collecting blood samples in the field and the processing of complete blood counts at the FMH lab was determined for EDTA tube samples up to 8 days old. Platelet count was not significantly different for up to 4 days (ANOVA $F_{(3,67)}=0.40$; $P=0.7574$), but counts declined significantly thereafter ($F_{(7,92)}=3.77$; $P=0.0013$). There was no effect of this delay on red blood cell count ($F_{(7,95)}=0.94$; $P=0.4786$). White blood cell counts increased significantly in samples measured over 1-8 days (Linear regression $F_{(1,101)}=13.98$; $P=0.0238$; $r^2=0.122$) at a rate of 521 cells/μL/day, accounting for 12% of the variation in WBC. It is unclear why this should occur, as there was no significant effect on mean corpuscular volume in samples up to 8 days old ($P>0.05$). It may be that the electrical properties of the leukocytes become more similar to those of erythrocytes, causing confusion between the two cell types by the counting machine.

Regional and seasonal differences were apparent in many chemical and hematological values (Figures 1-4), consistent with trends shown in Table 5. Plasma sodium (Figure 1a, b) mean values from SE Alaska were consistently higher than of seals from Kodiak or Prince William Sound (ANOVA spring $F_{(2,81)}$=11.46; P=0.0001; Fall 94-95 $F_{(2,77)}$=19.77, P<0.0001). Alkaline phosphatase values were significantly lower during fall months ($F_{(2,102)}$=15.01; P<0.0001) from SE Alaska than in the other two regions, though Prince William Sound seals were significantly higher in AP ($F_{(2,80)}$=24.91; P<0.0001) during spring than the other two regions (Figure 1g,h). Mean total protein was significantly higher in SE during spring and fall 1995 than in the other regions (Figure 2a,b). Fall BUN values were significantly lower among SE Alaska seals than elsewhere ($F_{(2,102)}$=4.08, P=0.0194; Figure 2c,d). Prince William Sound seals tended to have higher albumin concentrations and AG ratios than the other regions during fall (Figures 3b, f), but 1993 spring AG ratios from Kodiak seals (Figure 3e) were greater than all other spring values. Hematocrit showed a strong seasonal signal in SE Alaska, but not in Kodiak or Prince William Sound (Figure 4a,b). Because of limited sample size, apparent differences in platelet counts (Figure 4c,d) are difficult to interpret. However, platelet counts during fall 1993 from SE were much higher than in any other season, region or year. Similarly, though WBC was not significantly different among years or regions during spring, 1993 counts from SE seals were significantly higher than other fall values ($F_{(2,71)}$=3.16; P=0.0471; Figure 4e,f). Comparisons that reduce the regions into more specific site groupings within Kodiak or SE Alaska were not possible, since there were no years or seasons in which the relevant intraregional zones were visited.

Based on the reference ranges listed in Tables 2-4, seals showing significant elevations or depressions of clinical values were filtered from the database and are listed in Appendix 1. The distribution of these outlier values among the 3 regions combined for 1993-1995 were similar among the three regions (Figure 5). The three most frequent values with outliers were similar for all three regions; creatinine, total bilirubin, and CPK. Notable differences were found in that SE Alaska had no outlying values among AG ratios, and many more outliers in plasma sodium, chloride and total protein than the other two regions.

DISCUSSION

Thus far this project has successfully established sets of reference ranges for plasma chemistry and hematological values (Goal #1) that were derived from a dataset with larger sample sizes and broader temporal and geographic ranges than have previously been reported (Bossart and Dierauf 1990; Roletto 1993; Kopec and Harvey 1995; de Swart et al. 1995). We have also found that there can be statistically important effects of age, gender, handling, season and year on the variability in plasma chemistry and hematology values (Goal #2), consistent with recent findings of Kopec and Harvey

(1995) and de Swart et al. (1995). These effects must therefore be taken into account when performing seasonal, regional or interannual comparisons.

It is also becoming clear that there are regional differences in some clinical chemistry and hematology values, and in some seasonal patterns of their change. For example, SE Alaska seals show elevated sodium (Figure 1a, b), chloride and total protein (1995, Figure 2a,b) in both seasons, but decreased AP (Figure 1h), BUN (Figure 2d), and hematocrit (Figure 4b) during fall months. It was also found by Zenteno-Savin et al. (1996) that fall 1994 Prince William Sound seals had significantly elevated levels of haptoglobin (an acute-phase protein that is elevated in response to inflammation) as compared to summer 1994 SE Alaska seals. As yet we do not understand the biological implications of these differences, or whether they are clinically or biologically significant to the seals. A first interpretation of elevated electrolytes and protein is dehydration, but this is contraindicated by decreased hematocrit values. These comparisons have also not been controlled for other sources of variation deriving from age, gender, or handling techniques. There are undoubtedly numerous differential diagnoses or ecological interpretations that could produce patterns consistent with those shown here, and we are currently working on these issues by collaboration with ecologists, aquaria personnel and veterinarians, and by comparison to other research in progress involving many species of pinnipeds.

Screens of blood profiles for significantly elevated or depressed values suggest that in general the seals have not shown widespread signs of diseases that can be detected by this process. However, by definition of the reference range, not all statistical outliers will be unhealthy. Seals were not categorized as being 'healthy' or 'diseased' prior to developing the reference ranges, so values lying outside ± 2 standard deviations will include clinically sick as well as healthy seals. Thus, when interpreting seal blood profiles that only contain one or two outliers it is important to note that these may be statistical, rather than physiological outliers. An exception to this may be found in seal PV93SE17, collected in SE during fall 1993. This seal has the largest WBC recorded for any seal in the Gulf of Alaska by this study, and also shows a significantly high platelet count (Appendix 1). However, the bacteria *Moraxella* sp. was isolated from this seal, which is abnormal and possibly pathogenic (Lewis 1995). With the exception of sodium, chloride, total protein and AG ratio, distributions of outlying values were similar among the three regions (Figure 5), suggestive that there were no health concerns unique to specific localities.

We are continuing with lab and data analyses, and interpretation of these results. Specifically, we will:

1. Complete more haptoglobin analyses to determine the extent of regional and seasonal differences.

2. Complete other laboratory analyses, such as plasma iron content (related to infection), plasma water content (to index dehydration), and ketone bodies (related to nutritional status).
3. Combine leukogram differential count data from collaborators to perform regional, seasonal and interannual comparisons.
4. Model variability attributable to gender, age and handling effects in an attempt to 'normalize' data for other comparisons.
5. Examine patterns of concordance among blood values between sampling sites.
6. Participate in cruises in the fall of 1996 and incorporate those findings.
7. Compare chemical and hematological data with serological and contaminant results.
8. Develop ecological and clinical interpretations of patterns of change in blood values with season and region.
9. Combine these results with those from our measurements of harbor seal body condition to generate comprehensive assessments of health and condition.

We are also providing plasma samples to other researchers involved in alternative blood indices of health status, such as: determinations of heavy metal contamination based on plasma proteins; concentrations of hormones responsible for water balance and blood pressure control, which respond to many disease conditions; nitrous oxide concentration, which is an indicator of acute stress; and vitamin A, which responds to contaminant loads.

In future seal sampling efforts, collection of EDTA samples for complete blood counts will provide useful comparative data if these samples can be processed within about 4 days by laboratory technicians. Within Kodiak and SE Alaska regions, sampling of seals from sites among different zones (within the Kodiak region, for example, Shelikof Strait and the open ocean coast) within the same season will provide critical comparisons to separate location and seasonal effects on blood values within a region.

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Table 1. Sample sizes used for blood chemistry and hematology studies of harbor seals captured during spring (March-May), Summer (July-August) or fall (September-October) months in the Gulf of Alaska.

	Kodiak Archipelago	Southeast	Prince William Sound	Seasonal Totals
1993 Spring	4	9	13	26
Fall	1	12	15	28
1994 Spring			10	10
Summer		38		38
Fall	10	9	31	50
1995 Spring	8	19	22	49
Summer			15	15
Fall	9	9	20	38
Totals	32	96	126	254

Table 2. Harbor seal blood chemistry reference ranges calculated from samples collected during 1991-1995 in southeastern Alaska, Prince William Sound and the Kodiak archipelago (*n*=250 unless otherwise noted).

