AN ABSTRACT OF THE THESIS OF

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Title ABUNDANCE, MOVEMENTS AND FEEDING HABITS OF THE HARBOR SEAL, PHOCA VITULINA, AT NETARTS BAY, OREGON

Redacted for privacy

Abstract approved: Dr. Bruce R. Mate

Chapter One

Feeding habits of the harbor seal, Phoca vitulina, at Netarts Bay, Oregon were examined by the identification of fish otoliths recovered from seal scats and by direct observation of seals feeding in the bay. A total of 3800 fish otoliths were recovered from 149 scat samples collected between August, 1977 and May, 1979. A minimum of 24 species of fish were identified as harbor seal prey items. Otoliths from the Pacific sand lance, Ammodytes hexapterus, were the most common in the collection. Nine species of flatfish (Order Pleuronectiformes) were identified as seal prey, and in general, benthic and epibenthic fishes appeared to be important in the seal diet. Two previously unreported harbor seal prey species, Isopsetta isolepis and Radulinus asprellus, were identified from the otolith collection. Based on known distributions and abundances of the identified prey items, and on estimated prey sizes, it was determined that harbor seals had fed both in the bay and in the nearshore ocean.

Harbor seals in Netarts Bay were known to prey on chum

salmon (Oncorhynchus keta) during the annual return of these fish to the experimental hatchery on Whiskey Creek (operated by the Department of Fisheries and Wildlife at Oregon State University). Based on observed predation rates and estimated daily dietary requirements for harbor seals, it was estimated that seals feeding near the hatchery may have taken 9.1% of the 1978 chum return.

Chapter Two

Seasonal abundance of the harbor seal in Netarts Bay was documented from May, 1977 through December, 1979 by recording numbers of animals hauled out on sand flats at low tides. An annual cycle with low winter abundance, followed by increases through the spring (pupping) and summer (molting) to a peak in the late fall-early winter was found. This peak was coincident with the annual return of chum salmon to Netarts Bay, suggesting that this highly seasonal food source may have influenced seal abundance in the bay. Harbor seal counts at Tillamook Bay (15 km north) revealed an annual peak during the pupping and molting periods with relatively low numbers during the rest of the year. Pupping in both areas began by the second week of May and peaked by the second week of June. Observed ratios of pups to non-pup animals were similar to those reported for harbor seals in other areas.

Radio-tagging studies indicated that movement of harbor seals between Netarts and Tillamook Bays was common and frequent (a traveling distance by sea of 25 km). Mark-resighting estimates (Jolly-Seber method) indicated that the number of seals utilizing Netarts Bay may have been between 1.5 and 3.0 times the number hauled out at any time.

Abundance, Movements and Feeding Habits
of the Harbor Seal
Phoca vitulina,
at Netarts Bay, Oregon

by

Robin Franklin Brown

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Typed by Nancy Brown for: Robin Franklin Brown

For my father

Dr. Robert F. Brown

and

his new grandson

Jesse

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

FEEDING HABITS OF THE HARBOR SEAL,

PHOCA VITULINA,

AT NETARTS BAY, OREGON

FEEDING HABITS OF THE HARBOR SEAL, PHOCA VITULINA, AT NETARTS BAY, OREGON

INTRODUCTION

The Pacific harbor seal, *Phoca vitulina richardsi*, (Shaughnessy and Fay, 1977) is a common year-round resident of the Oregon coast that uses a variety of habitats including nearshore rocks, bays and river systems (Mate, 1977). Before complete protection was afforded the harbor seal by the Marine Mammal Protection Act (MMPA) of 1972, a combination of the Oregon State Bounty Program (1925-1972) and traditional harassment from commercial and sport fishermen kept these animals at relatively low numbers in most bays and rivers. Since 1972, the number of seals found in many of Oregon's estuaries has been on the rise (Snow, pers. comm.). At Netarts Bay, Oregon, approximately 110 km south of the Columbia River, this type of recent increase in harbor seal abundance has been observed.

Since 1969, the Department of Fisheries and Wildlife at Oregon State University has operated an experimental chum salmon (*Onchorhyncus keta*) hatchery on Whiskey Creek (Lannan, 1975), the major stream entering Netarts Bay. A primary objective of the hatchery program has been to rebuild the vestigal stock of Netarts Bay chum salmon. Predation by harbor seals on chum returning to the hatchery was easily observed near the mouth of Whiskey Creek. The present study of harbor seal feeding habits was initiated in response to concern over the impact that seals may have on the hatchery operations.

Food habits of harbor seals in the northeastern Pacific have been examined in Alaska by Imler and Sarber (1947), Wilke (1957), Kenyon (1965), Pitcher (1977), and Pitcher and Calkins (1979); in British Columbia by Fisher (1952) and Spalding (1964); in Washington by Scheffer and Sperry (1931) and Calambokidis et al. (1978); in California by Morejohn, et al. (1979) and Bowlby (1979); and in Oregon by Roffe (1980). The prey items identified in many of these studies have been summarized by Morejohn, et al. (1979). Harbor seals feed on a wide variety of fishes and cephalopods and in general appear to be opportunistic in their feeding behavior.

Most harbor seal feeding habit studies in the past have involved the analysis of stomach and intestinal contents from collected animals. Since the MMPA has restricted the collection of animals, many recent studies have relied more heavily on surface feeding observations and identification of prey hard parts such as fish otoliths, cephalopod beaks and lamprey jaws collected from seal scats to describe feeding habits (Morejohn, et al. 1979; Calambokidis, 1978; Bowlby, 1979; Roffe, 1980). An important advantage of this type of analysis is that the "population" being sampled is not altered during the study as is the case when animals are removed by collection. The low number of harbor seals commonly found in Netarts Bay (generally less than 100) precluded the collection of animals for stomach content analysis. Thus the techniques of surface feeding observation and scat collection were also adopted in this study.

Several recent studies have been designed to examine pinniped-fishery interactions and assess the impact that seals or sea lions may have on a commercial or sport fishery (Matkin and Fay, 1978; Mate, 1980; Roffe, 1980; Everitt, 1980), but no study is known to have examined the impact that predation by harbor seals might have on salmon aquaculture operations.

STUDY AREA

Netarts Bay is 7.4 km long on its north-south axis, by 2.1 km wide and has a surface area at mean high water of 1010 ha (Glanzman, et al. 1971). Large areas of sandy bottom are exposed in the bay during most low tides (Fig. 1). Harbor seals haul out on several of these sand bars to rest and depending upon the season, to nurse their young or to molt. Counts of harbor seals hauled out in Netarts Bay have revealed an annual cycle of abundance that peaks during the months of October and November (127 in November of 1978; Brown and Mate, 1980). Chum salmon return to the hatchery at Whiskey Creek between the last week of October and the last week of November. The coincidence of the peak in seal abundance and the timing of the salmon run suggested the potential for high predation levels.

Although seal predation on salmon has occasionally been observed in other parts of the bay (Fisher, pers. comm.), seals apparently take advantage of the concentrations of fish that occur as they funnel from the wide open bay into the narrow mouth of Whiskey Creek. The creek enters the bay in its shallow upper reaches so that low tides prevent salmon from returning to the hatchery. Only when the rising tide has flooded this area can salmon approach and enter the creek. Visual observations of seals feeding on salmon were made during high tides in the area surrounding the mouth of Whiskey Creek.

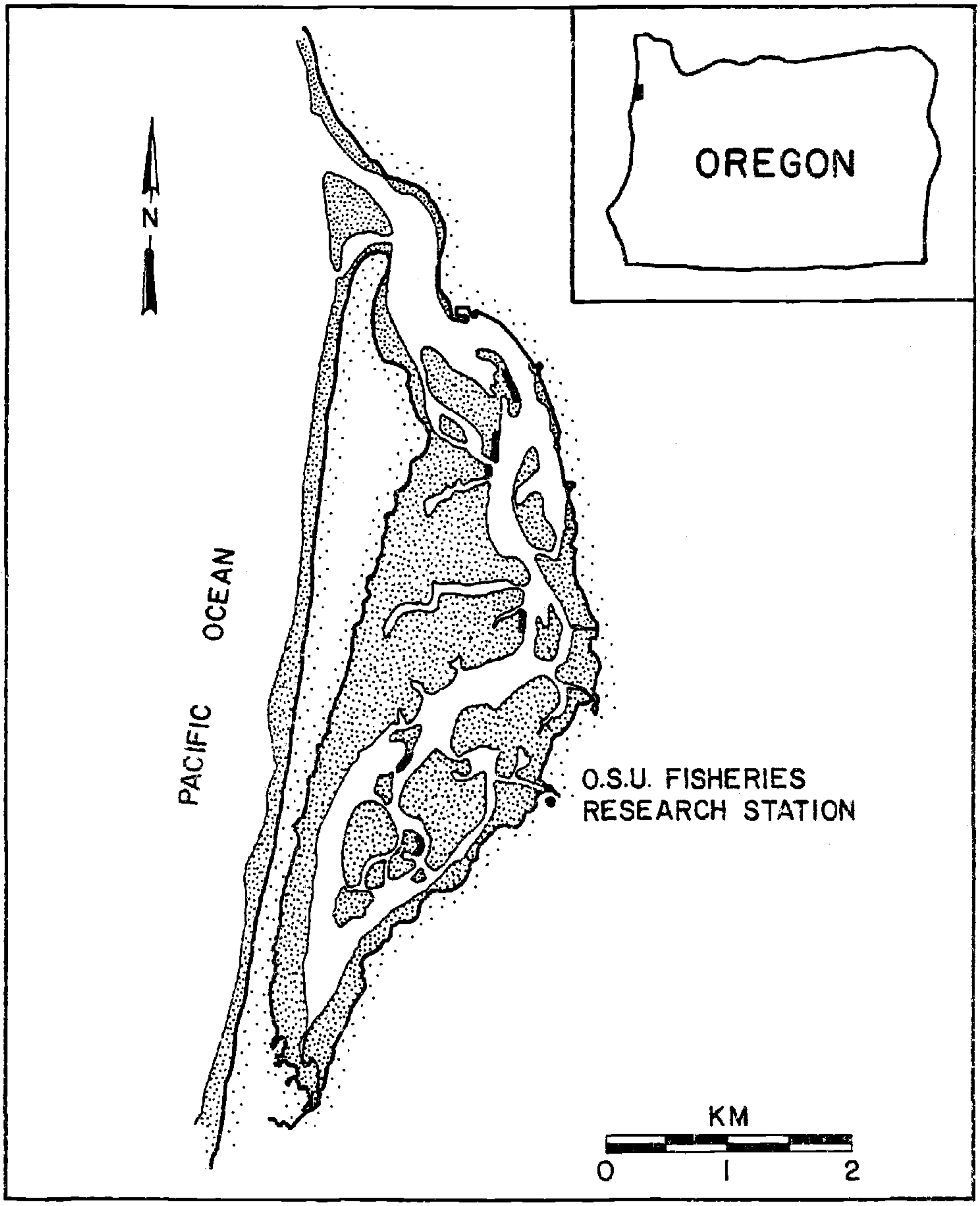

Figure 1. Netarts Bay, Oregon. The sand flats most commonly used as harbor seal haul-out areas are darkened.

METHODS

Harbor seal scat was collected (opportunistically) from haul-out areas within the bay between May, 1977 and May, 1979. Collected samples were placed in a 5% buffered formalin solution for two to four days, then washed with water over a 0.5 mm sieve. Any otoliths present were removed, air dried and stored in one-quarter dram shell vials with cotton stoppers. All otolith identifications were made by John E. Fitch of the California Department of Fish and Game.

In order to estimate the size of the fish that were taken by the seals, otoliths from the scat samples were measured under a dissecting microscope fitted with an ocular micrometer and when possible, compared to the lengths of otoliths from fish of known sizes. Most data on otolith length vs. standard length (SL) of fish used here were collected from specimens in various collections at the School of Oceanography at Oregon State University (see Appendix).

Seals preying on salmon near the mouth of Whiskey Creek were observed from a 4 m high blind using 10 X 50 binoculars and a 20-45X zoom spotting scope. The observation area included the lower 30 m of the creek and a semi-circular area centered at the mouth of the creek and extending out onto the bay with a radius of approximately 250 m. Harbor seals could occupy this area only when the tide was high enough to allow them deep water access or on the average, about 2.5 hours before and after the peak of each high tide. Observation periods varied from 1.25 to 6.0 hours. A total of 46 hours of observation were made over 11 days during the 1978 chum run (October 26 through November 24).

RESULTS AND DISCUSSION

SCAT COLLECTION

Although harbor seals were hauled out during 88.4% of the observed low tides, scat samples were found only on 42.9% of those days that the haul-out sites were examined. There was no apparent relationship between the number of seals hauled out and the number of scats found. The availability of scats for collection and examination was highly variable. Since scat samples could not be collected uniformly throughout the seasons (Fig. 2), a seasonal comparison of feeding habits was not possible. Most collections were made during the late summer-early fall months of August and September. The single sample from November of 1977 was collected after the chum run of that year. The six samples from October of 1978 were collected before the 1978 run began. Thus, seal predation on chum salmon in Netarts Bay could not be examined by this method of feeding habit analysis.

From May of 1977 through August of 1979, 149 scat samples were collected in Netarts Bay. Of these samples, 58 (38.9%) contained no identifiable otoliths. The remaining 91 (61.1%) contained a total of 3800 identifiable otoliths from at least 24 species (Table 1) and 13 families (Table 2) of fish. Two of these species, the butter sole (*Isopsetta isolepis*) and the slim sculpin (*Radulinus asprellus*), are previously unreported harbor seal food items.

