HAUL OUT PATTERNS AND DIET OF HARBOR SEALS, *Phoca vitulina*, IN COOS COUNTY, OREGON

by

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A THESIS

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

INTRODUCTION

The harbor seal, Phoca vitulina, is one of the most widely distributed seals in the northern hemisphere. The world wide distribution can be represented by a broken circle around the rim of the Arctic ocean, with four arms extending southward along the shores of Eurasia and North America. The east Pacific race, Phoca vitulina richardsi (Gray 1864) ranges from Herscel Island in the Aleutian chain of Alaska and Cedros Island off the coast of Baja California (Scheffer 1958).

Recent population estimates for harbor seals residing in Oregon waters vary greatly. Pearson and Verts (1970) report "probably fewer than 500 harbor seals in Oregon coastal waters". Mate (1977) estimated 2500 seals between latitudes 42°N and 46°N plus 1000 seals in the Columbia river, totalling 3500 seals in the state. It is the author's opinion that the latter estimate is closest to the actual number.

Phoca vitulina is considered non-migratory; however, several authors have observed seasonal changes in the number of seals at various haul out sites (Scheffer and Slipp 1944; Rosenthal 1968; Paulbitski and Maguire 1972). Peak numbers have been associated with pupping and breeding activities, yet few explanations have been presented to explain the decline in numbers of seals at haul outs during the nonbreeding season.

The authors cited above were observing haul out sites in inland waters or embayments. One simple explanation for the observed change is that the seals leave the bays and use near shore haul outs during the winter. In the Coos Bay area the bulk of the seals use a near shore haul out site (Pearson and Verts 1970) making this area an ideal location for documenting seasonal shifts in the utilization of various haul out sites.

The diet of the harbor seal has been a controversial topic since the 1500's (Joensen et al. 1976) In the Pacific northwest the root of the controversy is the contention by some that seals significantly reduce the numbers of salmonid fish. Their highly visible habit of eating large fish (such as salmon) at the surface is no doubt partially responsible for such beliefs (Spalding 1969). Although fishermen have long contended that pinnipeds take salmon from their nets and lines during commercial and sport fishing operations, what part of the diet these fish represent has not been well documented. In spite of this lack of understanding bounties have been offered, or professional hunters have been employed, by agencies in Oregon, Washington, British Columbia and Alaska since the early 1900's in an attempt to control the number of seals (Scheffer 1928). In 1972 the Marine Mammal Protection Act officially ended any seal control programs that had not already ended. Harbor seals and all other marine mammals in U.S. waters have been fully protected since that date.

Food habits of the harbor seal in the north east Pacific have been examined in Alaska by Imler and Saber (1947), Kenyon (1965) and Pithcher (1980a); in British Columbia by Fisher (1952) and Spalding (1964); in Washington by Scheffer and Slipp (1944) and

Calambokidis et al. (1978); and in Oregon by Brown (1981). Studies have also been conducted in the western Atlantic by Griffin (1936) and Boulva and McClaren (1979); and in the North Sea by Havinga (1933).

Until recently the only method used to determine pinniped feeding habits was gut content analysis. This method necessitates shooting many animals to obtain an adequate number of food samples. Imler and Sarber (1947) found that on average 40% of all harbor seals shot sunk out of reach before they could be recovered, and that over half the stomachs examined were empty. Of approximately 650 seals shot in their study, 400 were recovered and only 166 had sufficient material in their stomachs for tabulation. The Oregon seal population would be significantly reduced if an extensive diet study using the gut analysis method were conducted.

In situations where it is not desirable to shoot seals, or where populations are too small to support an extensive gut study, scat analysis has become an accepted method of studying prey utilization. (Ainley et al. 1978; Clambokidis et al. 1978; Brown 1981). Harbor seal scats were first noted to contain fish otoliths and other undigested fragments by Sceffer and Slipp (1944) though the value of otoliths in interpreting feeding habits was not realised until the 1960's (Fitch and Brownell 1968). Pitcher (1980b) showed that analysis from harbor seal scats can provide accurate information on most kinds of prey.

RESEARCH GOALS

The first goal of this research was to determine if the harbor seals in Coos County, Oregon exhibited the seasonal change in haul out usage described by other authors. If such a seasonal change was found, possible causes for it were to be examined.

The second goal of this research was to use the scat analysis method to establish a prey species list for the harbor seals frequenting the Coos Bay haul outs. Diet information analysis was to attempt to establish potential fisheries conflicts, possible prey preferences, and seasonal prey utilization of seals in the study area.