Variable	Mean	sd	Reference Range (±2sd)	Total Range (min-max)
Sodium[a]	146	5	136-157	132-167
Chloride[a,b]	107	4	99-116	96-122
Phosphorus[b,c]	5.0	1.4	2.2-7.8	1.6-14.5
Potassium[a]	3.8	0.6	2.6-5.0	2.7-12.2
Calcium[c]	9.6	0.6	8.4-10.8	7.9-11.8
Creatinine[c]	0.9	0.2	0.5-1.2	0.3-1.8
Glucose[c]	158	25	108-208	65-239
Blood Urea Nitrogen[c]	45	14	17-73	17-104
BUN:Creatinine	54	22	10-98	17-146
Cholesterol[b,c]	219	46	127-311	118-403
Total Protein[d]	7.7	0.8	6.1-9.3	5.0-9.4
Albumin[d]	3.1	0.2	2.6-3.5	2.3-3.8
Globulin[d]	4.6	0.7	3.2-6.0	2.2-6.7
Albumin:Globulin	0.7	0.1	0.5-0.9	0.4-1.5
Total Bilirubin[c,e]	0.4	0.2	0.0-0.6	0.1-2.4
Direct Bilirubin[c,e]	0.3	0.2	0.0-0.7	0.0-1.9
Alanine aminotransferase[f,g]	61	36	<133	9-798
Aspartate aminotransferase[f,h]	161	70	21-301	44-1164
Alkaline phosphatase[f,g]	66	32	2-130	20-440
Creatine phosphokinase[f,i]	1340	1132	<3604	130-16000
Gammaglobulin transferase[f,j]	19	8	3-35	7-197
Lactate dehydrogenase[f,j]	4083	1938	207-7959	422-21500
Haptoglobin[k]	105.0	53.3	0.0-211.6	20.7-244.7

[a]meq/L
[b]*n*=249
[c]mg/dL
[d]g/dL
[e]*n*=227
[f]IU/L
[g]*n*=248
[h]*n*=242
[i]*n*=247
[j]*n*=218
[k]mg Hb bound/dL; *n*=61

Table 3. Harbor seal hematological reference ranges calculated from samples collected during 1991-1995 in southeastern Alaska, Prince William Sound and the Kodiak archipelago.

Variable	Mean	sd	*n*	Reference Range (±2sd)	Total Range (min-max)
Hematocrit[a]	56	7	245	42-70	32-74
Hemoglobin[b]	23.2	3.3	192	16.6-29.8	14.7-35.8
MCHC[c]	46.3	4.9	192	36.5-56.1	25.5-72.0
MCH[d]	46.3	6.3	120	33.7-58.9	29.1-82.9
MCV[e]	110.1	7.4	122	95.3-124.9	85.2-132.6
Red blood cell count[f]	5.23	0.60	128	4.03-6.43	3.62-7.87
Platelet count[g]	316	165	125	0-646	5.6-1278
Plasma water[a]	91.0	1.4	44	88.2-93.8	89.9-99.1
Plasma specific gravity	1.004	0.008	44	0.988-1.020	0.983-1.017
Whole blood water[a]	73.4	1.9	49	69.6-77.2	70.7-79.1
Whole blood specific gravity	1.050	0.014	52	1.022-1.078	0.996-1.079

[a]%
[b]g/dL
[c]Mean corpuscular hemoglobin content; g/dL
[d]Mean corpuscular hemoglobin; pg
[e]Mean corpuscular volume, fL
[f]$10^6/\mu L$
[g]$10^3/cm^2$

Table 4. Harbor seal white blood cell count (n=173) and relative differential leukocyte count (n=147) reference ranges calculated from samples collected during 1991-1995 in southeastern Alaska, Prince William Sound and the Kodiak archipelago.

Variable	Mean	sd	Reference Range (±2sd)	Total Range (min-max)
White blood cell count ($10^3/\mu L$)	11.3	3.3	4.7-17.9	4.9-25.3
Neutrophils (%)	55	1	31-79	25-88
Banded neutrophils (%)	0	0		0-3
Monocytes (%)	3	1	1-5	0-15
Lymphocytes (%)	31	11	9-53	10-71
Eosinophils (%)	8	5	0-18	0-28
Basophils (%)	1	1	0-8	0-12

Table 5. Multiple regression matrix showing statistically significant effects (t values) of non-disease variables (age class: pup, yearling, subadult or adult; gender, elapsed times between capture or drugging and time of blood sampling, region, season: spring or fall; and year) on blood chemical and hematological parameters of harbor seals sampled in Prince William Sound, southeastern Alaska, and the Kodiak archipelago during 1993-1995 (n=89 unless noted otherwise).

	Age class					Elapsed Capture-Blood	Elapsed Drug-Blood	Region			Season		
	P	Y	S	A	Gender	Time	Time	PWS	Kod	SEA	Sp	Fa	Year
Sodium				2.51*						-2.55*		-5.01***	
Chloride											3.55***		
Phosphorus			-3.82***						-2.08*				
Potassium		3.36**											
Calcium				-3.34**				2.10*			-5.02***		
Creatinine				3.93***									
Glucose								-2.40*					3.55***
BUN				3.57***	3.29**								
Cholesterol	3.12**[f]			-3.38**		-2.48*		2.79**					
Protein				4.69***		2.63*						-3.22**	
Albumin							2.14*	4.27***			-3.53***		
Globulin				4.75***		2.35*					4.15***		
A:G ratio				-3.30**				3.36**				4.72***	
ALT						3.11**							
AST						4.11***							
AP		4.1***	2.01*						-2.04*			4.42***	
	3.32**												
CPK						4.37***							
LDH[a]				-2.45*		6.08***							
Hematocrit				-4.25***							2.66**		
Hemoglobin[b]					2.30*					-3.51***			
MCHC[b]											-2.43*		
MCH[c]										-2.58*	-3.29**		
RBC[d]				-5.85***						-4.39***			-3.02**
Platelet count[c]									3.02**	8.54***			2.92**
Neutrophils[e]						2.86**							
Banded Neut.[e]								-2.67**					
Monocytes[e]											-5.05***		
Lymphocytes[e]						-2.54*							
Eosinophils[e]						-3.78***							
Basophils[e]							2.60*	2.56*				2.83**	2.90**

[a] n=81
[b] n=83
[c] n=80
[d] n=82
[e] n=76
[f] *=0.05>P>0.01, **=0.01>P>0.001, ***=P<0.001