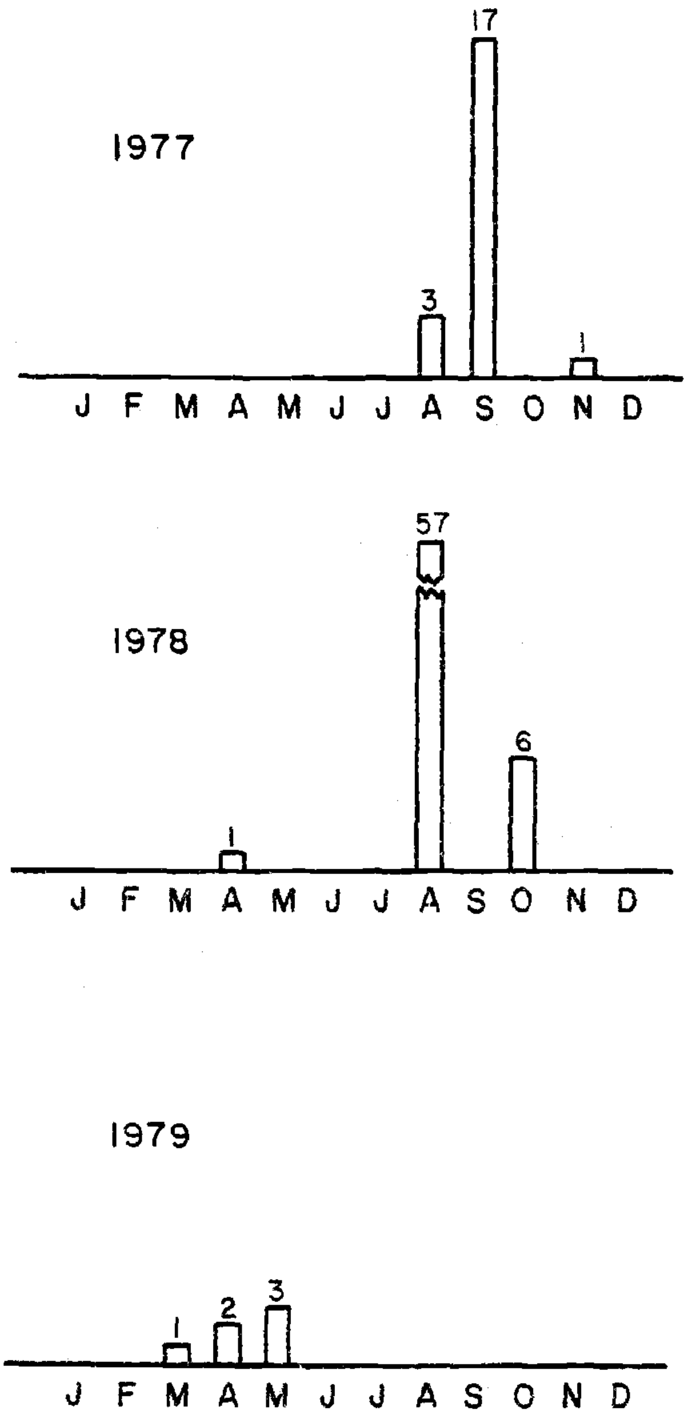

Figure 2. Collection by month of 91 harbor seal scat samples from Netarts Bay that contained identifiable fish otoliths (number at top of bar is number of samples per month).

TABLE 1. Species of fish identified as harbor seal prey by recovery and identification of fish otoliths from seal scat samples. Prey items are ranked by frequency of occurrence in the 91 scat samples collected at Netarts Bay, Oregon. The greater of either the left or the right otolith count for each species within each sample were combined to give the minimum number of fish represented in the entire otolith collection.

Species	Common name	Frequency No.	Frequency %	Minimum no. fish	(% of total)
Ammodytes hexapterus	Pacific sand lance	37	40.7	1503	(73.7)
Parophrys vetulus	English sole	30	33.0	126	(6.1)
Glyptocephalus zachirus	Rex sole	25	27.5	79	(3.8)
Citharichthys sordidus	Pacific sanddab	17	18.7	53	(2.6)
Leptocottus armatus	Pacific staghorn sculpin	16	17.6	54	(2.6)
Microstomus pacificus	Dover sole	16	17.6	39	(1.9)
Lyopsetta exilis	Slender sole	11	12.1	16	(0.8)
Clupea harengus	Pacific herring	8	8.8	22	(1.1)
Allosmerus elongatus	Whitebait smelt	7	7.7	10	(0.5)
Sebastes spp.	Rockfish	5	5.5	20	(1.0)
Microgadus proximus	Pacific tomcod	5	5.5	6	(0.3)
Cymatogaster aggregata	Shiner surfperch	5	5.5	24	(1.2)
Hexagrammos decagrammus	Kelp greenling	4	4.4	6	(0.3)
Thaleichthys pacificus	Eulachon	4	4.4	11	(0.5)

TABLE 1. (cont.)

Species	Common name	Frequency No.	Frequency %	Minimum no. fish	(% of total)
Anoplopoma fimbria	Sablefish	4	4.4	14	(0.7)
Citharichthys stigmaeus	Speckled sanddab	4	4.4	20	(1.0)
Isopsetta isolepis	Butter sole	4	4.4	6	(0.3)
Hypomesus pretiosus	Surf smelt	3	3.3	8	(0.4)
Engraulis mordax	Northern anchovy	2	2.2	4	(0.2)
Psettichthys melanostictus	Sand sole	2	2.2	2	(0.1)
embiotocid juveniles	Surfperch	2	2.2	7	(0.3)
Salmo gairdneri	Steelhead	1	1.1	1	(0.05)
Spirinchus starksi	Night smelt	1	1.1	1	(0.05)
Merluccius productus	Pacific hake	1	1.1	1	(0.05)
Radulinus asprellus	Slim sculpin	1	1.1	1	(0.05)
Platichthys stellatus	Starry flounder	1	1.1	1	(0.05)
unidentified osmerid	Smelt	1	1.1	2	(0.1)
unidentified embiotocid	Surfperch	1	1.1	1	(0.05)
unidentified pleuronectid	Flatfish	1	1.1	1	(0.05)

TABLE 2. Frequency of occurrence of otoliths from 13 Osteichthyes families in 91 harbor seal scat samples from Netarts Bay, Oregon.

	Frequency No.	Frequency %
Pleuronectidae	55	60.4
Ammodytidae	37	40.7
Bothidae	21	23.1
Cottidae	17	18.7
Osmeridae	14	15.4
Clupeidae	8	8.8
Embiotocidae	7	7.7
Gadidae	6	6.6
Scorpaenidae	5	5.5
Hexagrammidae	4	4.4
Anoplopomatidae	4	4.4
Engraulidae	2	2.2
Salmonidae	1	1.1

Otoliths of the Pacific sand lance (Ammodytes hexapterus) found in 37 (40.7%) of the 91 samples, were the most common in the collection. Sand lance were taken in large numbers by harbor seals using Netarts Bay. A minimum of 1503 sand lance were represented in the collection with a mean minimum number per sample of 40.6 and a range of 1 to 338 per sample.

Shabica, et al. (1976) identified 43 fish species in a limited survey of the icthyofauna of Netarts Bay in which the sand lance ranked 9th in abundance (2.4% of the total catch). The size range of the fish from the survey (60-140 mm SL) was similar to that taken by the harbor seals in the present study. The sand lance is often found in nearshore waters (Hart, 1973) as well as in bays, so that seals could have taken them in either area.

The Pacific sand lance has not been identified as an important prey item of the harbor seal in past studies. In Washington, Scheffer and Sperry (1931) found sand lance in only four of 81 (4.9%) harbor seal stomachs examined, and Calambokidis, et al. (1978) reported four sand lance otoliths out of a total of 1729 recovered from harbor seal scats. In the Gulf of Alaska, sand lance represented only 4.4% of the identified food items of 255 collected harbor seals (Pitcher and Calkins, 1979).

Flatfish (Order Pleuronectiformes) were found to be an important food of harbor seals using Netarts Bay. Two species of sanddab (Family Bothidae) and seven species of sole (Family Pleuronectidae) were identified from the otoliths collected there. Of these species, five were each found in 12% or more of the samples (*Parophrys vetulus*, *Glyptocephalus zachirus*, *Citharichthys sordidus*, *Microstomus pacificus*, and *Lyopsetta exilis*). Otoliths of the English sole (*Parophrys vetulus*) were found in 30 (33.0%) of the 91 scat samples and ranked second only to the Pacific sand lance by frequency of occurrence in the samples. However, English sole otoliths represented far fewer fish (a minimum of only 126, with a mean minimum number per sample of 4.2 and a range of 1 to 38 per sample) than did those of the sand lance.

Oregon estuaries are known to be important nursery habitats for many marine fish including several species of flatfish (Pearcy and Meyers, 1974). Juvenile English sole ranging from 30-120 mm (SL) were the third most abundant fish species identified in Netarts Bay by Shabica, et al. (1976). Approximately 90% of the English sole otoliths in the seal scat from Netarts Bay were from sole under 100 mm (SL). Although juvenile English sole have been found in the open ocean off the Oregon coast (Laroche and Holton, 1979), very few under 100 mm (SL) were found in the ocean near Netarts Bay by Demory (1971), and it is likely that seals fed on many of these fish within the bay. This is in contrast to the findings of Morejohn, et al. (1979) in California where harbor seals hauling out in Elkhorn Slough had taken primarily larger (120-320 mm SL) English sole from over the oceanic shelves, rather than smaller (20-140 mm SL) sole that were widely distributed throughout the slough.

Rex, Dover and slender sole, ranked third, sixth and seventh respectively by frequency of occurrence in the seal scats, are rarely found in estuaries and were not found in Netarts Bay by Shabica, et al. (1976). Demory (1971) found small ($\leq$ 180 mm SL) rex, Dover and slender sole in no less than 20, 10 and 30 fathoms of water respectively. These fish species, as well as the few larger English sole, were most likely taken by seals outside of Netarts Bay. Demory also found little separation by depth of large and small flatfish of the same species. Although the harbor seals had taken some larger fish, for the most part they may have selected for rex, Dover and slender sole under 200 mm SL.

Flatfish have been a frequently reported food of harbor seals. Calambokidis, et al. (1978) reported that 1.3% of the otoliths recovered from seal scats in Washington State from pleuronectids, while Scheffer and Sperry (1931) identified flatfish in 23 (28.4%) of 79 harbor seal stomachs. Between these extremes, Imler and Sarber (1947), Spalding (1964), Morejohn, et al. (1979), Pitcher and Calkins (1979), and Roffe (1980) reported pleuronectids in varying degrees of importance in the harbor seal diet.

Based on known distributions and abundances of the identified prey items, particularly in the Netarts Bay area (Gaumer, et al. 1973 and 1974; Shabica, et al. 1976; Forsberg, et al. 1977), fish preyed upon by harbor seals were categorized as bay or ocean forms (Table 3). While

TABLE 3. Probable harbor seal feeding areas based on known distributions and abundances of identified prey species (Miller and Lea, 1972; Gaumer et al. 1973 and 1974; Hart, 1973; Shabica, et al. 1976; Forsberg, et al. 1977). Asterisk indicates species that occurred in 12% or more of the 91 harbor seal scat samples collected at Netarts Bay, Oregon.

OCEAN	OCEAN OR BAY	BAY
*Glytocephalus zachirus**	*Ammodytes hexapterus**	*Parophrys vetulus**
*Citharichthys sordidus**	*Clupea harengus*	*Leptocottus armatus**
*Microstomus pacificus**	*Sebastes* spp.	*Cymatogaster aggregata*
*Lyopsetta exilis**	*Hypomesus pretiosus*	*Hexagrammos decagrammus*
Allosmerus elongatus	*Engraulis mordax*	*Citharichthys stigmaeus*
Microgadus proximus	*Psettichthys melanostictus*	*Platichthys stellatus*
Thaleichthys pacificus		
Anoplopoma fimbria		
Isopsetta isolepis		
Salmo gairdneri		
Spirinchus starksi		
Merluccius productus		
Radulinus asprellus		

certain open ocean fish rarely enter bays (e.g. M. productus, A. fimbria, M. pacificus), most estuarine species can at times be found in nearshore waters. However, many of the prey species identified in this study are common in Netarts Bay (Shabica, et al. 1976), again suggesting that seals fed both in the bay and in the open coastal waters.

Whether feeding in or out of Netarts Bay, the prey identified in the otolith collection indicated that harbor seals relied heavily on fish species that are found near the bottom of the water column. The seven top-ranking food items are all benthic or epibenthic species or, as in the case of the Pacific sand lance, spend at least some time closely associated with the sandy bottom substrate (Hart, 1973; Howe, 1980). The importance of bottom fish in the harbor seal diet has also been demonstrated in California by Morejohn, et al. (1979).

The approximate size ranges of some of the fish consumed by seals were estimated from the relationship between standard length and otolith length from collected fish specimens (Table 4). All otoliths recovered from the scat samples were measured except those that exhibited excessive corrosion (8.4% or all otoliths of those species listed in Table 4). A subsample of 621 Ammodytes otoliths (20.9% of the total number recovered) from 11 randomly selected scat samples (29.7% of those samples that contained Ammodytes otoliths) were measured to estimate the size range of this prey species. The estimated mean sizes for all species of fish listed in Table 4 generally fall between 60 and 180 mm SL.

TABLE 4. Estimated sizes of harbor seal prey species based on the relationship between otolith length and standard length for each species. Also given are the numbers of otoliths from collected fish specimens used to determine this relationship, and the numbers of otoliths from the scat samples that were measured.

Species	No. otoliths from scat samples	No. otoliths from collected specimens	Est. size of prey (SL, mm) range	Est. size of prey (SL, mm) mean
Ammodytes hexapterus	621	8	80-130	95
Parophrys vetulus	140	81	40-240	70
Glyptocephalus zachirus	113	78	50-280	165
Citharichthys sordidus	74	46	40-215	60
Leptocottus armatus	85	14	40-210	110
Microsomus pacificus	62	45	70-210	150
Lyopsetta exilis	21	47	80-205	135
Microgadus proximus	8	61	40-230	140
Cymatogaster aggregata	31	34	65-110	85
Citharichthys stigmaeus	29	61	50-100	65
Isopsetta isolepis	10	44	70-260	180
Psettichthys melanostictus	2	14	100-180	140

There are limitations to the utility of scat collection and prey hard part identification in the analysis of feeding habits. The inability to identify any seasonal changes in the harbor seal diet due to the irregularity of scat availability is an example of such a limitation. The relative importance of the different fishes in the diet may also be biased if the ratio between consumption of the head (i.e., the otoliths) and the body is not the same for all prey species. Some observations suggest that the heads of large fish such as salmon may not be consumed as often as those of smaller ones (Scheffer and Slipp, 1944; Roffe, 1980). However, otoliths from relatively large non-salmonid fish are not at all uncommon in seal stomach or scat samples (Fitch, pers. comm.). Harbor seals at Netarts Bay have been observed swallowing whole adult chum salmon (avg. wt. = 4.5 kg.). Thus they have the ability to swallow fish of considerably larger size than those identified from the otolith collection. The degree of this potential bias, though probably small in this case, is not known.