DESCRIPTION OF STUDY SITES

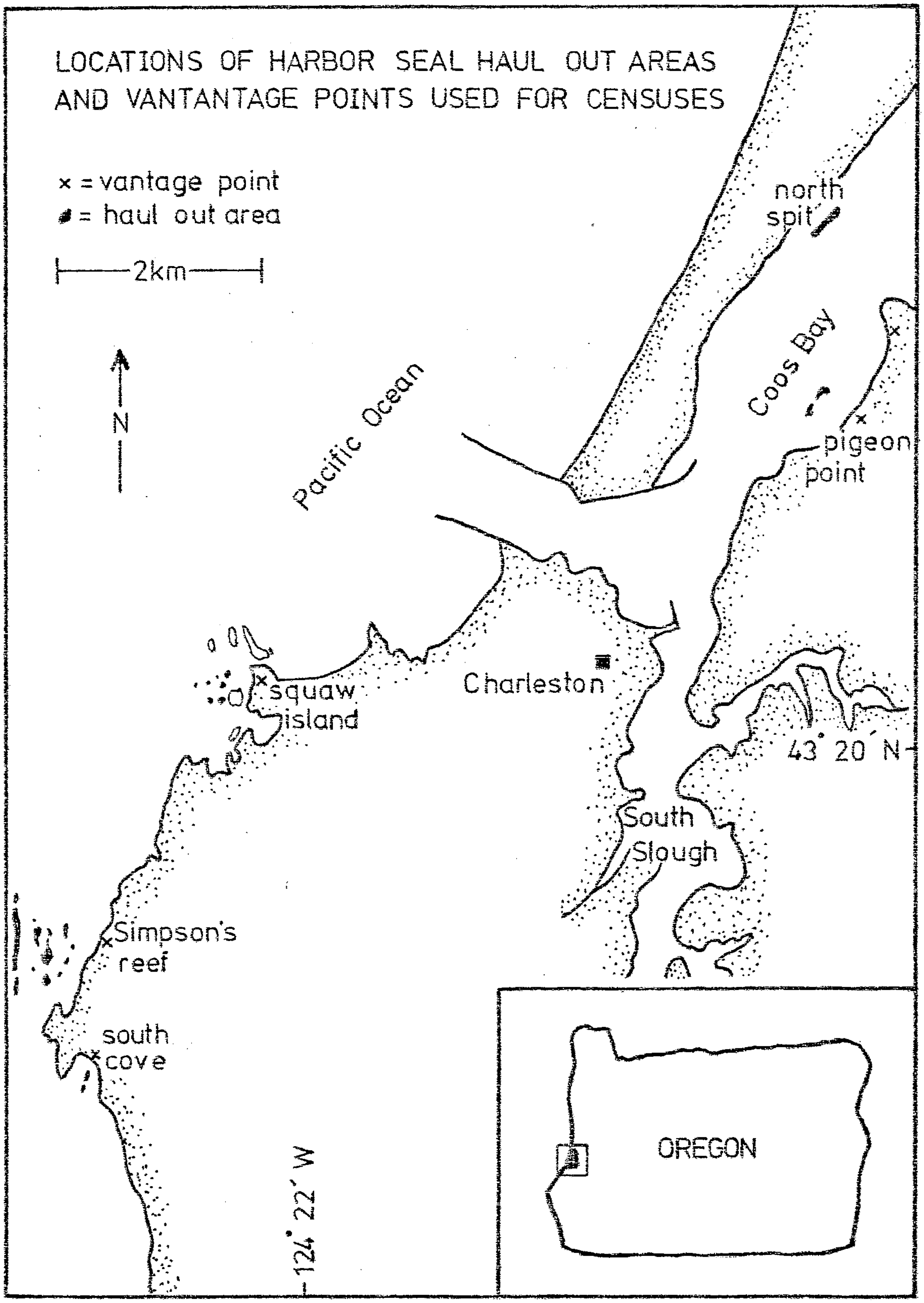
Harbor seals use five different haul out areas in the Coos Bay region. Two of the sites are in the estuary while the remainder are located on rocks south of the harbor entrance. The areas described below constitute all of the haul outs used by seals at the time of this study (see Fig.1). The next closest haul out to the south is Coquille rocks, some 25km away. The closest site to the north is the Umpqua river, some 45km away.

1. Pigeon Point.

The Pigeon point haul out consists of two dredge spoil islets on the east side of Coos Bay, about 5km from the harbor entrance. The islets are a mixture of sand and cobbles that merge with a tidal flat at low tides. It is possible to walk to the Pigeon point haul out when the tide drops below about 1.5 feet on the local tide charts. A channel on the landward side of the islets provides the seals access and escape routes to and from the haul outs. The channel is deep enough for seals to swim in during all but the lowest spring tides, at which time access is limited to the southern most islet.

Water submerges the southern islet when tidal heights exceed approximately 3.4 feet and the northern islet when it exceeds approximately 4.6 feet. Local tide heights typically range between 5 and 7 feet at high tide, meaning that no sites are available to seals at Pigeon point for several hours during high tide.

Figure 1. Map of the study area showing locations of harbor seal haul out areas and vantage points used for censuses.


LOCATIONS OF HARBOR SEAL HAUL OUT AREAS
AND VANTANTAGE POINTS USED FOR CENSUSES
× = vantage point
= haul out area
2km
N
Pacific Ocean
north spit
Coos Bay
pigeon point
Charleston
squaw island
South Slough
43° 20' N
Simpson's reef
south cove
124° 22' W
OREGON

2. North Spit.

On the west side of the bay about 2km up the bay from Pigeon point, is the North Spit haul out site, a sandy peninsula on the north side of a small vegitated island. Virtually all of this site is covered at high tide. At low tide the west side of the peninsula becomes continuous with the shore. The east side of the haul out adjoins water whenever it is exposed.

3. Simpsons Reef.

This complex of rocks lies on the north side of Cape Arago approximately 7km south of the Coos Bay harbor entrance. It is the largest harbor seal haul out site in the area (Pearson and Verts 1970). In addition to the harbor seal, the reef is used by Californian sea lions (Zalophus californianus), Steller's sea lions (Eumatopias jubata), and northern elephant seals (Mirounga anguistirostra).

A large outer reef serves as a breakwater, sheltering the more shoreward rocks from the direct force of the seas. Many of the rocks are awash during rough ocean conditions, but a small sandy beach, known locally as Shell island nearly always remains accessible to seals.

4. South Cove.

In the South Cove of Cape Arago (2km south of Simpsons Reef) two rocks are used by harbor seals. High tides cover them and they are often awash particularly during the winter, a time of southwestern swells.

5. Squaw Island.

Approximately midway between Simpsons Reef and the harbor entrance is a rocky complex known as Squaw Island. During periods of mild weather and seas, sites are available at all tidal heights but during storms this area is frequently awash.

CENSUS TECHNIQUE

Monthly daylight censuses of harbor seal haul outs in the Coos Bay, Oregon region were conducted from April 1980 to April 1981. On the census day hourly counts of seals at the haul outs were made from shore vantage points (Fig.1) using 20-45x spotting scopes, to determine the maximum numbers of seals hauled out that day.

Because the purpose of the census was to document possible seasonal variation in haul out utilization, peak numbers from each monthly count were used for seasonal comparisons. Census dates were chosen on the basis of their being most likely to produce the highest counts for that period. The principal factors that set the date of each census were tides and weather, as these have been shown to influence seal haul out behavior (Fisher 1952, Calambokidis 1978).