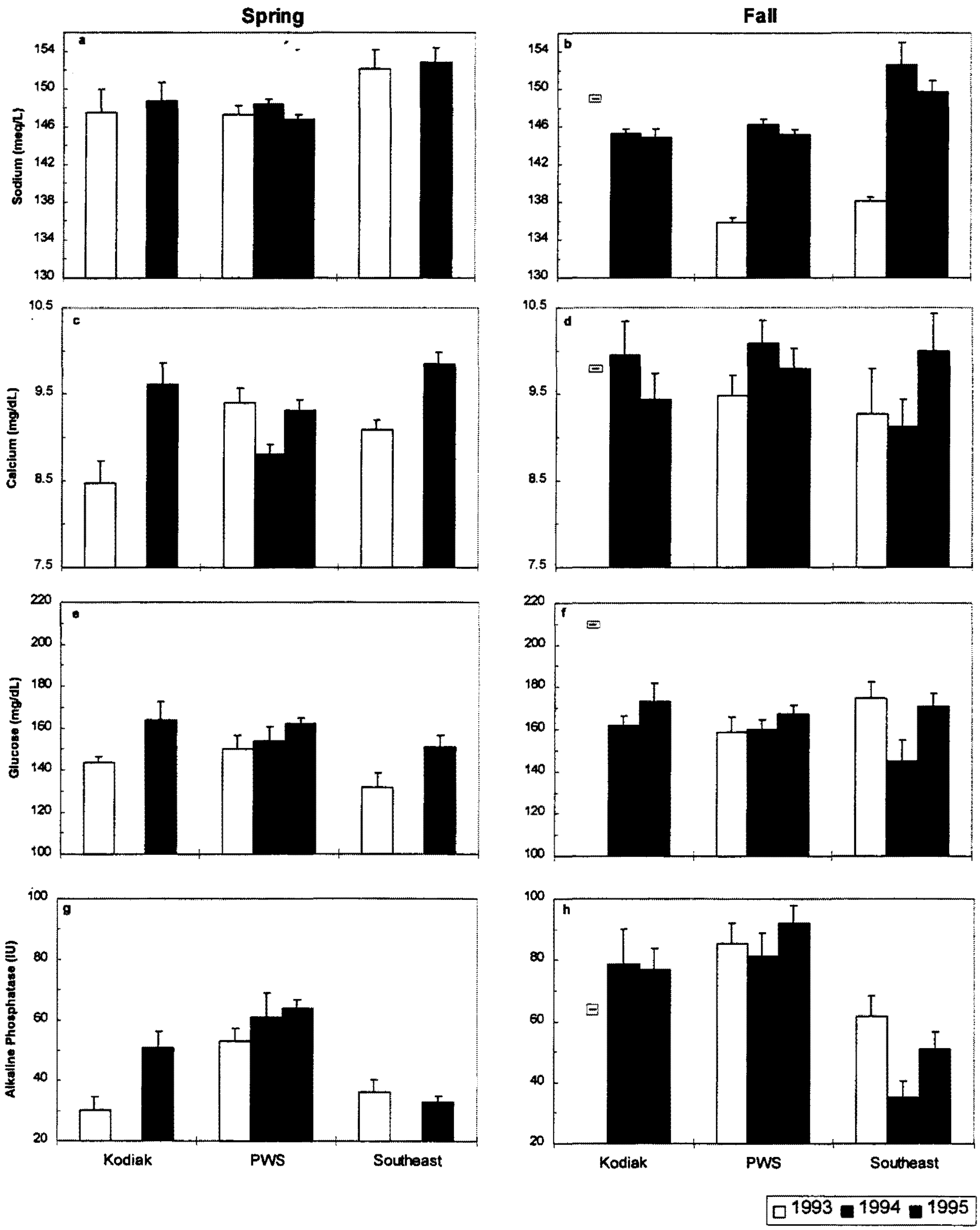

Figure 1. Comparisons of blood variables (mean±1SE) from harbor seals sampled during spring (March-May) and fall (September-October) months of 1993-95 from the Kodiak archipelago, Prince William Sound (PWS), and southeastern Alaska. Sample sizes for spring 1993-95, respectively: Kodiak 4, 0, 8; PWS 12, 10, 22; southeastern 9, 0, 19. Samples sizes for fall 1993-95, respectively: Kodiak 1, 10, 9; PWS 15, 24, 20; southeastern 9, 8, 9.

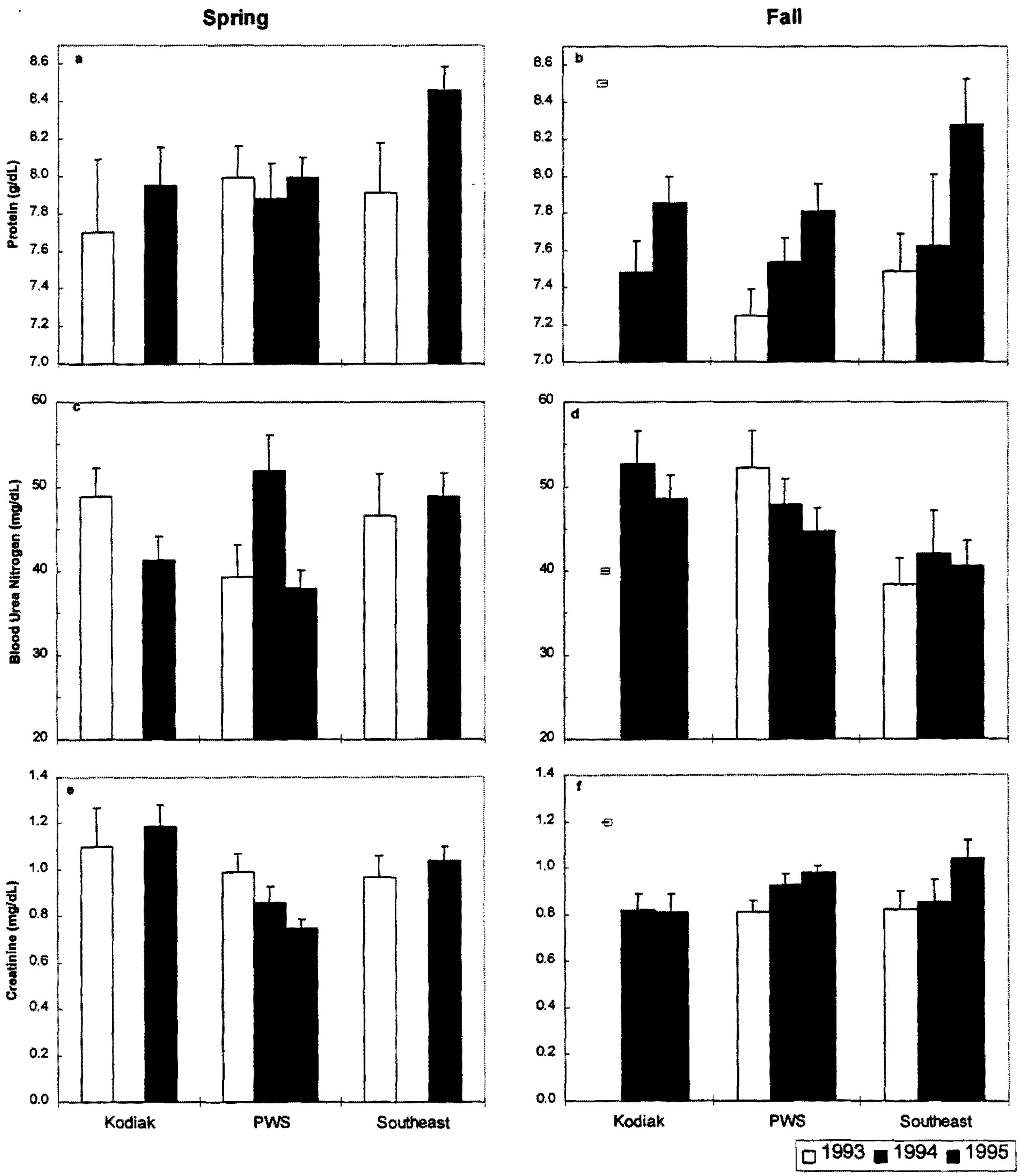

Figure 2. Mean (±1SE) plasma protein (a, b), blood urea nitrogen (c, d) and creatinine (e, f) of harbor seals sampled during spring (March-May) and fall (September-October) 1993-95 from the Kodiak archipelago, Prince William Sound (PWS), and southeastern Alaska. Spring sample sizes 1993-95 respectively were: Kodiak 4, 0, 8; PWS 12, 10, 22; southeastern 9, 0, 19. Fall 1993-95 sample sizes were: Kodiak 1, 10, 9; PWS 15, 24, 20; southeastern 9,8,9.