Other sources of bias in the relative importance of identified food items include variation in rates of digestion or passage through the gastro-intestinal tract of otoliths from different prey species, and variation in the amount of time between seal feeding and hauling out, which might result in the otoliths of some species being eliminated in the water. Of course, prey items that lack resistant hard parts (e.g., many invertebrates) will not be identified. Even in the presence of such limitations, scat collection and prey hard part identification can provide useful information on the quality and relative abundance of prey, especially in areas where food habits have not been previously examined.

SURFACE FEEDING OBSERVATIONS

The late fall run of chum salmon in Netarts Bay provides a highly seasonal food source that harbor seals are known to utilize. Observations were made in the vicinity of the salmon hatchery to estimate the impact that harbor seals feeding in this area may have had on the 1978 return.

During the 46 hours of observation made near the mouth of Whiskey Creek an observed minimum of 22 chum salmon were taken by harbor seals. Approximately 432 salmon returned to the hatchery during those high tides over which observations were made, resulting in an observed predation rate of 4.8% (22/432 X 100). Application of this observed rate of predation to the total estimated chum return (1819) resulted in an estimate of 89 salmon consumed by seals (Table 5).

The observed hourly predation rate (22 salmon taken in 46 hours = 0.48 salmon/hour) can also be used to estimate the impact seals had on the salmon return. Combining the hourly predation rate with the estimated number of feeding hours (both day and night) over the entire run (5 hours/high tide X 46 high tides/run = 230 hours/run) resulted in an estimated 110 salmon taken by seals or 5.8% of the total estimated return (Table 5).

TABLE 5. Observed and estimated impacts on the 1978 chum salmon run in Netarts Bay, Oregon, through predation by harbor seals in the Whiskey Creek area. DDR is the estimated daily dietary requirement for a harbor seal (5% of body weight per day; Fisher, 1952).

	salmon taken by seals	+	salmon trapped	=	salmon returning	per cent of returning salmon taken by seals
observed (46 hrs)	22	+	432	=	887	4.8
estimated (entire run)	89	+	1774	=	1863	4.8

observed predation rate (salmon/hr)	X	hrs high tide during run	=	salmon taken	per cent of 1884 returning salmon taken by seals
0.48		230		110	5.8

DDR	X	kg/ seal	X	salmon /kg	X	avg. no. seals/tide	X	high tides	=	salmon taken	per cent of 1951 returning salmon taken by seals
.05	X	70	X	.22	X	5	X	46	=	177	9.1

This estimate relies heavily on the assumption that harbor seal feeding rates were the same during both day and night high tides. Some pinnipeds, in particular sea lions and fur seals, are known to feed principally at night (Spalding, 1964; Mate, 1973). Spalding (1964) found food in harbor seal stomachs collected from one to two hours after sunrise, indicating the possibility of feeding during the early pre-dawn hours. Morejohn, et al. (1979) cited the high relative incidence of the spotted cusk-eel, Chilara taylori, in the harbor seal diet as evidence of night feeding. The cusk-eel, found to be essentially absent from otter trawls during daylight hours, was abundant in night trawls made in the same study area. Night-time predation on gillnetted salmon by harbor seals has been documented in the Columbia River and appears to be greater than that occurring during the day (Mate, 1980). Finally, more chum salmon return to the Netarts Bay hatchery on late afternoon or night high tides that on those occurring during daylight hours (Lannan, pers. comm.). Thus some evidence may indicate a potential for higher predation rates at night. Since this hypothesis has not been tested at Netarts Bay, the day and night predation rates were assumed to be the same.

A final estimate of the harbor seal impact on the chum return was made by assuming that the entire daily dietary requirement (DDR) of the seals (estimated at 5% of body weight per day by Fisher, 1952) was met solely by consumption of chum salmon in the Whiskey Creek area. The calculations (summarized in Table 5) resulted in an estimate of 177 salmon taken or 9.1% of the total estimated salmon return (1951).

If the entire DDR for seals feeding near Whiskey Creek was not made up of chum as was assumed, the impact on the run was overestimated. However, a seal weighing up to 90 kg would need to consume only one 4.5 kg salmon to meet its daily requirements. Conversely, if seals were not consuming the entire fish, each seal would need to take more to make up its daily requirement. Field observations suggested that little of the weight of each fish was wasted. Not being harassed in any way, seals on occasion took up to 45 minutes to completely consume their prey and, as was mentioned before, several salmon were seen to be swallowed whole indicating that consumption of the entire fish did occur.

The number of seals feeding in the area per high tide (five) was probably underestimated since only those seen at the surface at the same time were counted. The possibility of turnover and replacement of seals feeding in the area during a single high tide is an important consideration that could not be addressed in this study. Both of these possibilities would result in an underestimation of the impact on the chum run. Concerning the overall harbor seal impact on the Netarts Bay chum run, these estimates should be low since they consider predation only in one portion of the bay.

A harbor seal predation rate of 5-10% might be tolerated at aquaculture stations where runs of adult salmon are strong and fish return to the hatchery in large numbers (Lannan, pers. comm.). However, as in the case of the Netarts Bay chum salmon hatchery where an attempt is being made to rebuild a vestigal stock of salmon, any loss of eggs through predation on female spawners is considered serious. Since the sex ratio of adult chum salmon returning to the hatchery is approximately 1:1, a harbor seal predation rate of 9.1% would result in an estimated loss of 145,600 eggs (9.1% of the 1.6 million eggs taken at the hatchery in 1978). It has been suggested that large, gravid, slower moving female salmon may be easier targets for foraging harbor seals (Lannan, pers. comm.). Any preferential selection by seals for female salmon would result in an even greater loss of eggs.

SUMMARY AND CONCLUSIONS

The feeding habits of harbor seals using Netarts Bay, Oregon, were examined by identification of fish otoliths recovered from seal scat samples and by observation of seals feeding on chum salmon returning to the hatchery on Whiskey Creek. Otoliths from the Pacific sand lance, Ammodytes hexapterus, and the English sole, Parophrys vetulus, were the two most common in the collection, occurring in 40.7% and 33.0% of the 91 samples respectively. Flatfish (Order Pleuronectiformes) were the most commonly occurring group of fish and were represented by at least nine species. In general, benthic and epibenthic forms appeared to be very important in the harbor seal diet. The extent to which harbor seals use estuaries as feeding areas, as well as haul-out areas to rest and nurse their young, is an important consideration in determining critical habitat and its utilization. Based on the distributions and abundances of the prey species, and the estimated size of selected prey items, seals using Netarts Bay apparently fed both in the bay and in nearshore waters.

Based on observations made near the mouth of Whiskey Creek, harbor seals feeding in this area may have taken 9.1% of the 1978 chum salmon return resulting in an estimated loss of 9.1% of the eggs taken at the hatchery in 1978. In this case the loss of these reproductive materials is considerably more important than is the loss of salmon flesh.

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CHAPTER TWO

ABUNDANCE, MOVEMENTS AND POPULATION ESTIMATES OF THE HARBOR SEAL, *PHOCA VITULINA*, AT NETARTS BAY, OREGON

ABUNDANCE, MOVEMENTS AND POPULATION ESTIMATES OF THE HARBOR SEAL, *PHOCA VITULINA*, AT NETARTS BAY, OREGON

INTRODUCTION

The harbor seal, *Phoca vitulina*, is a wide ranging pinniped found in the northern hemisphere from Japan, Baja California, northeastern United States and France in the south to the Bering Sea, northern Baffin Bay and the Barents Sea in the north (Mansfield, 1967). Many aspects of the biology of the harbor seal in the northeastern Pacific (*P. v. richardsi*; Shaughnessy and Fay, 1977) including distribution, abundance, reproductive biology, behavior, and feeding habits have been examined (Scheffer and Sperry, 1931; Scheffer and Slipp, 1944; Imler and Sarber, 1947; Fisher, 1952; Spalding, 1964; Bishop, 1967; Bigg, 1969; Johnson and Jeffries, 1977 Pitcher, 1977; Calambokidis, et al. 1978; Roffe, 1980; Brown and Mate, 1980). However, only recently has emphasis been placed on studying movements of harbor seals or estimating population size by tagging studies (Divinyi, 1971; Paulbitski and Maguire, 1972; Bonner and Witthames, 1974; Summers and Mountford, 1975; Johnson and Jeffries, unpub. data; Pitcher and Calkins, 1979).

Since the implementation of the Marine Mammal Protection Act of 1972 there has been an increase in the number of harbor seals found in many Oregon bays and estuaries (Snow, pers. comm.). This may be due both to an overall population increase and a reduction in harassment that previously kept seals at low numbers in these areas. One estuary that has experienced such an increase is Netarts Bay, where the Department of Fisheries and Wildlife at Oregon State University operates an experimental chum salmon (*Oncorhynchus keta*) hatchery. A study of the harbor seals in Netarts Bay was prompted by concern over the impact that seals may have on hatchery operations through predation on returning adult salmon. An examination of harbor seal feeding habits has shown that seals feeding near the hatchery may have taken 9.1% of the 1978 return (Brown and Mate, 1980).

This paper describes the observed daily and seasonal abundance of harbor seals in the Netarts Bay study area. The results of tagging studies designed to examine movements and estimate the total number of harbor seals using Netarts Bay are also presented.

STUDY AREA AND METHODS

Harbor seal abundance in Netarts Bay (45° 25' N) was monitored between May, 1977 and December, 1979 by recording numbers of animals hauled out on the sand flats exposed by falling tides. The bay is not large (7.4 km X 2.1 km) and all haul-out sites could be surveyed from land using binoculars and a spotting scope. One to three of every 10 to 14 days were spent in the field recording abundance of harbor seals hauled out during daylight low tides. Notes on general weather conditions and the frequency and affects of human harassment were made. The first appearance of pups in the spring was recorded and regular pup counts were made until the reliability with which pups could be identified began to decline. Tillamook Bay (45° 32' N) about 15 km to the north (Fig. 3) is the nearest haul-out area that is also used regularly by harbor seals. Data on seal abundance and pupping was also recorded at Tillamook Bay, but with less frequency.

Harbor seals were captured at Netarts Bay in a nylon salmon gillet approximately 90 m X 4.5 m with 20 cm stretch mesh. Two small boats (14' in length) were used to deploy the net in the water in front of the haul-out area. All seals had usually entered the water by the time both boats had reached shore on either side of the haul-out site. The net was then retrieved from shore in the manner of a beach seine. From one to eight (avg. 2-3) seals became entangled in the net during a successful set. These animals were

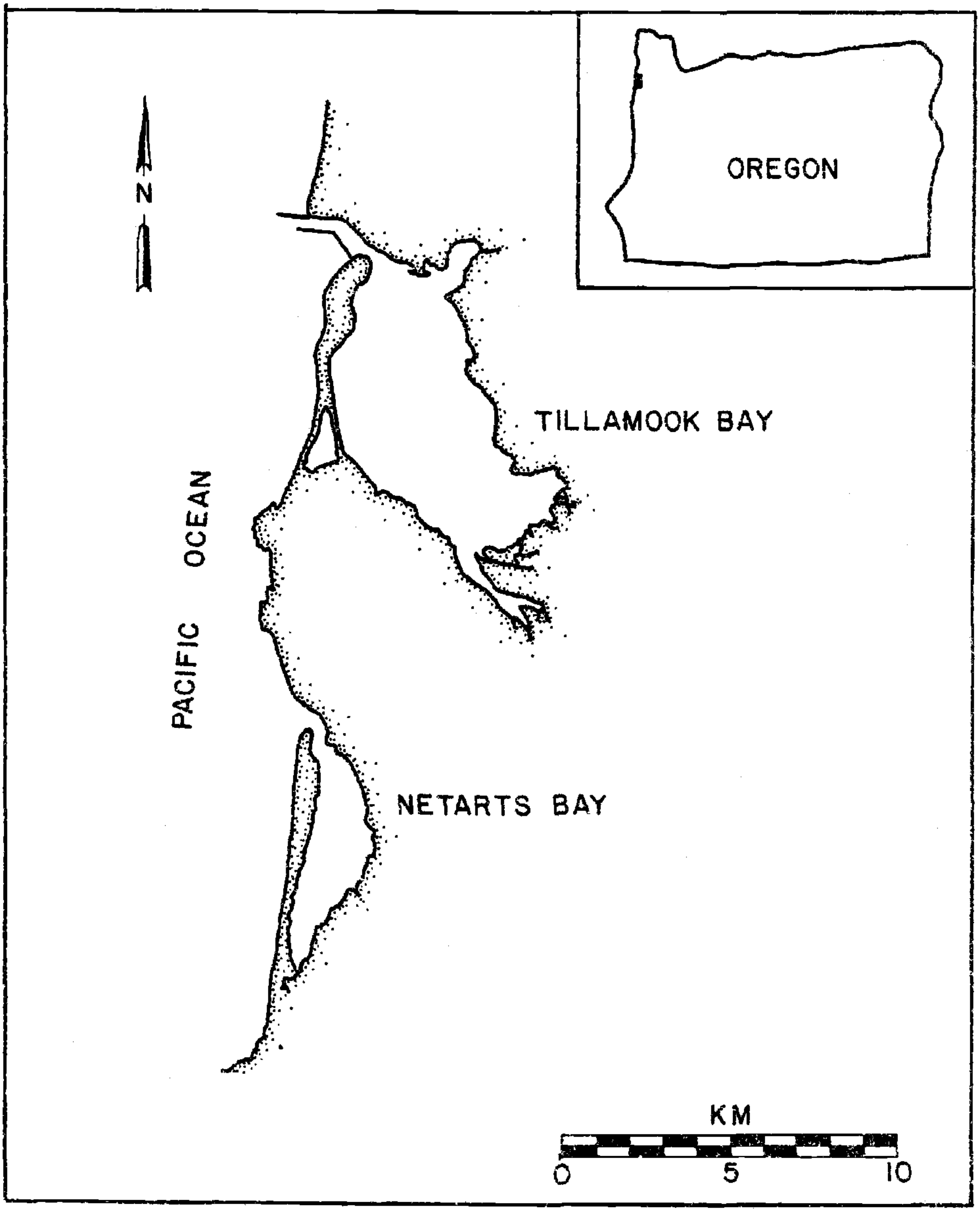

Figure 3. Netarts and Tillamook Bays on the northern Oregon coast.

removed from the net and placed in burlap sacks. Length, maximum girth, weight and sex were recorded.