Because rough seas have a negative effect on seal haul out behavior (Scheffer and Slipp 1944), census dates were limited to days having relatively mild ocean and weather conditions. Ocean conditions are generally rougher during winter months but census dates were chosen so that all major sites were available to the seals at sometime during the day.

Since high tides completely submerged a number of important hauling areas, (making them unavailable to seals), peak numbers were expected at some time other than the time of high tide. Census dates were chosen, weather permitting, so that counts could be made several hours prior to and after the daytime low tide, the time when these sites were exposed and available to seals.

Haul out sites were monitored throughout the study and spot check censuses made during each month confirmed that the all day counts were indicative of the census period. Records were kept of seals use of individual rocks within a haul out area to simplify counting and to detect possible site preferences. Notes on seal activity patterns and behavioral interactions were kept. Human activities on and near the hauling sites were also recorded.

DIET STUDY METHODS

Harbor seal scats were collected from the Pigeon Point and North Spit haul outs to obtain fish otoliths and other food remains. Scat collections were limited to days where the daylight low tides were lower that +1.0 feet, since shore access to the Pigeon Point haul out was cut off by water levels higher than this. The lower low tides in Oregon are in the morning hours during spring and summer, and in the afternoon and evening hours during fall and winter. The shorter winter day length meant a number of satisfactory low tides came after dark and were thus unsuitable for scat collection. There were daylight low tides low enough to permit scat collections each month and scats were sought at Pigeon Point during all months.

Individual scats were often pressed into the rocks and some substrate was usually collected with the scats. Scats were scraped from the substrate with a small shovel and then transported to the laboratory in sealed plastic bags. Scats were collected opportunistically from July 1978 through March 1981. Scat processing was accomplished in the following manner:

1. The bag with its contents was weighed.

2. Each sample was put into a tin can and covered with 2% buffered formalin. The can was vigerously shaken to emulsify the contents.

3. The "scat shake" slurry was washed through two sieve screens with pore sizes of 5mm and 0.5mm. The larger size screen allowed nearly all otoliths and food items to pass through, but retained rocks and

pebbles that were picked up when the scat was collected. The small screen retained food remains but allowed sand to pass through.

4. The material on the small screen was washed into a neutral gray colored pan. The large pore sieve was inspected for remains which, when present, were also transferred to the gray pan. Against the gray background otoliths, lamprey jaw parts and cephalopod beaks were readily discerned with the unaided eye. Numbers of other remains (vertebrae, scales, lenses, worms, and crustacean and echinoderm parts) were estimated and representative samples of each were collected.

5. To obtain a weight estimate for the scat the weight of the empty bag and the material that remained on the large sieve was subtracted from the original weight of the sample.

6. Material from each scat collected was sorted and stored in individual plastic vials. Fish otoliths were identified by J.E. Fitch, an authority in this field. Other remains were identified by the author.

All otoliths were sorted into lefts and rights for each species and the side having the largest number of otoliths was used to represent the minimum number of fish eaten. Similarly cephalopod beaks were grouped into inner and outer halves (Ingrid et al. 1971) and the side having the largest number was taken to represent the quantity eaten. It was not possible to accurately determine the number of lampreys or crustaceans eaten. An occurrence of their parts in a scat was regarded as representing only one individual, thus the numbers for these items may be low.

Seals have hauled out and presumably deficated on the Pigeon Point site for a number of years. Since substrate was picked up when the scats were collected, the presence of persistent accumulations of seal food remains in it could potentially bias the seasonal diet analysis. The substrate was examined to determine how much residual material it contained.

Three one square meter substrate "control plots" were layed out at the Pigeon Point scat collection site on May 26 1981. The top 2-3 cm of these plots was scraped up using the same technique used to collect scats, and examined for fish otoliths and other remains typically found in the scats. Substrate deeper that the top three centimeters was not sampled because it was never picked up with scats.

RESULTS

The highest counts from each monthly census of individual sites were combined to obtain a monthly maximum haul out attendance figure for the study area. The largest monthly maximum haul out attendance figure was from the July census when 844 seals were observed. The smallest was from the January census when 326 seals were observed. The transitions between the largest and the smallest figures were smooth and are summarized in Figure 2.