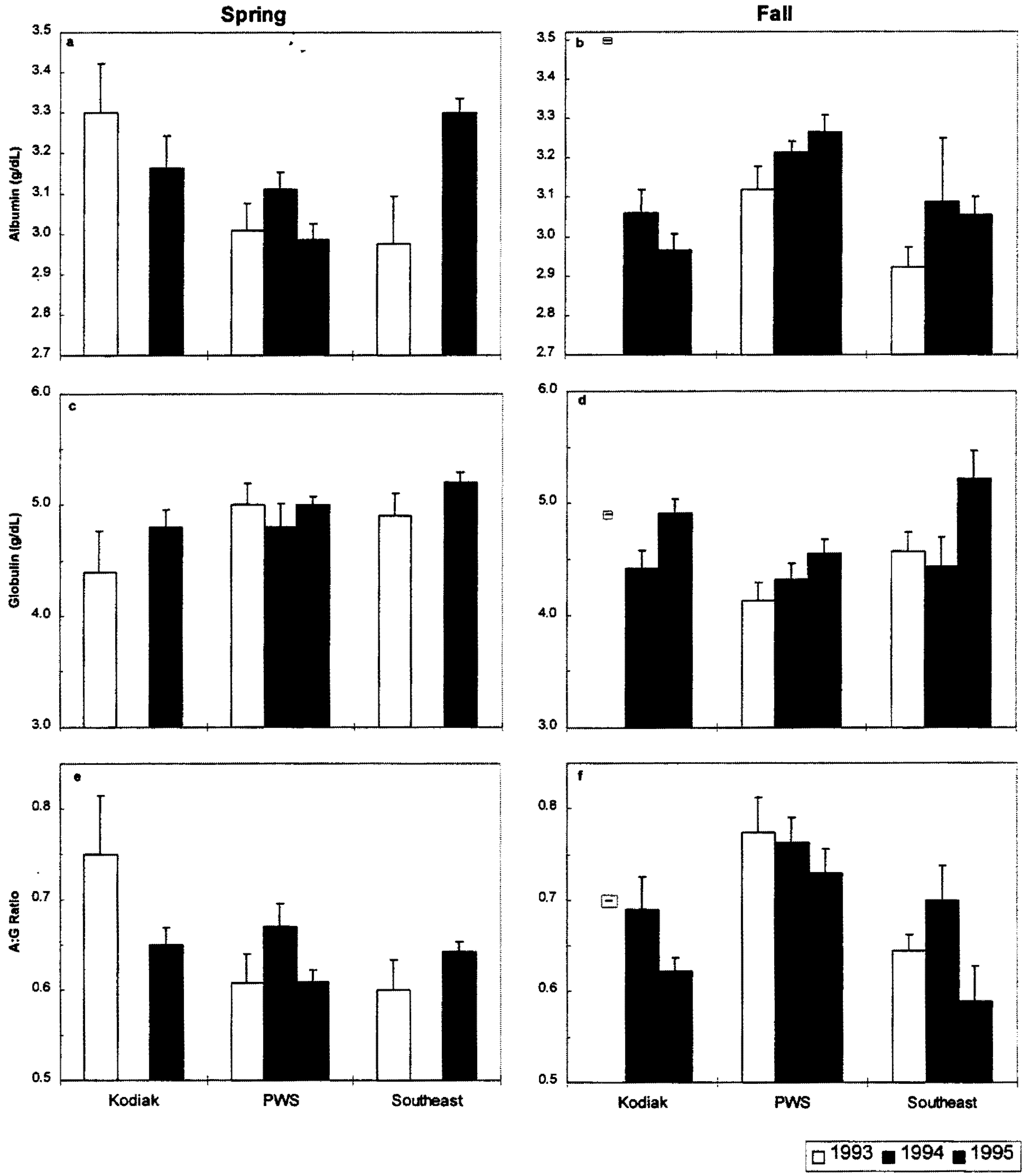

Figure 3. Mean (±1SE) plasma albumin (a, b), globulin (c, d) and albumin:globulin (AG) ratio (e, f) of harbor seals sampled during spring (March-May) and fall (September-October) 1993-95 from the Kodiak archipelago, Prince William Sound (PWS), and southeastern Alaska. Spring sample sizes 1993-95 respectively were: Kodiak 4, 0, 8; PWS 12, 10, 22; southeastern 9, 0, 19. Fall 1993-95 sample sizes were: Kodiak 1, 10, 9; PWS 15, 24, 20; southeastern 9,8,9.

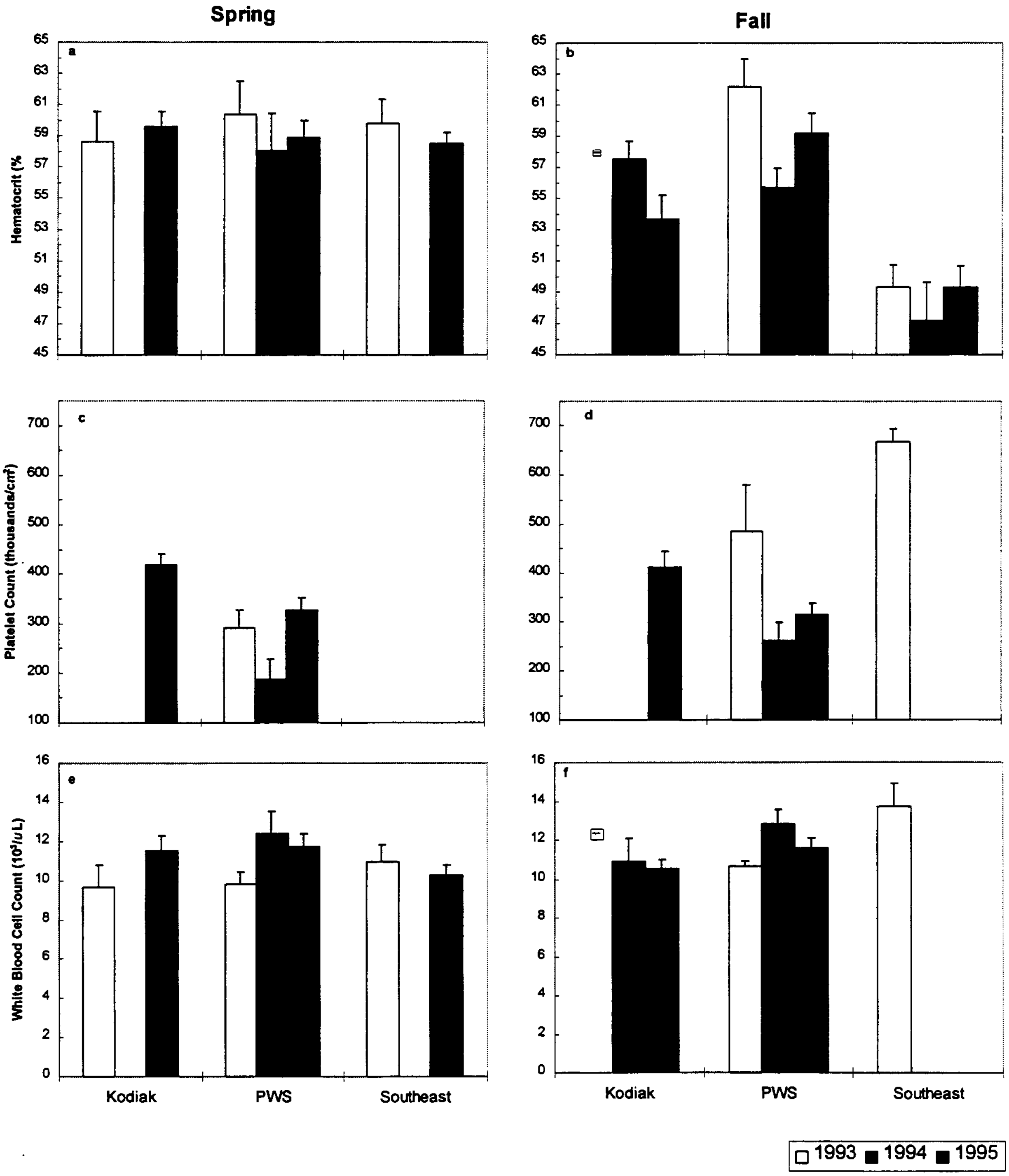

Figure 4. Mean (±1 SE) hematocrit (a, b), platelet count (c, d) and white blood cell count (e, f) of harbor seals sampled during spring (March-May) and fall (September-October) months of 1993-95 from the Kodiak archipelago, Prince William Sound (PWS) and southeastern Alaska. Sample sizes for 1993-95, respectively were: a) Kodiak 4, 0, 8; PWS 12, 10, 22; southeastern 9, 0, 19; b) Kodiak 1, 10, 9; PWS 15, 24, 20; southeastern 9, 9, 9; c) Kodiak 0, 0, 8; PWS 12, 9, 19; d) Kodiak 0, 0, 9; PWS 2, 23, 20; southeastern 7, 0, 0; e) Kodiak 4, 0, 8; PWS 12, 9, 22; southeastern 9, 0 18; f) Kodiak 1, 10, 9; PWS 2, 23, 20; southeastern 9, 0, 0).