Three types of tags or marks were applied. A plastic cattle ear tag (Allflex tags manufactured by Delta Plastics Ltd., New Zealand) was placed in the webbing of both hind flippers of each seal. These tags were color-coded for sex and capture series, numbered for individual identification and carried information that would permit their return if found. Each seal was marked with a 10-15 cm wide band of black dye (Jamar D, Jamar Chemical Co., North Andover, MA.) completely around the body at the point of maximum girth. These marks did not allow recognition of individual seals, but were useful in rapid field identification of tagged animals. Finally, most seals were equipped with radio transmitters attached by an ankle bracelet made of a neoprene coated nylon strap inside a braided nylon sheath (total weight = 84 grams). All radio tags and receiving equipment (manufactured by Telonics, of Mesa, Arizona) operated in a frequency range of 148-150 MHz.

Radio signals from tagged seals could only be received when those animals were out of the water. All haul-out sites in Netarts and Tillamook Bays were checked for tagged seals visually and with a radio receiver during daylight low tides. Most low tides at night were also checked by radio receiver for the presence of radio-tagged seals at the haul-out areas.

"Mark-recapture" theory was used to estimate the total number of harbor seals using Netarts Bay during the census period. Counts of seals hauled out in the bay constituted subsamples of the population, while reception of signals from radio-tagged seals allowed identification of marked animals within these samples. Since it was later determined that seals were moving into and out of Netarts Bay, the Jolly-Seber method (as outlined in Caughley, 1977), a method of analysis appropriate to open animal populations, was used to calculate the estimates.

RESULTS AND DISCUSSION

DAILY ABUNDANCE

Haul-out patterns in harbor seals are variable. Seals may haul out primarily at night (Paulbitski, 1975) or primarily during the day (Boulva, 1979); primarily on low tides (Johnson and Jeffries, 1977) or primarily on high tides (Calambokidis, et al. 1978).

All haul-out sites in Netarts and Tillamook Bays were submerged during high tides and although seals were seen in the bays at this time, no attempt was made to estimate their numbers. Seals usually began to haul out as soon as the falling tide had reduced the water depth over the haul-out site to about one to two feet. In general, if seals had not begun to haul out by the time the water level was just below the edge of the sand flat, no animals would haul out during that low tide. However, if at least a few had hauled out prior to this time, others might continue to haul out for one to two hours. If not disturbed, the seals would remain out until the rising tide forced them off the sand bar. Based on reception of radio signals from radio-tagged animals, and some visual observation, it was determined that harbor seals also hauled out on many low tides at night in both Netarts and Tillamook Bays.

Since water level directly determines the availability of the sand bars for haul-out areas, tide status is the most important environmental variable affecting haul-out patterns in both bays. Approximately 95% of the low tides annually were low enough to expose the haul-out sites in Netarts Bay, and seals were observed to haul out on 88.4% of all daylight low tides observed from May of 1977 through December of 1979. However, a high degree of daily variability in abundance of hauled-out seals was noted (Fig. 4, see also Calambokidis, et al. 1978). Seals at Netarts and Tillamook Bays hauled out in all types of weather, and (although no formal correlations were made) variations within the normal range of weather conditions generally did not appear to be a major influence on haul-out behavior. Certain extreme conditions however, may have affected normal haul-out patterns. Seals often appeared reluctant to begin hauling out in unusually high winds (yet if already hauled-out, high winds did not drive the seals into the water). On two of three occasions severe hail storms resulted in at least some of the seals abandoning the haul-out area.

Disturbance from human activity clearly affected seal haul-out behavior and may have contributed to daily variations in abundance. This was particularly true at Netarts Bay, a popular location for year-round sport crab fishing and clam digging. With the rare exception of low flying light aircraft, boat traffic associated with these activities was responsible for nearly all observed human-caused disturbances. Although often intentional, most were a result of negligence in passing too close to the haul-out area or in approaching too close for a better look or a photograph. Harbor seal reactions to disturbances varied from a "heads up" alerted response to the abandonment of the

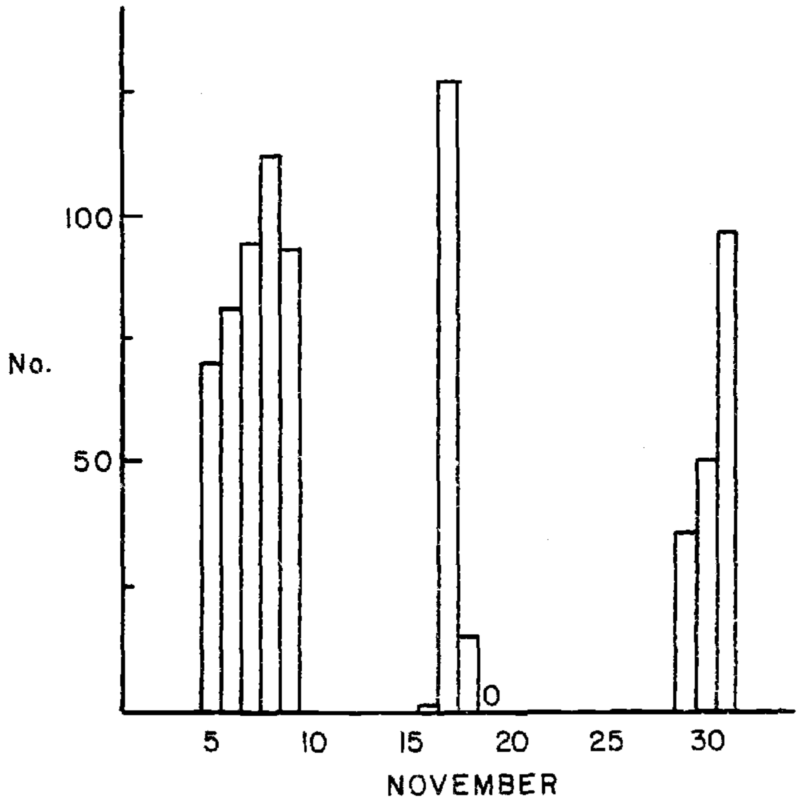

Figure 4. Maximum daily counts of harbor seals hauled out at Netarts Bay, Oregon, for Nov. 5-11, 16-19, 29-30 and Dec. 1, 1978, showing day to day variability in abundance.

area by all of the seals. In general, the seals in Netarts Bay were extremely tolerant of boat traffic. Boats moving parallel to the sand flats could usually pass within 30 m of shore without driving animals into the water. However, if a boat slowed or stopped in front of the seals at this distance or made a turn toward the beach, any or all seals might abandon the haul-out area.

Pitcher and Calkins (1979) categorized disturbances as major or minor depending upon the response of the seals; minor disturbances drove some of the seals into the water while major disturbances resulted in all seals leaving the haul-out area. At Netarts Bay, harbor seals often hauled out again following a disturbance, but usually in reduced numbers. The impact of human disturbance on seal behavior appeared to be greatest after abundance of hauled-out animals peaked during a low tide cycle (Table 6). By this time seals had already been hauled out for some time and so may have been less reluctant to leave the haul-out area.

SEASONAL ABUNDANCE

Seasonal increases in numbers of harbor seals hauled out in many areas have often been observed during the pupping/breeding period (Johnson and Jeffries, 1977; Everitt, et al. 1979). This may be due to an increase in gregariousness of adults as well as the addition of newborn animals to the population. In both Netarts and Tillamook Bays pupping began in the first two weeks of May and peaked in the first two weeks of June.

TABLE 6. Effects of minor and major human-caused disturbances on harbor seals hauled out at Netarts Bay, Oregon.

Disturbance Class	Timing of Disturbance	Result
Minor	During haul out period	Most seals hauled out again at same site in short period (30 secs.- 5 mins.); abundance continued to increase[1]
	After reaching peak abundance	Some, but not all seals might haul out again at same site; abundance always decreased
Major	During haul out period	Hauling out began again; most often at new site farther up bay[2]
	After reaching peak abundance	Many seals usually hauled out again at new site farther up bay, but always in fewer numbers[2]

[1] Even though numbers continued to increase, it was not known if they reached the peak they might have without disturbance

[2] If the seals were subsequently driven from the second site, they would rarely rehaul before the following low tide

Expressing the highest pup count as a percentage of the number of non-pup animals present is a useful first approximation of the fraction of the population that produced offspring (Table 7). These percentages for Netarts and Tillamook Bays (range of 16.5% to 27.3%) were similar to those reported for other areas. Calambokidis, et al. (1978) found a range of 15.2% to 24.0% for harbor seals in Washington. Boulva (1975) gave a figure of 25.7% as the percentage of pups with respect to the prewhelping (non-pup) population at Sable Island, Nova Scotia. Bigg (1969) also gave figures that indicated a percentage of pups with respect to the prepupping population of 25.7% for British Columbia. Identification of pups within groups of seals hauled out at Tillamook Bay was more difficult than at Netarts Bay, due primarily to the greater distances over which observations had to be made. It was estimated in the field that at least one out of five pups at Tillamook Bay may not have been identified. Correcting for this estimated error resulted in an increase in the pup percentages to 20.5% and 21.6% for 1978 and 1979 respectively.

Increases in numbers of hauled-out harbor seals have also been observed during the molting period (Everitt, et al. 1979; Johnson and Johnson, 1979). Molting in seals is known to be physiologically stressful (Geraci and Smith, 1976) and warming of the skin while hauled out may be important in speeding the process (Feltz and Fay, 1966). Harbor seals at Netarts and Tillamook Bays began to show evidence of the onset of the molting period during the first week of August and the

TABLE 7. Maximum pup counts, number of non-pup animals present during counts, and number of pups expressed as a percentage of the number of non-pup animals present (pups/non-pups X 100) for the 1978 and 1979 harbor seal pupping seasons at Netarts and Tillamook Bays, Oregon.

	1978			1979		
	pups	non-pups	pups/non-pups (X 100)	pups	non-pups	pups/non-pups (X 100)
Netarts Bay	15	55	27.3%	9	36	25.0%
Tillamook Bay	63	381	16.5%	58	334	17.4%

process was generally complete by the second week of September.

The seasonal cycle of abundance at Netarts Bay varied from the general trend of peak abundance occurring at the pupping and molting periods. A plot of monthly maximum counts of harbor seals hauled out from May 1977 through December 1979 revealed a seasonal cycle of low abundance in the late winter and early spring, an increase through late spring, summer and fall to a peak in the late fall-early winter, followed by a mid-winter decline (Fig. 5). The increase in abundance from early spring to early summer may be attributable to the onset of pupping, while the subsequent increase in late summer may be related to the molting period. Local changes in the abundance of seals may be affected by variations in the availability of food resources (Scheffer and Slipp, 1944; Fisher, 1952). The run of chum salmon (O. keta) to the experimental hatchery in the late fall (October-November) constitutes the only regular occurrence of a salmon species in Netarts Bay. The annual peak in seal numbers coincided with the salmon run, suggesting that this highly seasonal food source may have influenced seal abundance in the bay.

Seasonal abundance of seals in Tillamook Bay (Fig. 6) more closely resembled the general trend described earlier, with peaks during the pupping and molting periods and relatively lower abundance at other times of the year (the somewhat greater variability in numbers at Tillamook Bay may be partly a result of a much lower frequency of observations

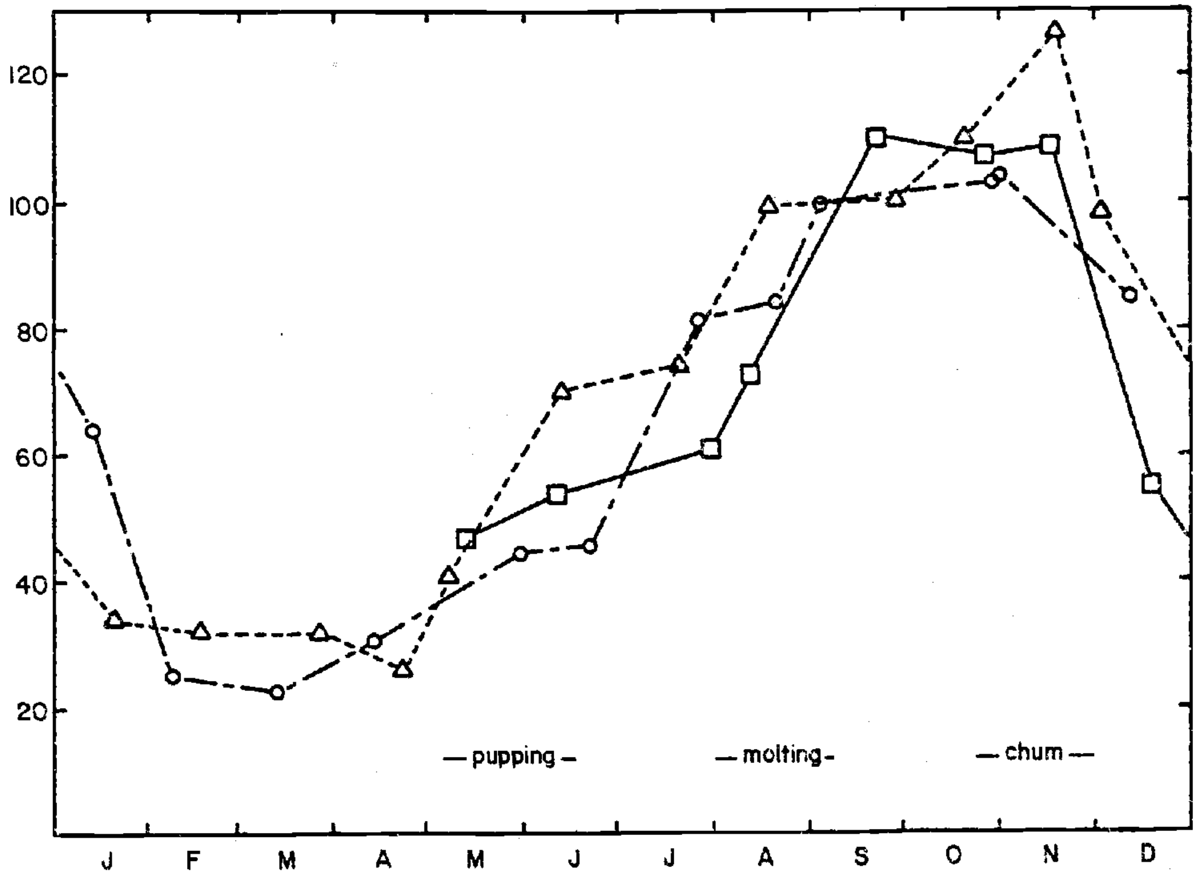

Figure 5. Monthly maximum counts of harbor seals hauled out at Netarts Bay, Oregon from May, 1977 through December, 1979 (——— 1977, ------1978, —·—·— 1979). Harbor seal pupping and molting periods are shown at the bottom of the figure, along with the timing of the chum salmon run.