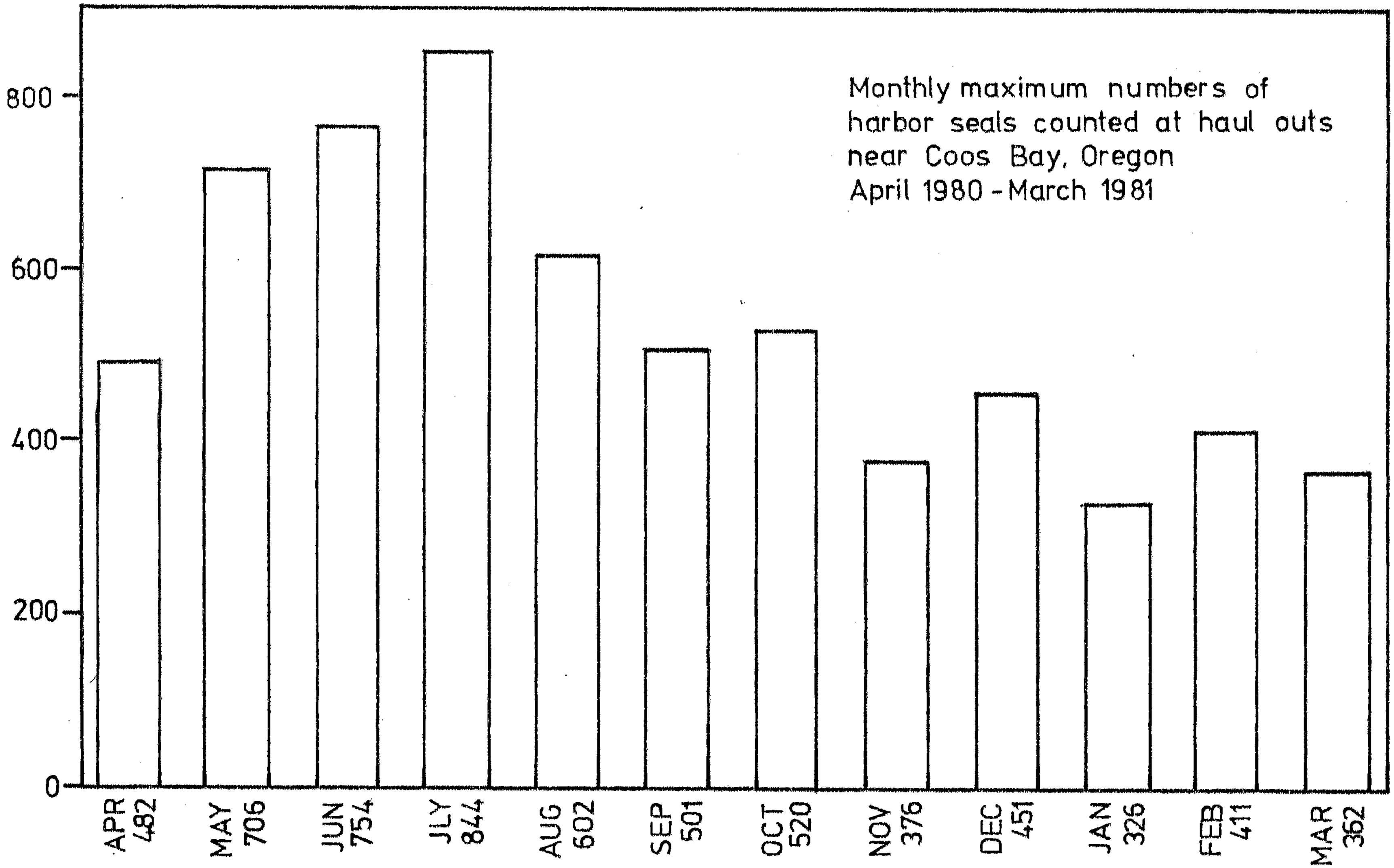
Peak numbers of seals at haul outs in the study area were closely related to the time of low tide (Table 1). Due to the tidal lag associated with Coos Bay, low tide at the Pigeon Point and North Spit sites came approximately half an hour later than the other sites.

Seasonal emmigration of seals from haul outs within the bay to local near shore sites could not be discerned. Monthly maximum haul out attendance figures for the bay site; Pigeon Point and North Spit; exhibited the same seasonal pattern as the nearshore sites; South Cove, Simpsons Reef and Squaw Island; (Figure 3).

The pupping season in Coos Bay begins in late April and peaks sometime in May. On May 17 1980 a total of 95 harbor seal pups were counted, and on May 30 1980 73 pups were seen. Very young pups were observed on North Spit, at Pigeon Point and at the Simpsons Reef haul out.

Sea lions hauled out only at the Simpsons Reef site. California sea lions were present in all months except June and July. Their

Figure 2. Monthly maximum haul out attendance figures for harbor seals determined from all day censuses of Coos Bay area haul outs from April 1980 - March 1981.



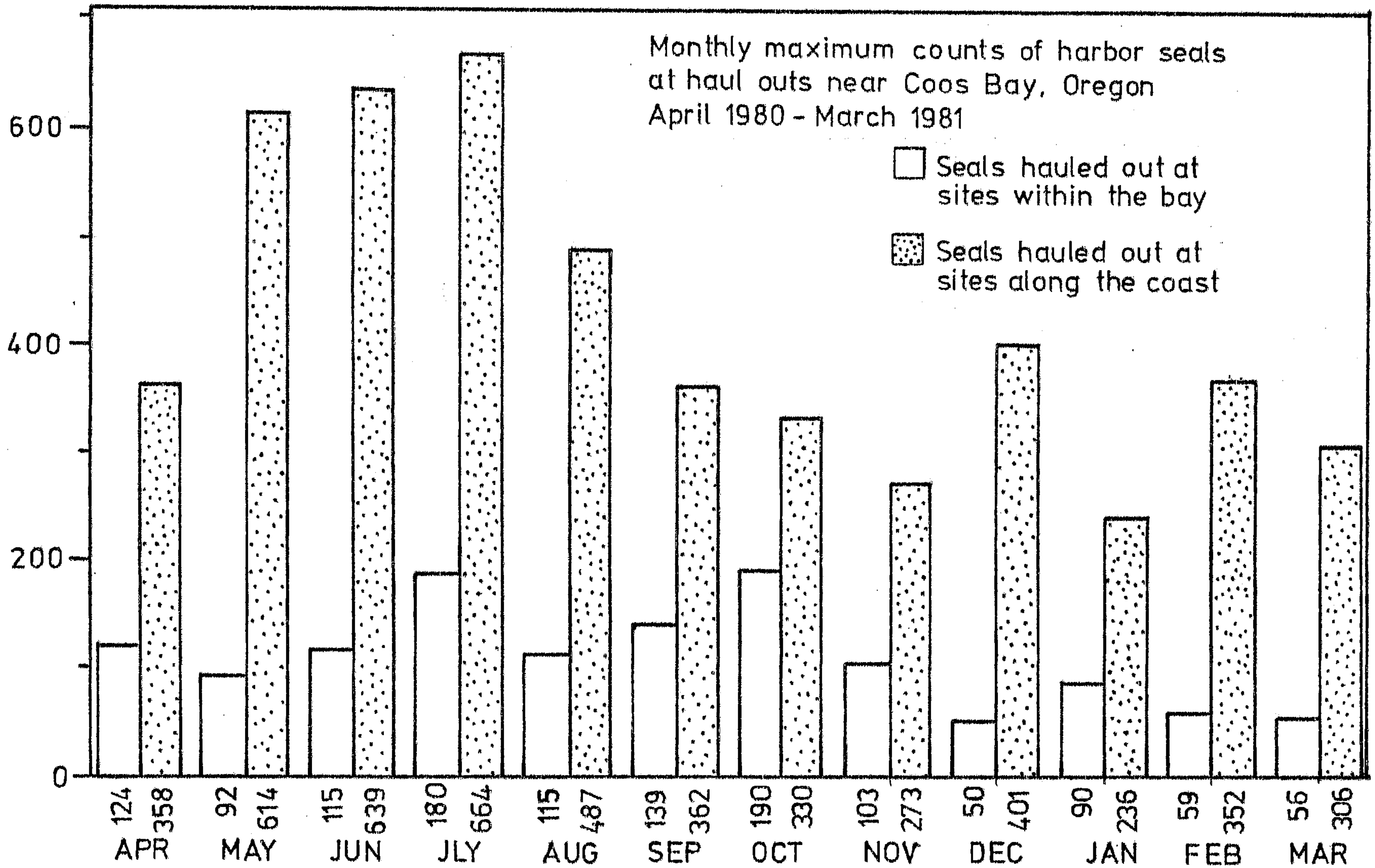
Monthly maximum numbers of harbor seals counted at haul outs near Coos Bay, Oregon April 1980 - March 1981