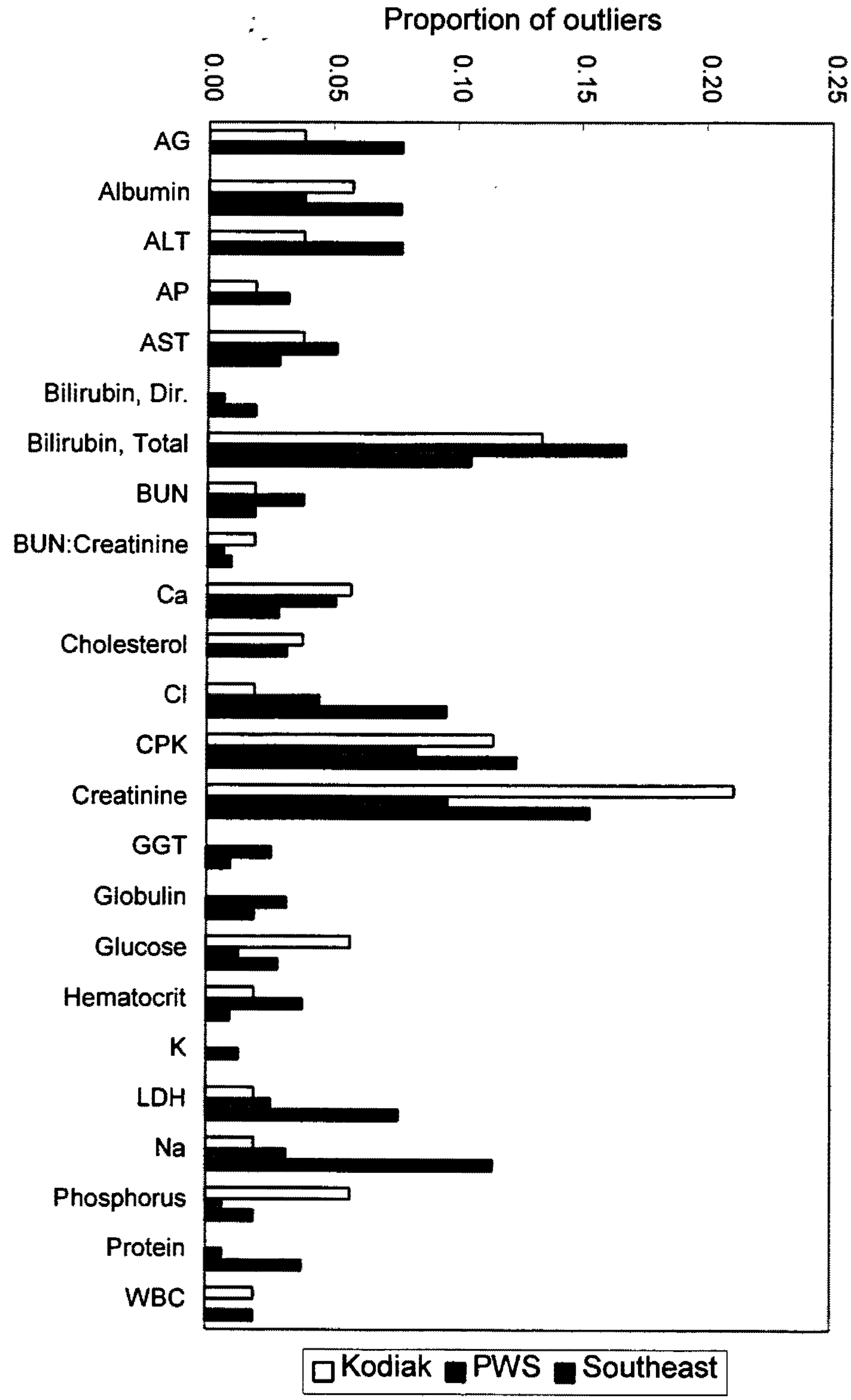

Figure 5. Distributions of clinical chemistry and some hematological values that fall outside of reference ranges (±2 sd) for harbor seals sampled from the Kodiak archipelago, Prince William Sound (PWS) and southeastern Alaska during spring (March-May) and fall (September-October) months of 1993-95. Proportions are of total number of outlying values within each region (Kodiak n=52; PWS n=155; southeastern n=104), and exclude values from samples that were lipemic, hemolytic, or collected posthumously.

APPENDIX 1.

Harbor seals sampled from Kodiak archipelago that showed outlying chemical or hematological values.

PV93KO01	7.9 Calcium
	121 Chloride
PV93KO03	8.2 Calcium
	1.2 Creatinine
PV93KO04	0.9 AG
	3.6 Albumin
	10656 CPK
	1.5 Creatinine
	1 Total Bilirubin
PV93KO05	3.5 Albumin
	1.2 Creatinine
	210 Glucose
PV94KO02	1.2 Creatinine
PV94KO03	78 BUN
PV94KO05	161 AP
	0.6 Total Bilirubin
	17.82 WBC
PV94KO06	11.8 Calcium
	2.2 Phosphorus
PV94KO07	116 BUN:Creatinine
	0.5 Creatinine
PV94KO10	0.9 AG
	378 Cholesterol
PV95KO01	1.5 Creatinine
PV95KO02	1.2 Creatinine
	212 Glucose
	1.6 Phosphorus
	0.7 Total Bilirubin
	35.4 MCHC
PV95KO03	4579 CPK
	1.6 Creatinine
PV95KO04	3.5 Albumin
	137 ALT
	358 AST
	356 Cholesterol
	0.14 Monocytes
PV95KO05	4810 CPK
	0.6 Total Bilirubin
PV95KO06	0.7 Total Bilirubin
	0.15 Monocytes
PV95KO07	8005 CPK
	159 Sodium
	0.6 Total Bilirubin
PV95KO08	16000 CPK
	1.2 Creatinine
	9447 LDH
	2 Phosphorus
	0.6 Total Bilirubin
	0.88 Neutrophils
PV95KO10	.0.5 Creatinine
PV95KO12	1.2 Creatinine
PV95KO13	5015 CPK
	231 Glucose
PV95KO14	0.01 Banded Neutrophils
PV95KO15	157 ALT
	358 AST

Harbor seals sampled from southeastern Alaska that showed outlying chemical or hematological values.

PV93SE01	120 Chloride
	1.2 Creatinine
	100 Glucose
	162 Sodium
PV93SE02	122 Chloride
	161 Sodium
	0.7 Total Bilirubin
PV93SE03	8646 CPK
PV93SE04	1.3 Creatinine
	157 Sodium
PV93SE05	16000 CPK
	1.3 Creatinine
	79 BUN
	9515 LDH
PV93SE06	2.3 Albumin
	8.3 Calcium
	0.5 Creatinine
PV93SE08	3.5 Albumin
	1 Dir. Bilirubin
	1 Total Bilirubin
PV93SE11	1.4 Creatinine
PV93SE19	104 BUN:Creatinine
	98 Chloride
	0.5 Creatinine
	662 Platelets
	17.75 WBC
PV93SE20	228 Glucose
	136 Sodium
	690 Platelets
PV93SE13	7.8 Phosphorus
	809 Platelets
PV93SE17	647 Platelets
	20.75 WBC
PV93SE16	3.95 RBC

PV94SE01	8 Calcium
	0.5 Creatinine
PV94SE03	3.5 Albumin
	118 Chloride
	1.3 Creatinine
	164 Sodium
PV94SE05	2.3 Albumin
	8.1 Calcium
	4226 CPK
	3.1 Globulin
	5.3 Protein
PV94SE06	3.8 Albumin
	319 AST
	117 Chloride
	11240 CPK
	1.9 Dir. Bilirubin
	58 GGT
	9935 LDH
	157 Sodium
	2.4 Total Bilirubin
	32 Hematocrit
PV94SE07	0.9 AG
	8756 CPK
	7986 LDH
	0.6 Total Bilirubin
PV94SE08	118 Chloride
	4997 CPK
	7988 LDH
	157 Sodium
	0.9 Total Bilirubin
PV94SE09	0.6 Total Bilirubin

PV95SE01	217 Glucose
PV95SE02	3.5 Albumin
	120 Chloride
	1.3 Creatinine
	165 Sodium
	9.4 Protein
PV95SE03	3.6 Albumin
	117 Chloride
	164 Sodium
	9.3 Protein
PV95SE04	120 Chloride
	21500 LDH
	167 Sodium
	0.6 Total Bilirubin
PV95SE05	376 AST
	6148 CPK
	21500 LDH
PV95SE07	513 AST
	11 Calcium
	120 Chloride
	16000 CPK
	21500 LDH
	163 Sodium
PV95SE09	0.6 Total Bilirubin
PV95SE10	1.2 Creatinine
PV95SE11	1.3 Creatinine
PV95SE12	4192 CPK
	1.3 Creatinine
PV95SE13	1.8 Creatinine
PV95SE16	3.6 Albumin
	3881 CPK
	1.2 Creatinine
	8196 LDH
	157 Sodium
	0.7 Total Bilirubin
PV95SE17	77 BUN
PV95SE18	5146 CPK

Harbor seals sampled from southeastern Alaska that showed outlying chemical or hematological values, continued.