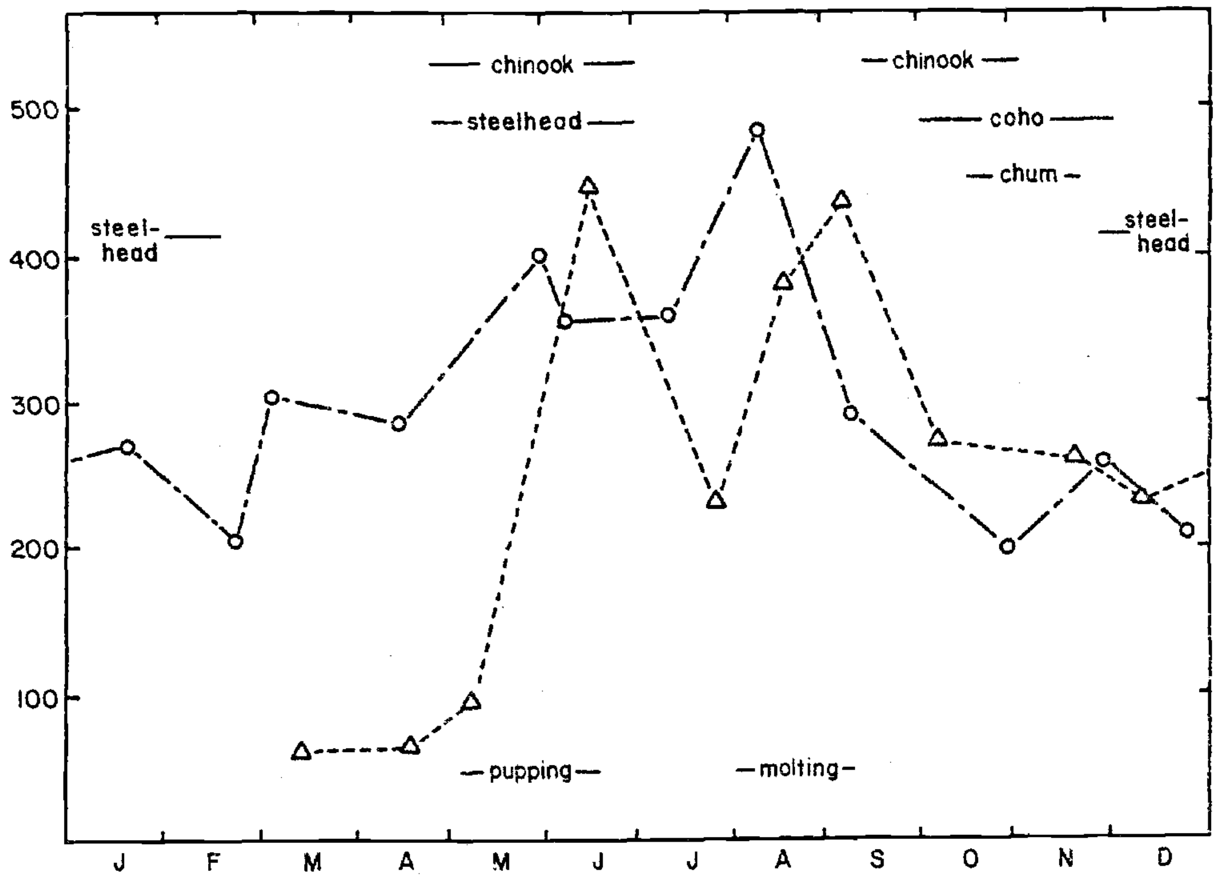

Figure 6. Monthly maximum counts of harbor seals hauled out at Tillamook Bay, Oregon from March, 1978 through December, 1979 (----- 1978, —·—· 1979). The annual runs of salmon and steelhead in the bay are shown at the top of the figure; harbor seal pupping and molting periods are at the bottom.

in this part of the study area). In contrast to Netarts Bay, several salmonid species occur regularly in Tillamook Bay, including spring and fall runs of chinook salmon (*Oncorhynchus twhawytscha*), summer and winter steelhead runs (*Salmo gairdneri*), and late fall-early winter runs of coho (*Oncorhynchus kisutch*) and chum salmon (Heckeroth, pers. comm.). The spring-summer peak in seal abundance partially overlaps the timing of the spring chinook and summer steelhead runs (and the out-migration of spawned-out summer steelhead later in the summer). However, seal abundance declined and was relatively low from September through December when fall chinook, winter steelhead, coho and chum salmon were all found in the bay (the seasonal peak in salmonid abundance). This apparent lack of correlation between seal abundance and salmonid abundance in Tillamook Bay was in contrast to the situation in Netarts Bay where it was suggested that the presence of chum salmon may have influenced harbor seal abundance.

MOVEMENTS

The harbor seal has generally been considered a non-migratory animal (Scheffer and Slipp, 1944) but very little is known about small scale movements. Local movements have been suggested to occur in response to changes in food supply (Fisher, 1952), weather conditions (Loughlin, 1978), human disturbance (Newby, 1971), hunting pressure (Pearson and Verts, 1970), and pupping or breeding behavior (Bartholomew, 1949).

The increase in abundance of seals hauled out at Netarts

Bay in the fall (over and above that which occurred during the pupping and molting periods) coincided with the general decline in the number of seals hauled out at Tillamook Bay during the fall, suggesting movement of animals between the two bays. In order to determine if such interchange did occur, 12 harbor seals were captured, tagged and released in Netarts Bay (8 males and 4 females), 11 of which were equipped with radio transmitters. The useful ground-to-ground transmission range of the radio tags was approximately 5 km. One aerial survey of the study area determined the useful ground-to-air range to be about 15 km. Haul-out sites in Netarts Bay were checked visually for tagged seals and both bays were monitored from land for signals from radio-tagged animals.

Five of the 11 radio-tagged seals (45.4%) made at least one move from Netarts Bay to Tillamook Bay (a distance by sea of about 25 km), three of the five made at least one round-trip from Netarts Bay to Tillamook Bay and back, and one visited both bays at least twice (Fig. 7). Since these signals were received manually (only when personnel were in the field), this recorded level of movement is a minimum estimate of the true level of interchange between the bays during this time period.

Some seals may be more prone to movement than others. One animal ("Chunker") was "re-sighted" only seven times, but had made at least two round-trips between Netarts and Tillamook Bay. Conversely, another animal, ("Bee") was resighted

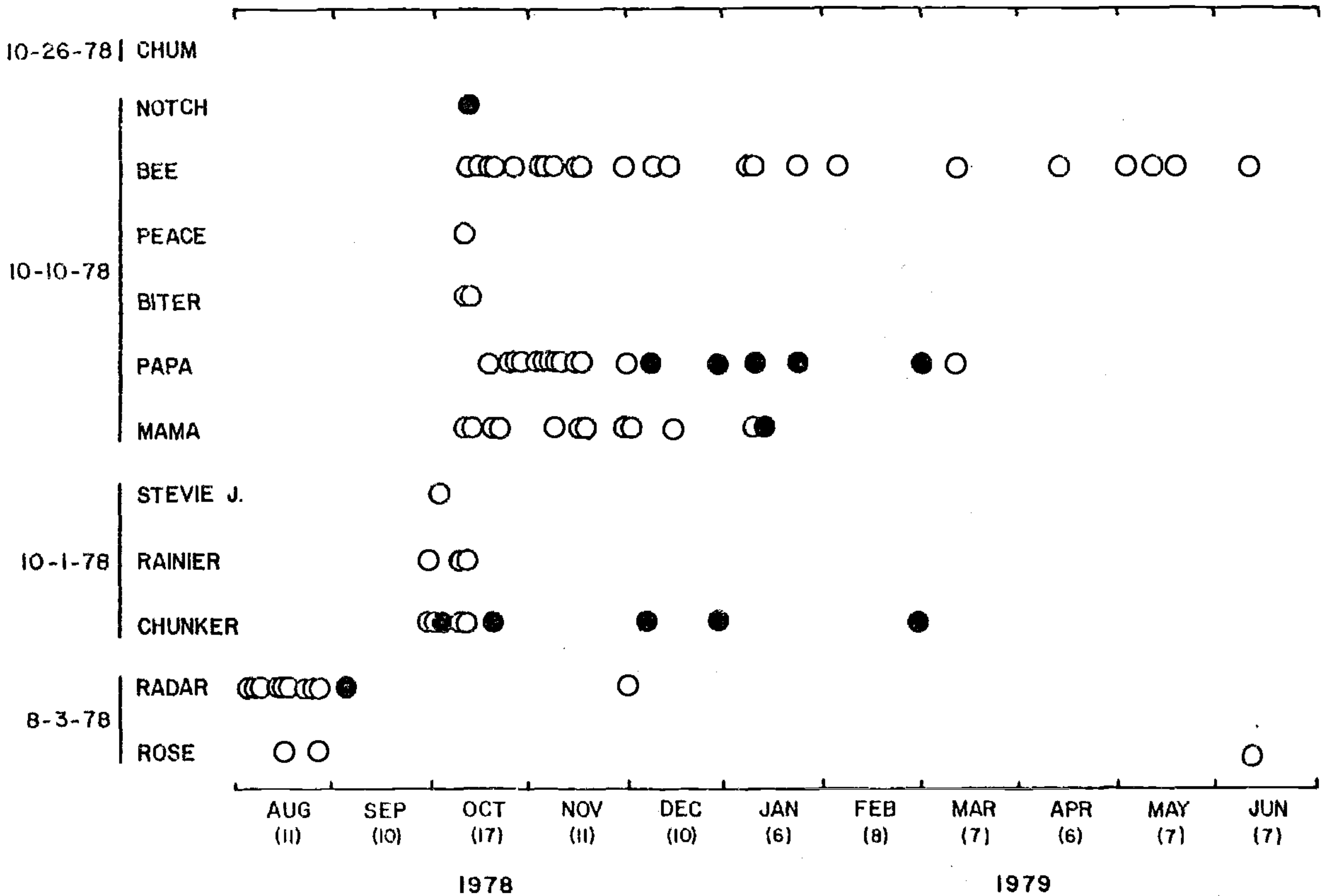

Figure 7. Summary of visual and radio "recaptures" of 12 harbor seals captured, tagged and released at Netarts Bay, Oregon (tagging date appears at left margin). Open circles represent "recaptures" at Netarts Bay; closed circles represent "recaptures" at Tillamook Bay. Figures in parentheses under months are resighting efforts in days per month.

more often and over a longer period than any other tagged seal, but was always found at Netarts Bay.

Other investigators have also reported evidence of long distance movement as well as haul-out site loyalty in harbor seals. A newborn pup tagged on Tugidak Island, Alaska was found three years later less than 5 km from the tagging site (Divinyi, 1971). Bonner and Witthames (1974) reported the dispersal of 55 tagged juveniles from The Wash, East Anglia and their subsequent recovery up to 250 km from the tagging area. Two radio tags were recovered from seals tagged at Grays Harbor, Washington; one 40 km north on the open coast and the other 100 km south in the Columbia River (Johnson and Jeffries, unpubl. data). Pitcher and Calkins (1979) radio tagged 35 harbor seals in Alaska and reported that while 8 animals had used haul-out areas ranging from 24 to 194 km from the tagging site, 23 were found only at the hauling area where they were captured. These "resident" seals were found at the home site on between 40% and 50% of the days during the study period.

Rates of movement of 19 to 27 km/day were reported by Pitcher and Calkins (1979) for four seals tagged in Alaska. These rates are minimal since the route taken by the animals was unknown and the travel time was probably less than the time between observations. One tagged seal found at Netarts Bay on a morning low tide was located at Tillamook Bay on the morning low tide of the following day, giving a similar minimum rate of movement of 25 km/day.

Since 1978, harbor seal tagging studies at Netarts Bay have continued and a minimum traveling distance of 150 km has been recorded for one animal. Tagged at Netarts Bay on 19 October, 1979 and last seen there on 25 October, this seal was found hauled out at Whale Cove, 75 km to the south, on 6 November. The same animal, seen three times at Whale Cove between 6 November and 2 December, was again found at Netarts Bay on 21 and 22 December.

POPULATION ESTIMATES

Eberhardt, et al. (1979) reviewed the use of mark-recapture theory in tagging studies designed to estimate the size of pinniped populations. Primarily concerned with species of economic value, most of these studies have involved the tagging of newborn pups and their subsequent recovery in a commercial harvest (Kenyon, et al. 1954; Best and Rand, 1975; Sergeant, 1975). Others have used the resighting of tagged animals as the "recaptured" samples (Brown, 1957; Siniff, et al. 1977). The reception of radio signals from tagged animals amoung groups of harbor seals hauled out in Netarts Bay was similar to the latter approach.