Table 1. The relationship between monthly maximum haul out attendance and the time of low tide.

Date of census	Time of daylight low tide(s) to nearest hour	Tidal elevation (feet)	Time in hours before(-) and after(+) low tide that max. no. of seals were observed: Nearshore sites	Bay sites
11 Jan 1981	1000	2.7	0	-2.5
14 Feb 1981	1500	-0.1	0	-2.5*
20 Mar 1981	1800	0.5	-2	-1.5*
25 Apr 1980	1500	0.8	+1	-3.5*
17 May 1980	0900	-1.4	+1	+5.5*
29 June 1980	0800 2000	-1.3 2.7	+1	-4.5*
13 July 1980	0800 2000	-1.2 2.6	0	-1.5*
3 Aug 1980	1200	1.4	+2	+1.5*
28 Sept 1980	1000	1.7	0	+0.5*
19 Oct 1980	1500	2.3	+2	-1.5
15 Nov 1980	1200	3.2	-3	-2.5
16 Dec 1980	1400	1.6	-3	-3.0

* indicates human disturbance occured at these sites on the census day.

Figure 3. Monthly maximum haul out attendance figures for harbor seals at bay haul outs (Pigeon Point, North Spit) and nearshore haul outs (South Cove, Simpsons Reef, Squaw Island) determined from all day censuses of the Coos Bay area harbor seal population from April 1980-March 1981.



Monthly maximum counts of harbor seals
at haul outs near Coos Bay, Oregon
April 1980 - March 1981
Seals hauled out at sites within the bay
Seals hauled out at sites along the coast
600
400
200
0
124 358
APR
92 614
MAY
115 639
JUN
180 664
JLY
115 487
AUG
139 362
SEP
190 330
OCT
103 273
NOV
50 401
DEC
90 236
JAN
59 352
FEB
56 306
MAR

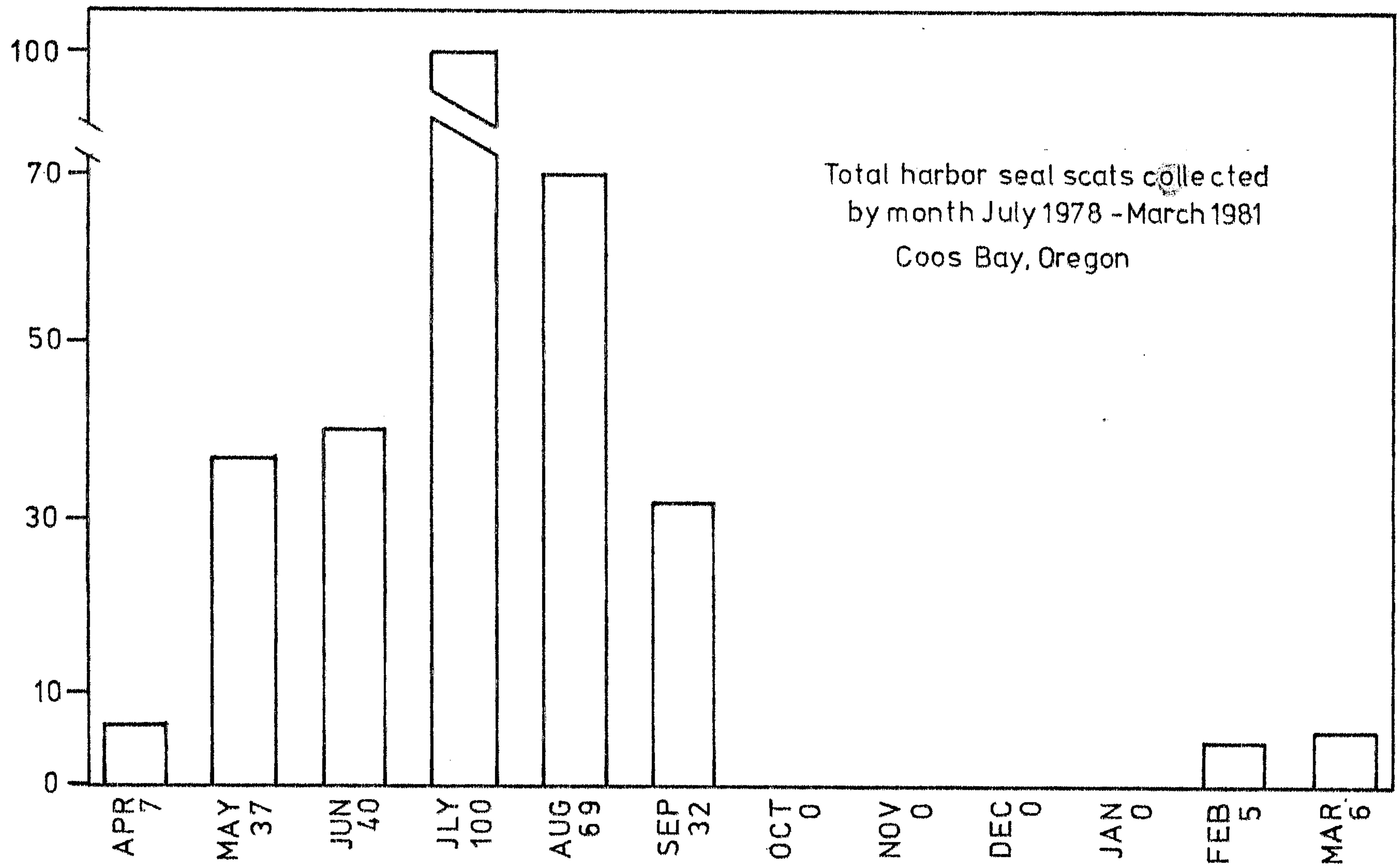
numbers peaked in October when 279 individuals were counted. This observation agrees with the migration patterns for this species described by Mate (1977). Steller's sea lions were present in all months but December, January, February and March. The population built to a maximum of 113 individuals during the August count. A monthly account of sea lion numbers at Simpsons Reef is given in Appendix 1. Juvenile Northern elephant seals were observed at Simpsons Reef during the months of April through September. The maximum count was four during the July and September censuses.