PV95SE20	6.2 Globulin 9.4 Protein 0.6 Total Bilirubin
PV95SE21	1.5 Creatinine
PV95SE22	0.6 Total Bilirubin
PV95SE23	1.3 Creatinine
PV95SE24	4486 CPK
PV95SE25	4757 CPK
PV95SE27	7.8 Phosphorus

CHAPTER FIVE

OBJECTIVE 6

Determine the reproductive rate, age and sex composition, and level of human disturbance at Tugidak Island during pupping and molting periods and compare results to similar data collected in the 1970s

HARBOR SEAL PRODUCTIVITY AND FIRST-YEAR SURVIVAL IN THE GULF OF ALASKA

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ABSTRACT

Harbor seal numbers declined 72-85% in the western Gulf of Alaska from the 1970s to the 1990s. We found that yearling seals made up a smaller percentage of the seals on Tugidak Island during the pupping period in 1994 than in the 1970s. The percentage of pups among seals ashore, and the greatest percentage of adult females observed with pups showed little change over the years except possibly between 1994 and 1995. The onset and peak day of pupping was 8 - 10 days earlier in the 1990s than in the 1970s.

INTRODUCTION

Tugidak Island in the western Gulf of Alaska was once one of the largest harbor seal (*Phoca vitulina richardsi*) haulouts in the world. Biennial counts conducted on Tugidak from 1976 through 1988 detected a 72% - 85% decline in the number of harbor seals using the island (Pitcher 1990). The decline has continued through the early 1990s, and similar declines have been noted elsewhere in the Gulf of Alaska (Frost and Lowry 1994; Hoover-Miller 1994). We tested the hypotheses that the decline is a result of (1) a change in productivity, or (2) a change in first-year survival.

METHODS

Harbor seals were counted and classified by age and sex during the pupping period in June 1977, 1978, 1994, and 1995. Observations were made using a spotting scope (20X) and binoculars from atop 30 meter cliffs overlooking the haulout beach. Seals were placed into one of three age categories: pup, yearling (identified as the smallest size class of seal excluding pups), and older. Sex was determined by presence or absence of a penile opening when the ventrum was visible. We compared percentages of pups and yearlings during the peak pupping period, which we defined as a nine day period that centered around the maximal pup count.

RESULTS

1. The percentage of yearlings among seals ashore (excluding pups) (Figure 1) was significantly different between years: Kruskal-Wallis statistic=15.92, p=0.0012. A Bonferroni multiple comparison procedure with alpha=0.05 showed that 1994 was significantly different from 1977 and 1978, but no other years were significantly different. The size of difference we are able to detect is limited by small sample sizes.

2. There is evidence that the percentage of pups among seals ashore (excluding yearlings) (Figure 2) is different between years: Kruskal-Wallis statistic=8.10, p=0.0439. A Bonferroni multiple comparison procedure with alpha=0.05 found that a significant difference may exist between 1994 and 1995 only.

3. The greatest percentage of adult females observed with pups showed little change between 1977 (96%), 1978 (93%), 1994 (89%), and 1995 (92%) although the percentages were significantly different X^2=8.36, df=3, p=0.0391.

4. Pupping began about June 1 in 1977 and 1978, and the maximal number of pups were counted between June 18-21. In 1994 and 1995, pupping began about May 23, and the maximal number of pups were counted on 11 June.

DISCUSSION

Although overall numbers of seals hauling out on Tugidak Island have decreased greatly between the 1970s and 1990s, productivity appears to be stable. The decreased percentage of yearling seals ashore may reflect reduced first-year survival rates, changes in behavior, or both. We do not know whether the earlier pupping dates in the 1990s resulted from decreased intervals between fertilization and implantation, decreased gestation periods, or shifts in the entire annual cycle. Nor is the significance to the population decline apparent. Decreased food availability is suspected of contributing to the population decline. Our data suggest that prey important to Gulf of Alaska harbor seals in their first year of life should be investigated. In the Gulf of Alaska in the 1970s, capelin (*Mallotus villosus*) were eaten four times as often by first-year harbor seals as by older seals (Pitcher and Calkins, 1979).

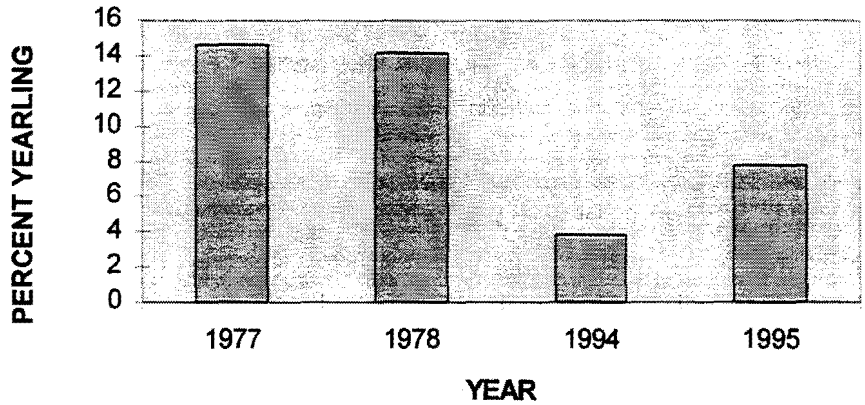

Figure 1. Percentage of yearlings ashore (excluding pups).

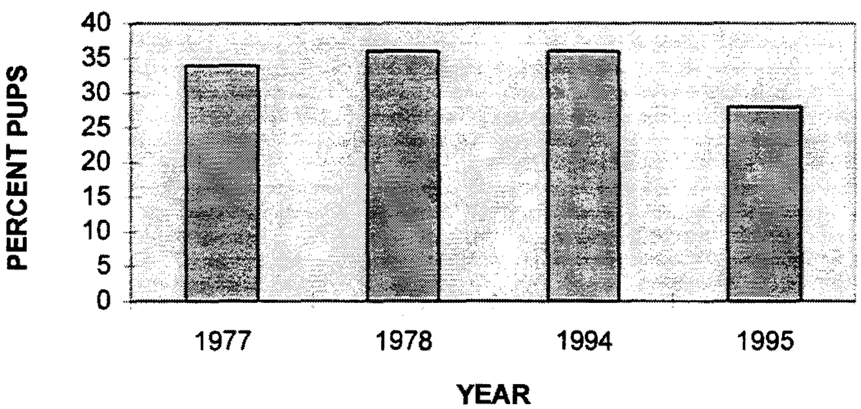

Figure 2. Percentage of pups ashore (excluding yearlings).

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CHAPTER SIX

OBJECTIVE 7

Determine stock structure of harbor seals in Alaska.

GENETIC STUDIES OF ALASKA HARBOR SEALS

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INTRODUCTION

Molecular genetic techniques are increasingly being used to investigate intraspecific structure, and, more specifically, to identify genetically discrete populations that can be managed as separate management stocks (Avise 1994, Dizon et al. 1992). The National Marine Fisheries Service (NMFS) has tentatively divided harbor seals (*Phoca vitulina richardsi*) in Alaska into three stocks, Southeast Alaska (SE), Gulf of Alaska, and Bering Sea (Small and DeMaster 1995), but there is little genetic data available to support those divisions.

As well as revealing population genetic structure, molecular techniques can be used to investigate the consequences of population decline on spatial and temporal patterns of genetic variation. Rapid population declines can result in the loss of important genetic heterozygosity which may affect individual and population 'fitness' and compromise a population's ability to respond to environmental change (Franklin 1980, O'Brien and Evermann 1988). Estimates of diversity at several independent loci may be informative when used in conjunction with detailed ecological data in determining the relative importance of environmental and genetic factors in not only causing population decline, but also in inhibiting population recovery.

Differences in population trends among regions may be due in part to differences in the ecology and behavior of harbor seals within each region. For example, seals in one area may be more philopatric or exhibit more closed mating strategies or grouping patterns than seals in another area. Such differences could affect survival rates and influence productivity and rates of recolonization of depleted areas. Molecular genetic studies can provide important insights into behavioral ecology and demography (Amos et al. 1995, Avise 1995). In particular, such investigations can determine whether aspects of harbor seal biology differ among regions, and whether those differences can help explain the differing population trends.

One of the objectives of this project during the past year has been to determine the stock structure of harbor seals in Alaska. The approach to accomplishing this has been for the Alaska Department of Fish and Game (ADF&G) to supply samples and some support for analysis to the NMFS Southwest Fisheries Science Center (SWFSC). The SWFSC is doing molecular genetic analysis of the samples, initially looking at mitochondrial DNA (mtDNA). The results of the mtDNA work will be used as part of a Master of Science thesis project by Robin Westlake at San Diego State University.