In October, 1978 ten radio-tagged harbor seals were released in Netarts Bay. Between 2 October and 7 November, radio-tagged animals were identified among groups of seals hauled out in the bay during 14 censuses. These data were used to calculate estimates (Jolly-Seber method) of the total number of harbor seals using Netarts Bay during the census period (Table 8).

TABLE 8. Mark-"recapture" estimates (Jolly-Seber method) of the total number of harbor seals (N_i) using Netarts Bay between Oct. 2 and Nov. 7, 1978. M_i is the total number of marked animals that had been released into the population prior to the *i*th census, $\hat{M}_i$ is the estimated number of marked animals in the population just prior to the *i*th census, n_i is the "recaptured" sample size, and m_i is the number of marked animals in the sample.

Census date	i	M_i	$\hat{M}_i$	n_i	m_i	$\hat{M}_i/m_i$	N_i
1 Oct.	1						
2	2	3	2.0	60	1	2.0	120.0
4	3	3	2.0	44	1	2.0	88.0
9	4	3		77	2		
10	5	3		77	2		
11 Oct.	6	9	6.0	51	3	2.0	102.0
12	7	9	6.0	54	2	3.0	162.0
19	8	9		90	2		
20	9	9	3.0	115	2	1.5	172.5
25	10	9	3.0	72	1	3.0	216.0
26	11	9	3.5	80	2	1.75	140.0
27 Oct.	12	10	3.0	67	1	3.0	201.0
5 Nov.	13	10	3.0	50	2	1.5	75.0
6	14	10	3.0	81	2	1.5	121.5
7	15	10	2.0	94	1	2.0	282.0

For this method to yield unbiased estimates of N_i, the following assumptions must be valid:

1) On the average, the radio-tagged seals in the population had the same expectation of being hauled out during any particular census as did those seals that were not tagged.

2) On the average, the tagged seals "resighted" during any particular census had the same expectation of being "resighted" subsequently as did the tagged seals that were not "seen" during that census.

3) Tagged seals did not lose their tags during the census period.

The first assumption requires implicitly that, on the average, mortality rates were not different for marked and unmarked animals. It was not believed that any tag-induced changes in mortality rates occurred during this study. This assumption also requires that "normal" haul-out patterns were not altered by the tagging process, and that there was no tagging-induced emigration of marked animals from the study area. Since eight of the 12 harbor seals tagged in 1978 hauled out again by the first low tide following their tagging event, it appeared that the tagging process was not traumatic enough to drive these animals from the study area.

The loss of radio tags was a possible source of error for these estimates. At least two radio tags deployed in October were lost within several months; one of which may have been lost during the census period. Using a similar attachment device, Pitcher (1979) reported a minimum loss of 5% over a four month period for radio tags used on harbor seals in Alaska. Thus, due to some unknown degree of tag loss, the number of seals using Netarts Bay as a haul-out area may have been overestimated.

Whenever the number of marked animals in the population is low, as it was in this study, the estimates should be viewed with caution. However, as a first order approximation, it is important to note that the estimates of N_i range from 1.5 to 3.0 times the number of seals that were hauled out (n_i) during each particular census (similarly the ratio $\hat{M}_i/m_i$ ranges from 1.5 to 3.0). The high estimate for the month of October (216) was 1.9 times the high count of seals hauled out during that month (115). The final estimate of 282 for November 7 was 2.4 times the high count of seals in Netarts Bay for that month (127 on November 17). These ratios of the estimated population to the largest direct count are similar to that reported by Summers and Mountford (1975) where a mark-recapture estimate of 3915 harbor seals in the Wash, East Anglia was approximately two times the greatest recorded count (1722). The fact that "resident" harbor seals in Alaska were found at the home site between 40% and 50% of the times that the haul-out site was checked (Pitcher and Calkins, 1979) also suggests that approximately one-half of the "resident population" may be hauled out at any particular time.

SUMMARY

Seasonal maximum abundance of harbor seals hauled out in Netarts and Tillamook Bays occurred in the late fall and summer months respectively. The observed seasonal abundance at Tillamook Bay resembled that described for harbor seals in many other areas, with peaks in numbers of hauled out animals during the pupping and molting periods. The seasonal peak in harbor seal abundance at Netarts Bay coincided with the timing of the return of adult chum salmon, suggesting that this salmonid run may have influenced harbor seal abundance in the bay.

Availability of haul-out areas was regulated by tide height, while human disturbance was common and may have effected variations in daily abundance. At least 45.4% of the harbor seals captured and radio-tagged in Netarts Bay were also using Tillamook Bay as a haul-out area (traveling a distance by sea of 25 km). The greatest recorded distance traveled by a harbor seal tagged at Netarts Bay was 150 km. Mark-recapture estimates from data on "resightings" of tagged animals indicated that the number of seals actually using Netarts Bay as a haul-out area may have been 1.5 to 3.0 times the number seen at any one time.

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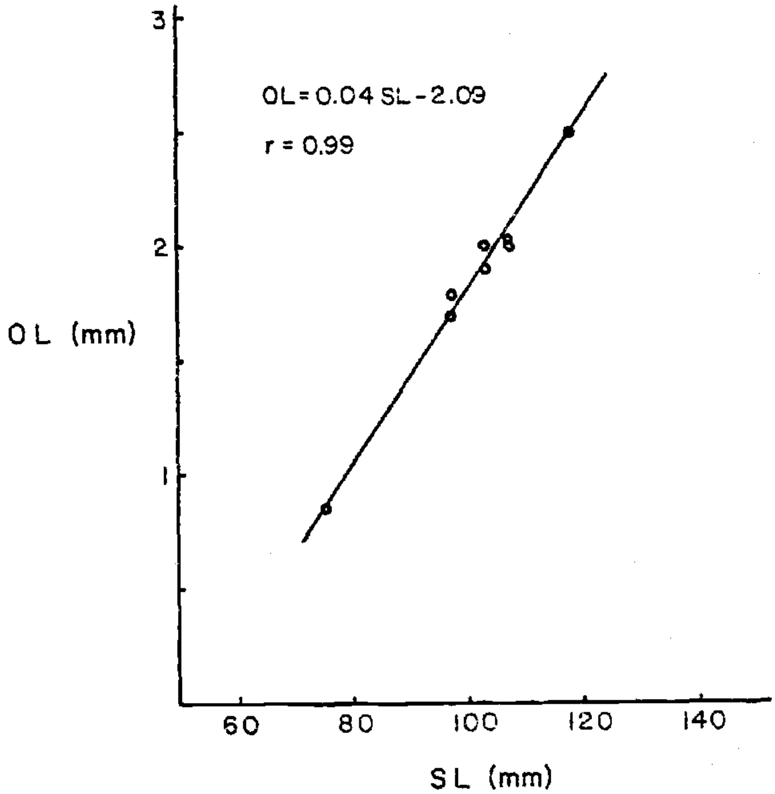
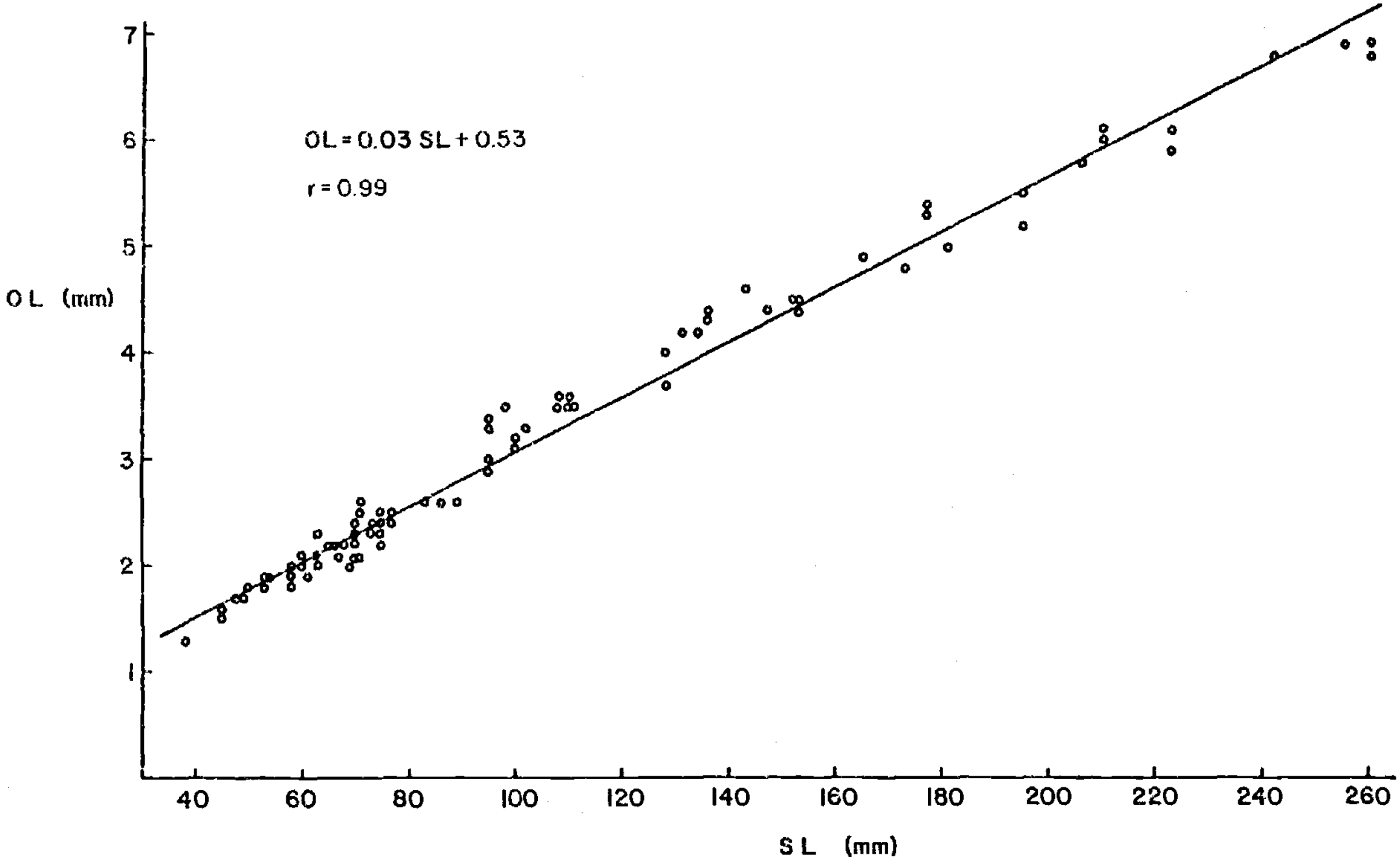
APPENDIX



Relationship between otolith (sagitta) length (OL) and standard length (SL) of Ammodytes hexapterus (n=8).



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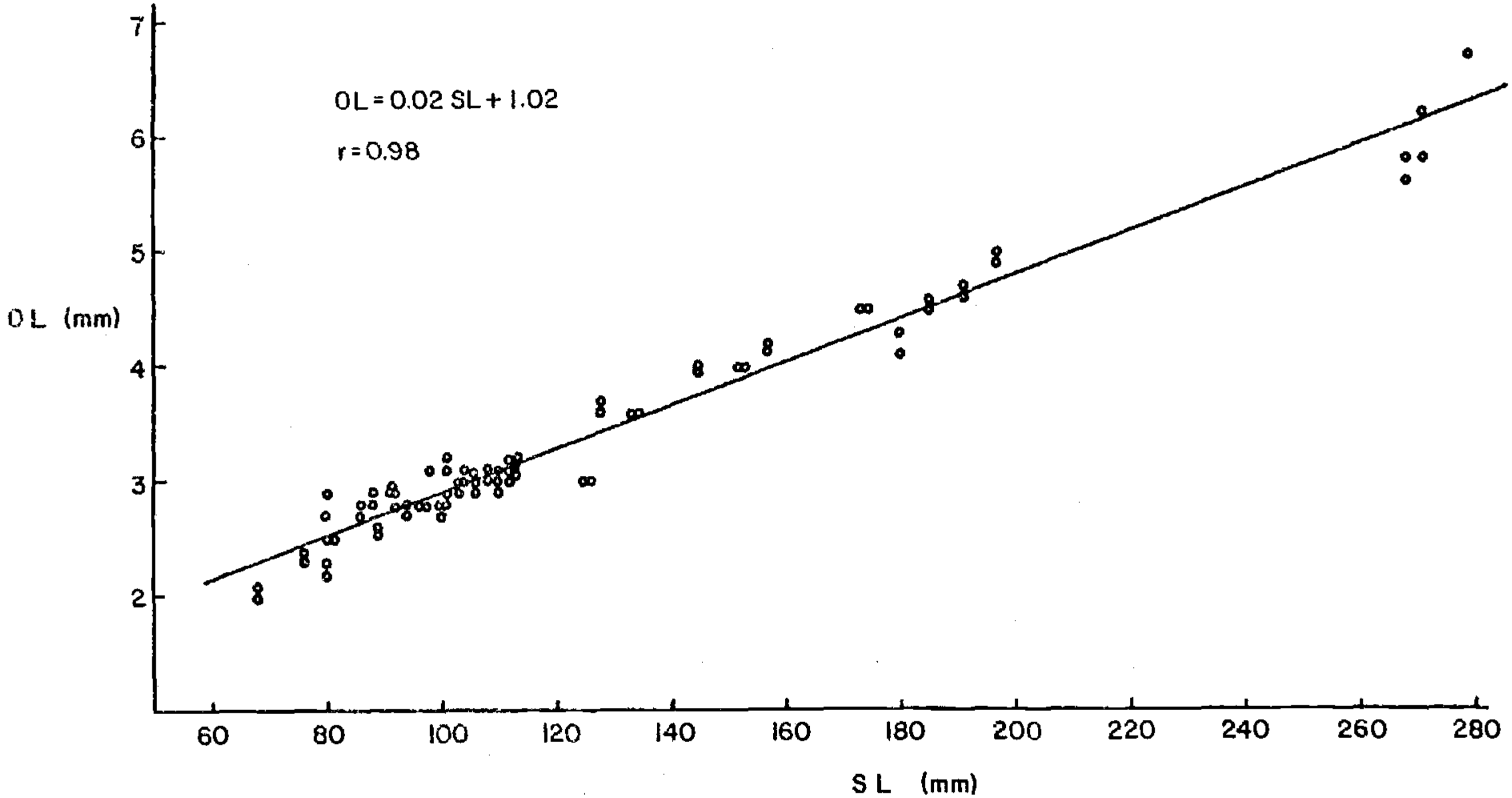