A total of 296 harbor seal scats were collected from the North Spit and Pigeon Point haul out sites. The greatest number of scats collected for any one month was for July, when a total of 100 scats were gathered. No scats were found when these sites were visited during October, November, December and January. The number of scats collected each month is shown in Figure 4.

Seventeen scats (6%) contained no identifiable remains. 279 scats (94%) contained fish remains and 230 (78%) contained fish otoliths. 2669 fish otoliths representing a minimum of 1695 fish of 45 species were examined. Prey items other than fish included two species of cephalopod, (Octopus bimaculatus and Loligo opalescens), and the lamprey, Lampetra spp. Crustacean parts were also present to a much lesser extent. Table 2 summarizes the diet study results.

880 (52%) of the fish identified were bottom dwellers. 799 (47%) were mid water types. 18 (1%) of otoliths were not identifiable. A summary of fish species by family is presented in Table 3.

Figure 4. Number of harbor seal scats collected from the Pigeon Point and North Spit haul out areas by month, from July 1978 - March 1981.



Total harbor seal scats collected by month July 1978 - March 1981 Coos Bay, Oregon

Table 2. Prey species of Coos Bay harbor seals identified from fish otoliths and skeletal remains found in scats. Prey items are ranked by frequency of occurence; percent frequency of occurence; total number of individuals for each species and the % of the total prey items that each species represents.

Species	Common name	Frequency No.	Frequency %	No. of individuals	% of total
Leptocottus armatus	Staghorn sculpin	87	29	323	19
Parophrys vetulus	English sole	67	22	220	12
Cymatogaster aggregata	Shiner surfperch	59	20	353	20
Clupea harengus	Pacific herring	57	19	125	7
	Cephalopod beaks	45	14	107	6
Citharichthys stigmaeus	Speckled sand dab	38	13	80	5
Glyptocephalus zachirus	Rex sole	30	10	103	6
Lampetra tridentata	Pacific Lamprey	26	9	-	-
Microgadus proximus	Pacific tomcod	25	8	41	2
Isopsetta isolepis	Butter sole	24	8	34	2
Psettichthys melanostictus	Sand sole	21	7	26	1
	Crustacean parts	16	6	-	-
Hypomesus pretiosus	Surf smelt	15	5	47	3
Sebastes spp.	Rockfish	12	4	24	1
Ammodytes hexapterus	Pacific sand lance	12	4	43	2
Allosmerus elongatus	Whitebait smelt	11	4	40	2
Platichthys stellatus	Starry flounder	10	3	15	1
Lyopsetta exilis	Slender sole	8	3	12	*
Damaliichthys vacca	Pile perch	8	3	11	*
Microstomus pacificus	Dover sole	6	2	10	*
Citharichthys sordidus	Pacific sanddab	6	2	10	*
Phanerodon furcatus	White surfperch	6	2	9	*
Artedius spp.	Sculpins	4	1	4	*
Thaleichthys pacificus	Eulachon	3	1	18	1
Enophyrs bison	Buffalo sculpin	3	1	7	*

Table 2 cont.

Species	Common name	Frequency No.	%	No. of individuals	% of total
Anoplopoma fimbria	Sable fish	3	1	4	*
Ophiodon elongatus	Ling cod	3	1	3	*
Atheresthes stomias	Arrow toothed flounder	3	1	3	*
Embiotoca lateralis	Striped surfperch	3	1	3	*
Chitonotus pugetensis	Rough back sculpin	3	1	3	*
Salmo gairdneri	Steelhead	2	*	13	1
Gadus macrocephalus	Pacific cod	2	*	4	*
Pholis spp.	Gunnel	2	*	4	*
Clevlandia ios	Arrow goby	2	*	3	*
Trichodon trichodon	Pacific sand fish	2	*	2	*
Lepidogobius lepidus	Bay goby	2	*	2	*
Hemilepidotus spp.	Irish lord	1	*	7	*
Eopsetta jordani	Petrale sole	1	*	2	*
Hippoglossoides elassodon	Flat head sole	1	*	2	*
Engraulis mordax	Northern anchovy	1	*	2	*
Coryphopterus nicholsii	Blackeye goby	1	*	1	*
Scorpaenichthys marmoratus	Cabezon	1	*	1	*
Poroclinus rothrocki	Whitebarred prickleback	1	*	1	*
Oncorhynchus kisutch	Silver salmon	1	*	1	*
Hyperprosopon ellipticum	Silver surfperch	1	*	1	*
Trachurus symmetricus	Jack mackeral	1	*	1	*
Merluccius productus	Pacific hake	1	*	1	*
unidentified osmerid	Smelt	1	*	1	*
unidentified fish		16	5	18	1

* indicates less than 1%

- indicates that the number of individuals could not be determined

Table 3. The frequency and number of otoliths from harbor seal scats by family.