This report describes progress made to date in the SWFSC-ADF&G harbor seal study. ADF&G has also provided samples to several other studies that have dealt with genetics of harbor seals but have not specifically addressed the question of stock identity within Alaska. Those studies are identified and their results are briefly described.

METHODS

Skin samples for genetics analysis have been collected from each seal captured by ADF&G since 1993. A sample approximately 0.5 cm in diameter was taken from the interdigital webbing of each hind flipper using a punch, and preserved in 20% dimethyl sulphoxide saturated with sodium chloride. Samples from seals collected in previous years have also been made available for genetics studies. Historical samples were of skeletal muscle that had been frozen at -12°C. Since 1993, all genetics samples we have collected from harbor seals have been sent to SWFSC, and samples and extracted DNA are archived there.

Samples have been provided to five separate research groups (Table 1).

Since laboratory and data analyses of genetics samples have not been done by this project, details of those methods are not described in this report. Readers should consult the referenced publications for a full description of analytical techniques.

RESULTS

The harbor seal genetics studies to which ADF&G has provided samples have had varying geographic scope. One has been worldwide, one compared the North Atlantic with the North Pacific, one included the west coast of the U.S., one British Columbia and Alaska, and one Alaska and Russia. The first three studies are largely complete and results have been published, while the other two are ongoing and only preliminary results are available.

Lehman et al. (1993) did a DNA fingerprinting study of harbor seals in the western U.S. that included three samples from Prince William Sound (PWS). The results showed geographic partitioning among the west coast localities surveyed (PWS, Puget Sound,

Table 1. Summary of harbor seal genetics investigations that have used samples supplied by ADF&G.

Investigators	Number of Samples Analyzed to Date: Bering Sea	Kodiak Region	Prince William Sound	Southeast Alaska	Other	Types of Analyses
Lehman et al.	--	--	3	--	--	DNA fingerprinting
Kappe et al.	--	--	15	10	--	DNA fingerprinting, microsatellites
Stanley et al.	12	--	--	--	--	mtDNA sequencing
Burg et al.	--	29	30	30	15	mtDNA sequencing, microsatellites
Westlake et al.	23	20	28	20	28	mtDNA sequencing

Washington coast, San Francisco Bay, and San Miguel Island), but the sample size was too small to address variation within Alaska.

Kappe et al. (1995 and submitted) did multilocus DNA fingerprinting on harbor seal samples from several regions. Results showed that seals from the Pacific (*P. v. richardsi*) could be clearly differentiated from those in either the western (*P. v. concolor*) or eastern (*P. v. vitulina*) Atlantic. They found a very low level of genetic variation in seals from the eastern Atlantic, but a much higher level of variation in the North Pacific (samples from SE and PWS).

Kappe (pers. comm.) found differences in microsatellite groupings of seals sampled in Alaska. Within PWS seals from Seal Island (10), Applegate Rocks (1) and Bay of Isles (1) were in group I. Seals from Channel Island (3) were in group II. In SE samples, 8 seals were in group II and 1 was in group I.

Stanley et al. (1996) used mtDNA sequencing to look at genetic relationships among harbor seals worldwide. They found clear differences between seals in the Atlantic and Pacific oceans, and between the east and west coasts of each ocean. The only samples they analyzed from Alaska were from Bristol Bay, and they found that seals from that region were more closely related to populations in Japan and the Commander Islands than to Washington and California.

Burg et al. (1995 and pers. comm.) did both mtDNA and microsatellite analysis of seals from British Columbia and Alaska. She found considerable genetic diversity in both analyses. Preliminary results suggest differences between seals in Alaska and northern B.C. compared to those from Vancouver Island and the adjacent mainland.

The primary study that is using molecular genetics to examine relationships among harbor seals in Alaska is being done at the NMFS SWFSC (Westlake et al. 1995, 1996). As of May 1996 they have sequenced mtDNA from 119 samples (23 from the Bering Sea, 71 from the Gulf of Alaska, 20 from SE, and 5 from Russia). They have found 49 variable sites of which 35 were phylogenetically informative. A preliminary analysis grouped samples according to the three regions used by NMFS in stock assessment reports (Small and DeMaster 1995). Based on the 114 sequences from Alaska, no statistically significant genetic differentiation was found among the three areas combined. However, pair-wise comparisons among the three PBR areas showed that the Bering Sea sample was significantly differentiated from the Gulf of Alaska. If Russian samples are included with others from the Alaskan Bering Sea, both the Gulf of Alaska and SE are significantly different from the Bering Sea. Pairwise comparisons between smaller geographic units (Bering Sea, Kodiak, PWS, and SE) suggested a significant difference between samples from the Bering Sea and PWS, but not between other areas.

DISCUSSION

In recent years a number of studies have been initiated to use molecular genetic techniques to examine relationships among harbor seals in different regions. Several of those studies are still ongoing and results from them are preliminary or have been incompletely reported.

Study results show that molecular genetics (either mtDNA sequencing or DNA fingerprinting) can clearly differentiate harbor seal subspecies, and also show major differences between populations on a relatively large geographic scale such as the eastern and western Atlantic (Stanley et al. 1996, Kappe et al. submitted). DNA fingerprinting has shown that eastern Pacific harbor seals have much higher genetic diversity than those in the Atlantic (Kappe et al. 1995 and submitted).

At a smaller geographic scale, analysis of microsatellite DNA polymorphisms demonstrated that the European harbor seal population is highly structured and that there is little movement of breeding individuals between sub-populations (Goodman et al. 1993). Mitochondrial DNA sequencing found considerable haplotype diversity in seals from Washington, Oregon, and California, and an analysis of molecular variance found significant differences in haplotype frequencies among regions (Lamont 1995). Based on DNA fingerprinting Lehman et al. (1993) concluded that "there is geographic population-genetic partitioning in the harbor seal along the west coast of North America." Preliminary analysis of microsatellites suggests differences among seals in PWS and between PWS and SE (Kappe, pers. comm.).

The study that specifically addresses the issue of stock structure in Alaskan harbor seals began in 1994. Currently 351 samples are available with sufficient numbers from most areas (Westlake, pers. comm.). ADF&G and NMFS are continuing to collect and archive samples. At the SWFSC, emphasis to date has been on laboratory work to extract and sequence mtDNA. Preliminary analyses of the data have shown equivocal results (Westlake et al. 1995, 1996). Possible explanations for the results are that: 1) there is no geographic population structuring; or 2) the population is structured but the power of statistical tests for detecting differences was low due to relatively small samples sizes or some other reason. The need for large sample sizes is especially great when examining species like harbor seals that are relatively abundant (Taylor and Dizon 1996). SWFSC researchers caution against drawing conclusions about management units for Alaska harbor seals at this time based on their preliminary results.

Additional samples are currently being sequenced, and sequencing will continue until sample sizes and geographic coverage are adequate. At that time the data will be fully analyzed to determine whether there is geographic partitioning of genetic structure in Alaskan harbor seals, the amount of genetic exchange between areas, and the appropriate boundaries of management units. Complete results of this study are expected to be available in December 1996.

Much remains to be learned about the genetics of harbor seals in Alaska, and the samples and analytical techniques needed for such studies are now available. For that reason this project will continue to provide support for work to be done at the SWFSC during 1996-1997. In addition to the mtDNA study, laboratory protocols will be developed to screen for allelic variation at a number of microsatellite loci. A set of samples from a number of well studied haulout areas that represent different habitats and show differing population trends will be screened for each variable microsatellite locus. Results will be evaluated to determine whether microsatellite analysis can yield information on the history and behavioral ecology of populations that may be used in the design of management policies.

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CONCLUSIONS AND RECOMMENDATIONS

The first overall objective of this project was to monitor the trend in harbor seal numbers in selected areas. The general areas selected were SE and the Kodiak archipelago, and specific trend routes were surveyed in each. Surveys were conducted in 1993, 1994, and 1995, and results were compared to previous years. Based on these analyses we conclude that harbor seal numbers in the Ketchikan area have increased since 1983 at an average rate 8% per year. There was no significant trend in seal numbers near Sitka, perhaps because surveys were only done in only four years and there were differences in observers and timing. Counts on the trend route in the eastern and southern Kodiak area appeared to be stable or possibly increasing. On the southwest beach of Tugidak Island counts during the molt have continued to decline (at 7.9% per year) but show indications of stabilizing. While these data provide encouraging indications that the decline may have stopped in the Kodiak region, it is too soon to conclude that seal numbers have begun to recover.