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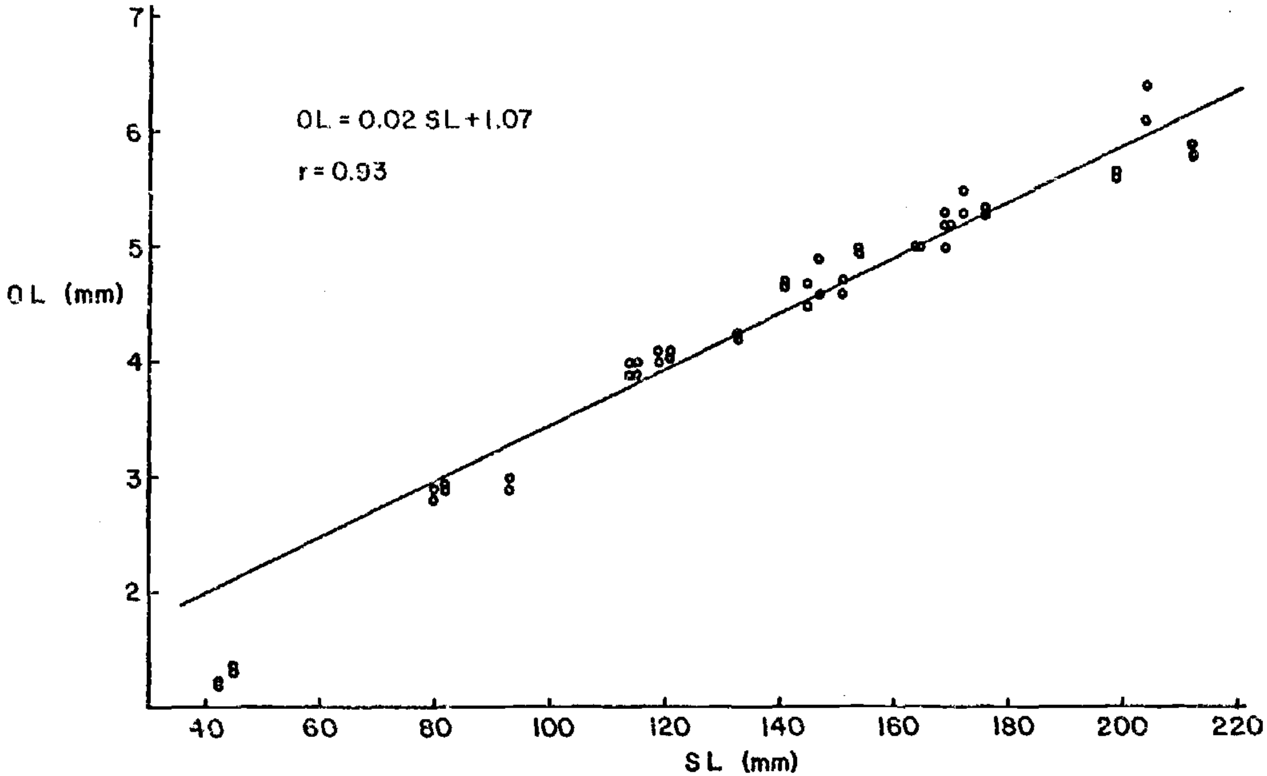

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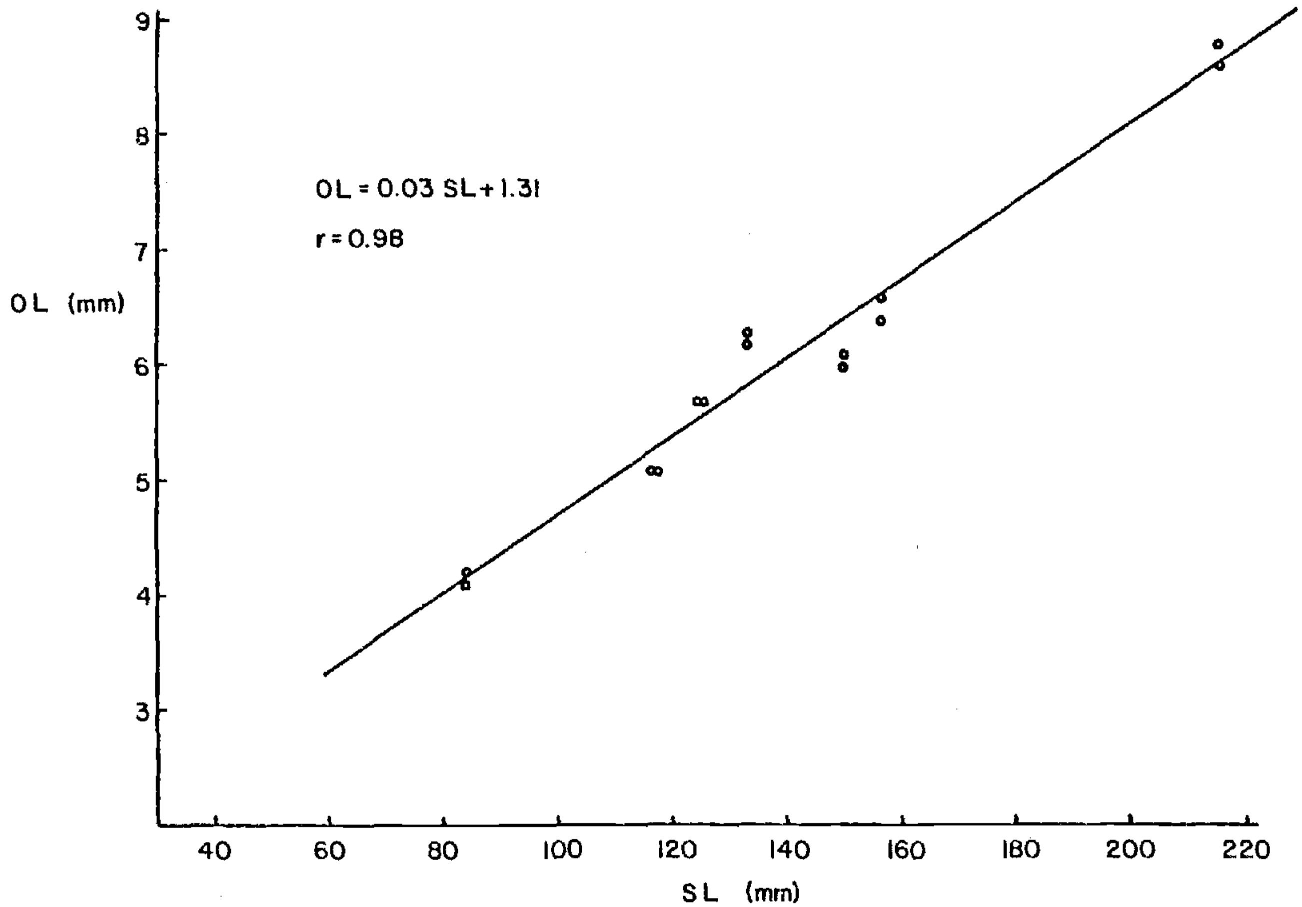

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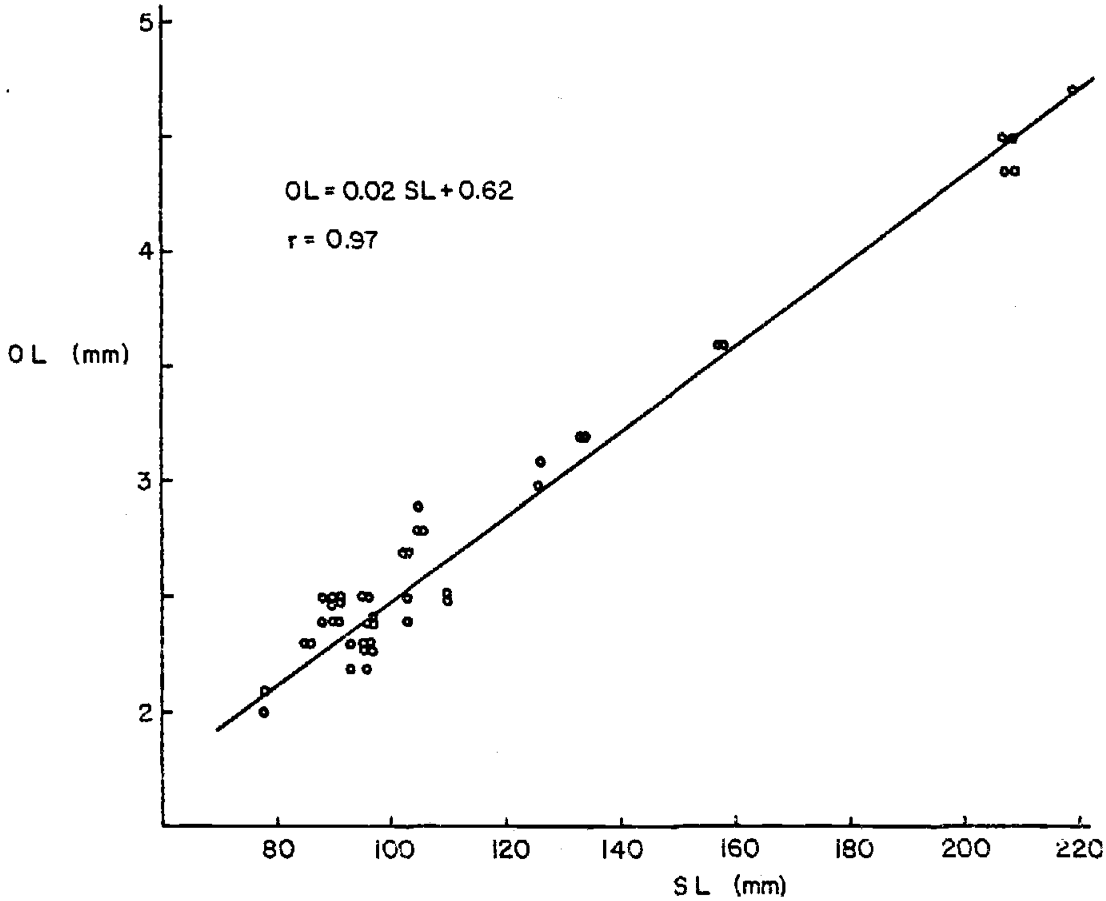

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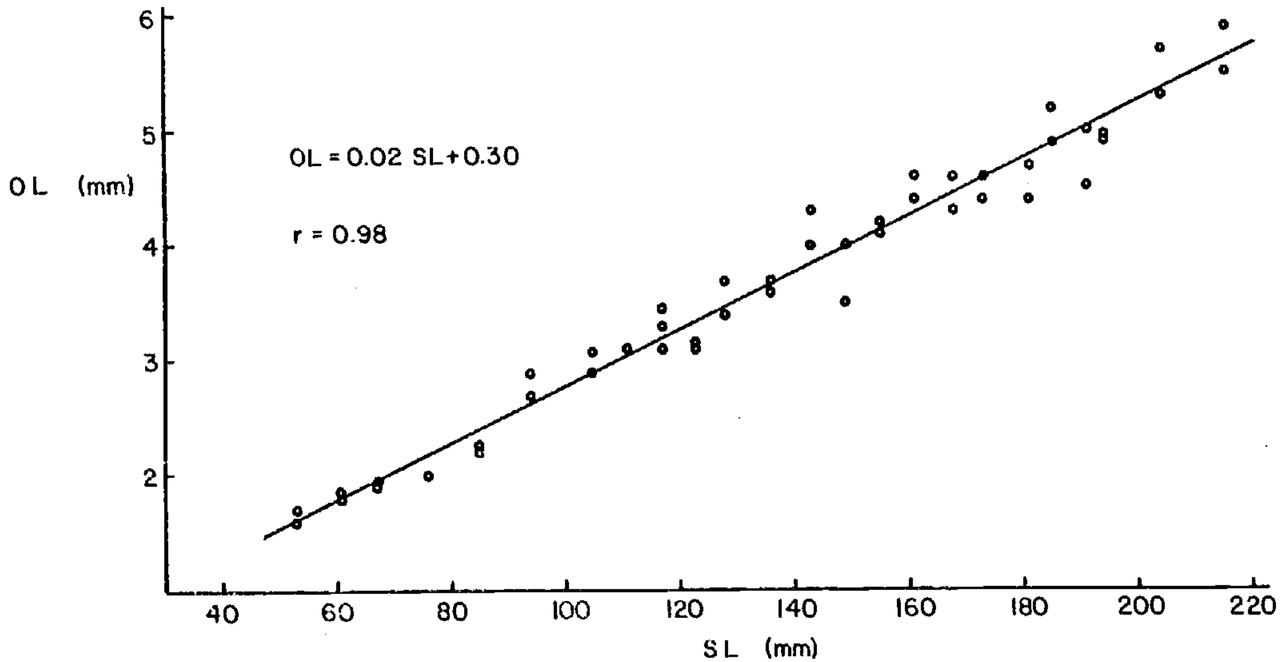