Family	Frequency No.	Frequency %	No. of individuals	% of total fish
Pleuronectidae	171	31	431	27
Cottidae	99	18	345	21
Embiotocidae	77	14	377	23
Clupeidae	57	10	125	8
Bothidae	44	8	90	6
Osmeridae	30	5	106	7
Gadidae	27	5	45	3
Ammodytidae	12	2	43	3
Scorpaenidae	12	2	24	1
Gobiidae	5	1	6	*
Salmonidae	3	*	14	*
Anoplopomatidae	3	*	4	*
Hexagrmmidae	3	*	3	*
Pholididae	2	*	4	*
Trichodontidae	2	*	2	*
Engraulididae	1	*	2	*
Merlucciidae	1	*	1	*
Carangidae	1	*	1	*
Stichaeidae	1	*	1	*

* indicates less than 1%

Algae, small mollusc shells, and sand dollar tests were found in the scats but their presence was disregarded due to the likelyhood of them coming from the substrate that was picked up when the scats were collected. Plastic was present in two scats and a sub fossil great white shark tooth (<u>Carcharodon</u> sp.) was apparently picked up off the bottom coincidently with a bottom fish (J.E. Fitch pers. comm.).

The substrate "control plot" samples collected at the Pigeon Point site had a combined weight of 52 Kg and contained a total of 33 fish otoliths, one lens, one vertebrae, and three cephalopod beaks. The top 2 - 3 cm of Pigeon Point substrate contained an average of 0.63 fish otoliths per kilogram, (range 0.35 - 0.88), or an average of 11 otoliths per square meter, (range 6 - 16).

The largest amount of substrate collected with any scat was 2Kg, and in the majority of cases much less than this was collected. With many scats, especially those collected at the North Spit haul out, a sandy surface, virtually no substrate was collected with the scat. Thus a maximum of two otoliths could have been contributed to the scat from the substrate collected with it.

DISCUSSION

The population of harbor seals near Coos Bay exhibits a distinct seasonal variation in day time haul out useage. There was a difference of 518 seals between the high (July 844) and low (January 326) haul out attendance figures. To eliminate the possibility that any single monthly count did not represent the census period, the monthly census results were lumped into seasonal blocks, and the mean of the counts within the blocks was compared. The mean maximum number of seals hauled out during spring (March - May) was 499 seals; summer (June - August) 733; fall (September - November) 465; and winter (December - January) 396. The difference between the high and the low seasonal figures was 337 seals.

It should be restated that this species is regarded as being non migratory and if 844 seals were hauled out at one time during the year, there should be some way of accounting for them during the rest of the year. Factors that influence pinniped hauling activities are tides, weather and time of day, (Clambokidis et al 1978), human disturbance (Millias 1904, Brown 1981), molt (Johnson and Johnson 1979), copulation, pupping, energy conservation and food availability (Bartholomew 1970). Each of these factors will be examined for its potential to explain the seasonal pattern of haul out usage found in the Coos Bay area.

Tidal Height, Weather and Time of Day.

The diel and tidal related haul out patterns of the harbor seal are variable. Boulva and McClaren (1979) found "... almost no seals stay ashore in the dark" and " on Sable Island seals haul out independently of the tides". The same authors found the haul out behavior elsewhere in Atlantic Canada to be closely related to the tides. Clambokidis et al. (1979) found tidal related influences varied from site to site. Paulbitski and Maguire (1972) found seals to haul out primarily at night.

This study did not investigate night time use of Coos Bay haul outs. Mark Webber (pers. comm.) saw seals at night at the Simpsons Reef haul out in July 1976. No other information on night useage of the other sites could be found.

Tidal height did effect the haul out schedule of seals in this study. Water covers haul outs at South Cove, North Spit and Pigeon Point almost every high tide, and individual rocks at Simpsons Reef are awash during high tide, meaning fewer sites are available to seals at this time. Day time peak numbers did coincide with low tides.

Boulva and McClaren (1979) observed that harbor seals in Nova Scotia do not haul out when wind chill corrected temperatures dropped below -15°C. However wind chill corrected temperatures in Coos Bay never reached this temperature during the study period, and no wind or air temperature related behavioral changes were discerned. The negative effects of rough seas on haul out attendance have already been discussed in the census technique section. The census technique was developed to minimize the influence of weather and it is felt that the methods used ruled out weather as a cause of seasonal pattern of haul out useage.

Human Disturbance.

The harbor seal is by nature a very shy animal, and hauled out seals are very difficult to approach either by boat or on foot. The simple presence of humans near a haul out site is often all that is needed to cause every animal to flee into the water. Because all harbor seal haul out sites in the Coos Bay area are prone to human disturbance, this was examined as an element influencing haul out activities.

The intertidal areas of Coos Bay and Cape Arago are frequented by humans year round, with use being most intense during the summer/ vacation season. Seals at the North Spit and Pigeon Point haul outs are most frequently disturbed. These areas are popular recreational clamming beds and at tides below +1 feet it was not unusual to count several hundred people in the vicinity of the haul outs. Seals left the haul outs when clammers were nearby and typically did not haul out again that day (North Spit), or hauled out shortly after all the clammers had left (Pigeon Point).

Coos Bay is an important wintering area for waterfowl and gunshots were heard regularly during the duck hunting season. Gun shots elicited various responses from the seals. Distant shots resulted in no response at all, or caused resting seals to raise their heads and look about. Closer, louder shots caused either some, or all the seals to flee into the water. Seals would not haul back out again if shooting continued and waited tens of minutes after quiet was restored to haul back out, if they were to haul out at all again that tide.