The second overall objective was to investigate factors that may be affecting harbor seals in selected study areas. Factors that have been proposed that may have affected seal numbers include reduced prey availability, either by environmental changes or through commercial exploitation, human caused mortality through harvest or incidental take in fisheries, diseases, pollutants, and predation by killer whales (*Orcinus orca*) and sharks. Perhaps the favored hypothesis is undernutrition that may have led to reduced survivorship and/or productivity. This is also the leading hypothesis regarding the decline in Steller sea lion numbers over much of their range (Calkins and Goodwin 1988, Merrick 1995).

A similarity between the Steller sea lion and harbor seal declines is that for both species numbers are stable or increasing in SE but declining in other parts of the state. That has led to recommendations for comparative studies of sea lions in the two regions (NMFS 1992), and we have taken a similar approach with harbor seal studies. If it proves possible to identify factors that differ between areas, research could then focus on those factors and try to determine their relationship to the population decline. Most of this research is ongoing and the analyses presented in this report are preliminary and in some instances incomplete.

Movements, diving behavior and time spent hauled-out of satellite tagged harbor seals were highly variable among individuals in both SE and in the Kodiak area. While seals appeared to dive deeper in SE and more frequently in the Kodiak area, it is uncertain if this is biologically significant or is a function of sampling, large individual variation, or differing habitats. A strong seasonal pattern in diving was evident in both areas. Seals dove much deeper in fall and winter than during the late spring and summer. Satellite-tagged seals spent similar proportions of time hauled out in both areas but differences could have be masked by small sample sizes, variation associated with individuals, season and sex and age classes, or sampling biases. Dive diversity appeared greater for SE harbor seals which may reflect more diversity in depths available to seals in that area. Data for an additional 21 seals tagged in 1995 will increase samples sizes and will be reported in 1997. We plan on satellite tagging an additional 16 seals in fall of 1996. Eight of these tags will be deployed on seals in outside waters of SE which will allow comparisons of behavior in deep open-water habitats of SE and the Kodiak area.

Several disease agents with the potential for population level impacts were detected in harbor seals throughout Alaska. However, no evidence was found that suggests that populations have been or are currently being impacted by these diseases. There appeared to be no difference in exposure rates in SE and other areas of the state.

Regional differences in some clinical chemistry and hematology values were found, but their biological significance is currently not understood. Zenteno-Savin et al. (1996) found that harbor seals from Prince William Sound had higher levels of the acute phase protein haptoglobin than seals from SE. Differing haptoglobin levels may be indicative of different stressor levels, or may be the result of genetic or seasonal sampling differences.

Preliminary results of field studies on Tugidak Island, where mean molting season counts have declined by 94% over the past 20 years, indicated that the rate of pup production is probably at a comparable level to that of the late-1970s, but that the proportion of yearlings counted on the beaches may be reduced. Pupping was 8-10 days earlier than in the late-1970s.

There is only sparse evidence suggesting that the harbor seal decline in the Gulf of Alaska has been associated with undernutrition. Pitcher and Calkins (1979) reported low blubber thickness in seals collected from the Kodiak area in 1977 when numbers were sharply declining. The decline occurred during a period when there was apparently a major shift in the marine ecosystem of the Gulf of Alaska, marked by increased water temperatures (Francis and Hare 1995, Kerr 1992, Trenberth and Hurrell 1995). Concurrent with this oceanographic shift were major changes in shellfish and finfish abundance and composition (NRC 1996, J. E. Blackburn, pers. commun.). Findings that harbor seal pupping on Tugidak island is over a week earlier in the mid-1990s than during the mid-1970s suggests that the nutritional status of that population may have improved. Since harbor seal populations in the Gulf of Alaska have undergone major declines (-94% on southwest Tugidak Island between 1976 and 1995), density dependent relationships of harbor seals to their prey should have changed substantially regardless of changes in the marine environment. There are indications that undernutrition was involved in the concurrent decline of Steller sea lions in the Gulf of Alaska (Calkins and Goodwin 1988, Pitcher et al. 1996).

If the decline in harbor seal numbers in the Gulf of Alaska has halted and numbers have begun increasing, comparative studies between harbor seal populations in SE and the Kodiak area may not be the best way to investigate causes of the decline. A basic assumption for these comparative studies was that the factors responsible for the decline were still operating to a similar degree when the studies where conducted as they had been earlier. There is now some question if this assumption is correct. However, findings of differences in haptoglobin levels and some clinical chemistry and hematology values may indicate that some stressor may be affecting harbor seals in the two regions differently. Also differences in dive frequency could indicate increased foraging effort in the Kodiak area.

The final overall objective was to provide information to NMFS that would be of use in harbor seal conservation and management. Prior to this study, little work had been done on the biology of harbor seals in Alaska since that of Pitcher and Calkins (1979) in the mid-1970s, except for studies in Prince William Sound that were done as a result of the *Exxon Valdez* oil spill (Frost and Lowry 1994). The work described above presents much new information on the biology and ecology of harbor seals. Current information on trends in abundance should be of use to NMFS in evaluating status of stocks and deciding if and where protective actions may be required. The genetics study being conducted with the NMFS SWFSC should provide the data needed to identify biologically appropriate management units. Satellite telemetry studies, when completed, should provide detailed information on distribution, movements, and habitat use and behavior both on land and at sea. These are the types of studies that have been recommended to resolve uncertainties concerning management needs for harbor seals and related species in Alaska (Swartzman and Hofman 1991).

Recommendations

1. Trend surveys should be repeated in the Ketchikan, Sitka, Kodiak, and Tugidak areas in 1996. If data collected on the Ketchikan survey route indicate a continuation of the 1983-1995 trend, survey frequency should be reduced to alternate years. Surveys should continue on an annual basis for the other areas until the current trend is clear and then consideration should be given to an alternate year schedule.

2. A trend route should be developed in the eastern Gulf of Alaska in 1996 based on the previous NMFS range-wide survey of that area.

3. During trend surveys all groups of seals on haulouts should be photographed for counting in addition to direct counts or estimates. Annual timing of the surveys should remain consistent. It is also desirable to retain as much consistency in observers and pilots as possible. When this is not possible the prior and current observers should review the survey route together before the surveys to ensure comparable coverage. A formal survey protocol should be developed to ensure consistent survey methodology between observers.

4. More detailed analyses of the movements, dive, and haulout data should be undertaken when larger sample sizes are obtained. Because some seals are using a variety of habitats, dive data should be integrated with location data on a finer scale, as seals may have different diving patterns in different habitats. To date dive behavior has only been analyzed on a broad geographic basis and localized patterns may be

masked. The actual amount of time spent underwater and thus presumably foraging should be investigated.

5. Small satellite tags should be placed on pups and juveniles to increase sample sizes of these age classes. There are indications that body size and growth rates of juveniles are affected by variations in food availability and that diving ability was correlated with body size.

6. Future research should investigate which aspects of foraging behavior are most likely to indicate differences in foraging effort and prey availability. More information is needed on how harbor seals allocate their time during foraging trips on activities such as swimming, diving and resting. Reconfigured SDRs or perhaps traditional time depth recorders (TDRs) should be considered for their ability to measure certain details of behavior at sea, such as dive bouts, surface time, time spent traveling, and vertical distance traveled.

7. Researchers should continue to archive harbor seal sera for future disease testing when it is determined to be appropriate. Disease data should be statistically analyzed to determine if regional differences in exposure rates exist. Relationships of ages of animals and exposure rates should be investigated where adequate samples are available.

8. Physiological studies of blood chemistry and hormonal parameters that have shown regional differences should be continued. Preliminary data suggest that Gulf of Alaska harbor seals may be experiencing a higher level of stress than SE animals. The biological significance of the differences, and, if possible, the factors that are causing them, should determined.

9. The molecular genetics research program currently underway at the NMFS SWFSC should be continued. In addition we recommend that: a) tissue samples for genetics analyses should be routinely collected as part of all harbor seal research projects and subsistence sampling programs, and samples should be appropriately preserved and sent to the SWFSC for archival; b) mitochondrial DNA analyses should continue until sample sizes are adequate to test for population structuring with appropriate statistical power.; c) statistical analyses of mtDNA results should consider not only the three preliminary stocks used in NMFS stock assessment reports, but also other reasonable geographical units; and d) microsatellite studies should be initiated to further investigate aspects of harbor seal genetics that may have ecological and management significance.

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