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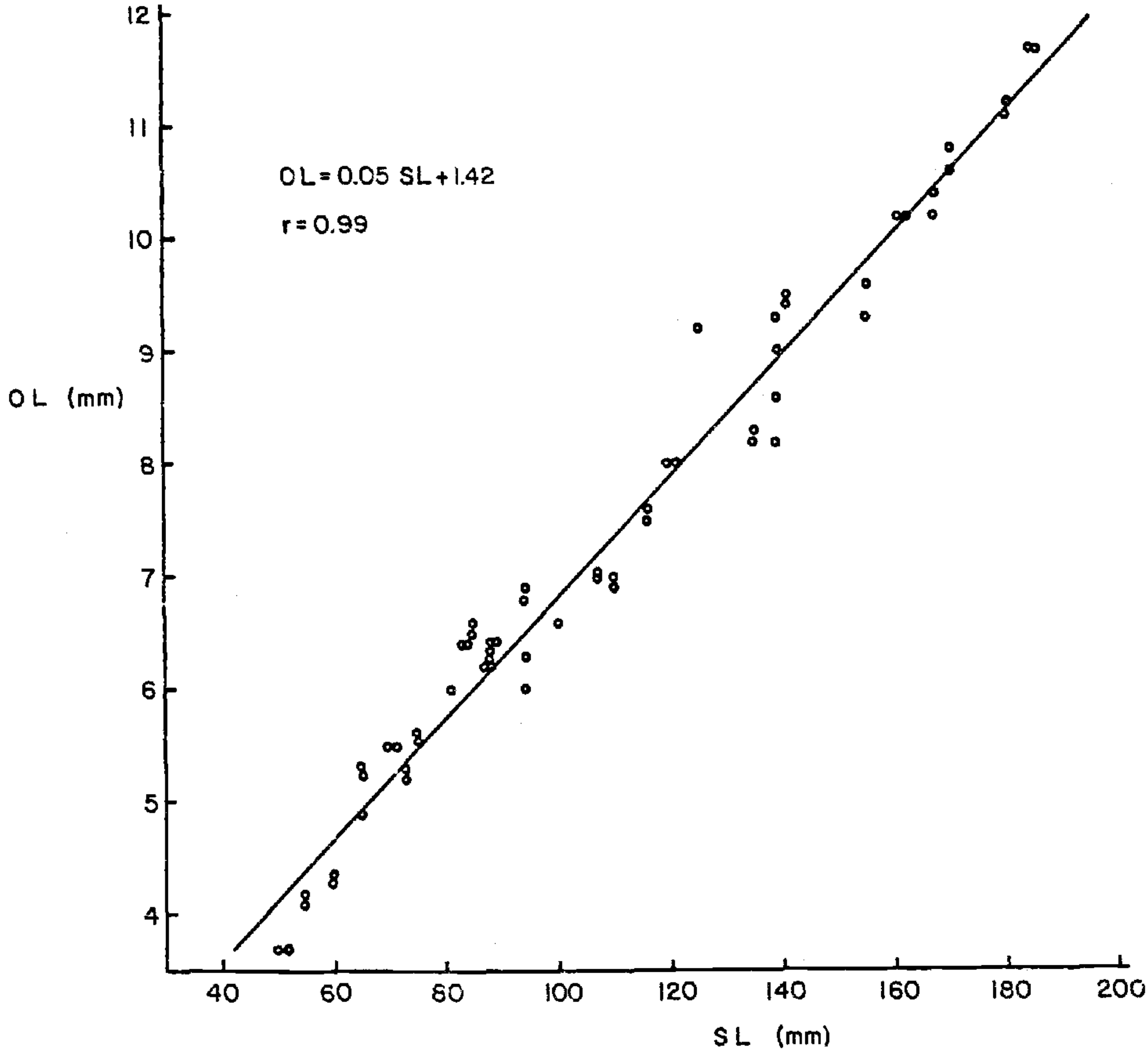

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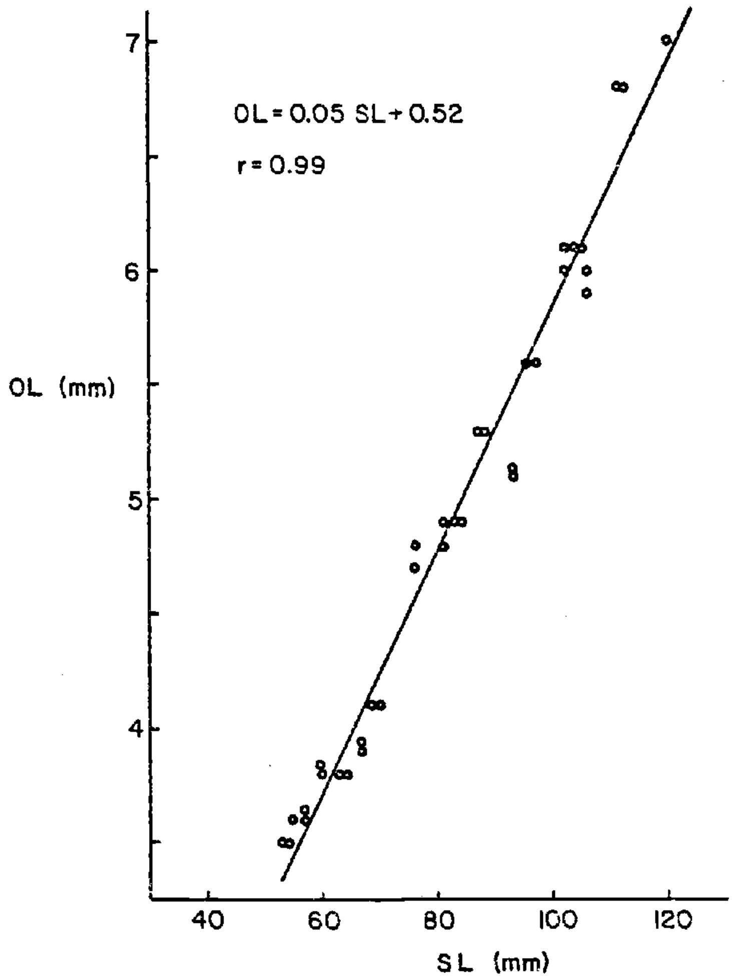

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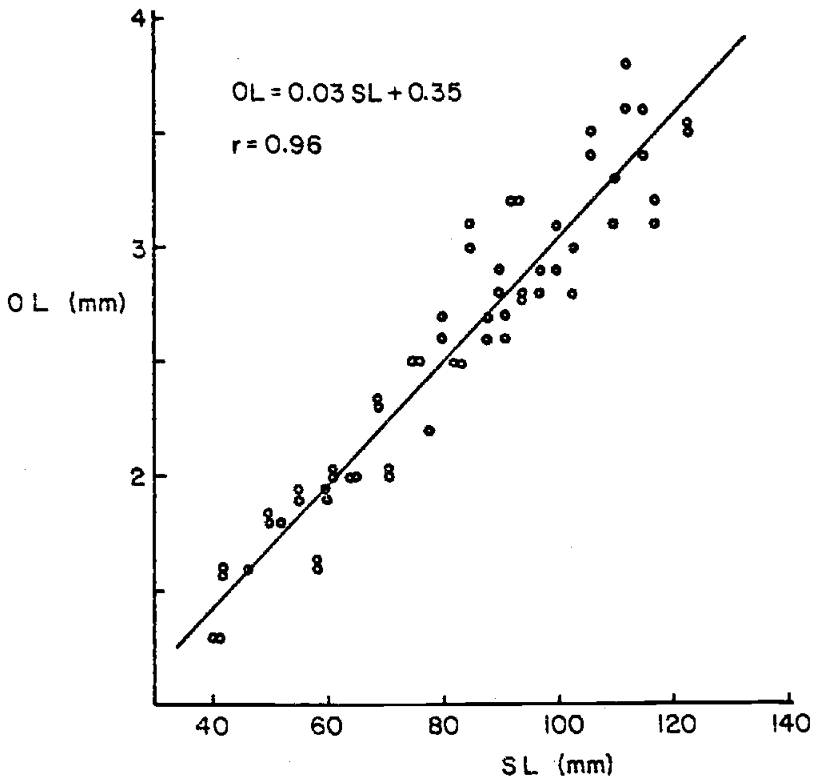

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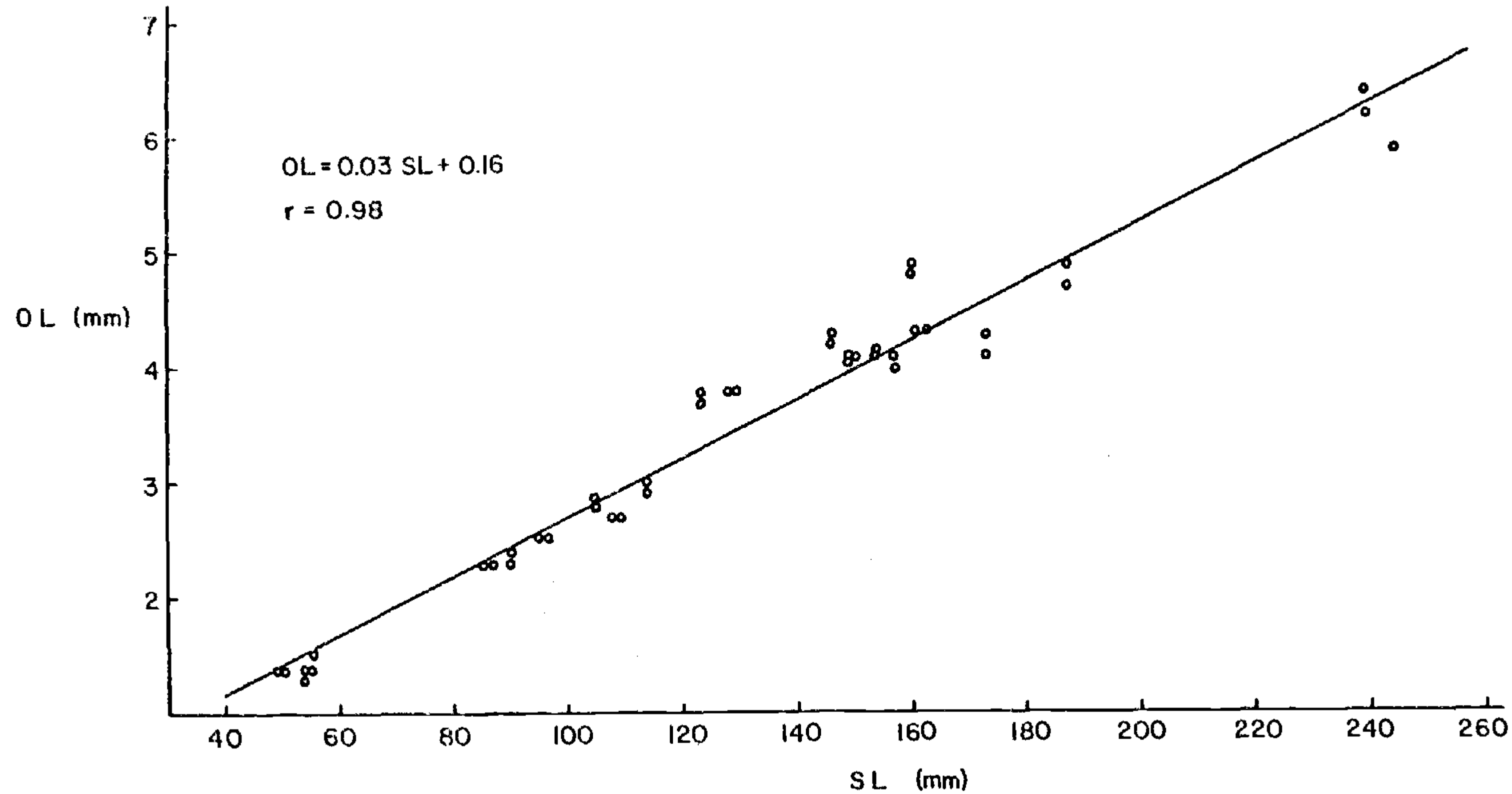

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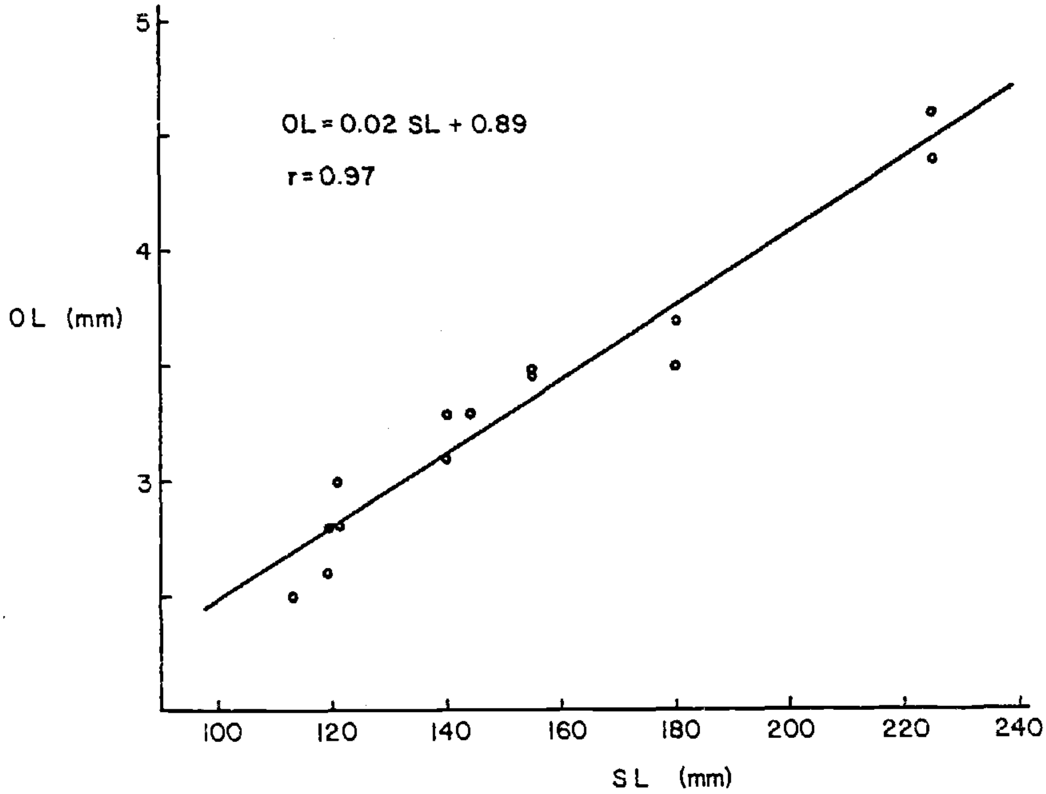

Relationship between otolith (sagitta) length (OL) and standard length (SL) of <u>Psettichthys melanostictus</u> (n=14).