Small recreational boats are very abundant in the area of the Coos Bay haul outs. People fishing near the haul outs, or small boats passing close by often caused the seals to leave the haul outs. Large boats and ships did not appear to affect the haul out behavior, probably because these vessels stayed within the deep channel and did not approach close enough to cause a disturbance.

The rocky intertidal area of Cape Arago (Simpsons Reef) is visited by many people, although human disturbance here is not so noticeable as most of the seals haul out on the outer most inaccessible reef. Seals do use the inner rocks during all months but use is heaviest when seas wash the outer reef. They also use the inner rocks of Simpsons Reef more during the pupping season, a time when school field trips appear to be the most frequent. The effects of human disturbance on pup survival are not known.

The Squaw Island site was the least accessible of the haul outs, and human disturbance here was minimal. The South Cove haul out is close to the beach access area, and although human disturbance was not observed here the potential for it exists.

The seals in the Coos Bay area seem capable of tolerating the present level of disturbance, however humans have the potential to reduce the number of seals at the haul outs through out the year, although it was most often observed during the spring and summer months. Disturbance is lowest in the winter months and does not appear to be the cause of the winter decline of haul out attendance.

Molt.

The hauling out activities of the Northern elephant seal are greatly influenced by molt (Scammon 1874). Fur replacement for this species is very dramatic, hair is sloughed off in great sheets and a sizeable measure of the animals fat reserves are used to complete the process (Harrison and King 1965). Elephant seals stay on the hauling out grounds the entire time that it takes to molt, a period of several weeks.

In contrast molt in the harbor seal is a sequential process. A captive animal in Washington state began molting in late August and was nearly finished by the end of September. Hair replacement begins in the hind parts and progresses anteriorly finishing around the head (Scheffer and Slipp 1944). The same authors saw wild seals in Washington state in various stages of molt on October 7 1942. Fisher (1952) observed an early stage of molt in British Columbia on August 8 1946. Molt was not observed during this study, but the time of molt given by others does not coincide with the July peak in haul out attendance. It seems unlikely then that molt is responsible for the summertime increase of harbor seals at the haul outs.

Copulation.

Copulation in some pinnipeds occurs almost exclusively on land (Bartholomew 1970). Because many pinnipeds have a highly synchronized breeding season, large concentrations are found at the haul outs at the time of copulation. Copulation has rarely been observed in the harbor seal (Venables and Venables 1956) because it occurs most often in the water (Newby 1973). Seal copulation was not seen during this study, but other authors have observed it during September and October (Scheffer and Slipp 1944, Fisher 1952). Thus copulation is not likely to be responsible for the observed seasonal difference of harbor seal haul out use.

Demographic Changes: Pupping and Mortality.

Some pinnipeds pup almost exclusively on land (Bartholomew 1970), resulting in increased numbers of individuals at the haul outs during the pupping season. The extent to which harbor seals pup on land is not clear. Venables and Venables (1956) state that pupping occurs both on land and in the water. Newby (1973) found placentas well above the high tide water mark, indicating that births do occur on land. All authors agree that wherever they are born, pups are capable of swimming and diving from the moment of birth. Newby (1966) made similar observations on the swimming ability of a premature fetal harbor seal cut from the placenta of its mother. Although it is not clear how often pupping occurs in the water it is considered a very likely possibility.

That some harbor seal females give birth on land opens the possibility that an increase in seal haul out attendance may be due to the presence of pups and nursing mothers. In the Coos Bay area the pupping season ranges from mid April to early June, with the peak of pupping occuring in May. Although the presence of new born pups may be partly responsible for an increase, it is difficult to account for the seasonal difference of 337 seals by the presence of pups alone. (The 17 May census of newborn pups showed 95 were present at all haul outs). Females with pups may increase their haul out attendance during the nursing period meaning that if each pup in the area were accompanied bt its mother 190 pups and nursing mothers could be expected. This figure still does not account for the seasonal difference and it is felt that the presence of pups and nursing mothers is not the sole explaination for the winter/summer difference in haul out attendance; seals other than pups or nursing females must be involved.

Since all age classes of seals were counted in the censuses a seasonal peak in mortality could account for the lower numbers of seals during the winter months. Published mortality data do not support this contention. Bigg (1969) estimated an average annual mortality rate for harbor seals in British Columbia. From birth to five years annual mortality was 20% for females and 21% for males, and the average annual mortality for all age classes was 20%.

A reliable formula for determining the actual population size based on the number of harbor seals counted at the haul outs has not been published. Because of this uncertainty the high count of 844 seals was the only figure that could be safely used to calculate the annual mortality of harbor seals in the Coos Bay area. Using Biggs 20% annual mortality rate it is calculated that 168 harbor seals die from the Coos Bay population each year. This figure is approxim--ately half of the 337 seals that make up the difference between the summer and the winter counts. Using available information mortality cannot fully account for the winter decline in haul out useage. Improved techniques for estimating total population size may show mortality to be a more important element in the explaination of seasonal haul out attendance differences.

Energy Conservation and Food Availability.

Ocean surface and air temperatures along the Oregon coast vary little throughout the year. The mean annual ocean surface temperatures is 12 - 13°C, and the monthly average air temperatures range between 5 and 15°C throughout the year (U.S. Geological Survey 1970).

Hart and Irving (1959) determined the resting metabolic rate for harbor seals and the lowest air and water temperatures in which the resting rate could be maintained. They found this "critical temperature" to be 20°C in water and 2°C in air. Below these temperatures it was necessary for the animal to expend energy to maintain a normal body temperature. They state "... oxygen consumption began to increase in water temperatures below 20°C and increase to nearly twice the thermoneutral (resting) rate at 0°C".

Using Hart and Irvings findings and local water temperature data, the expected metabolic rate for harbor seals floating in Oregon waters can be calculated. In water 14°C a seals oxygen consumption will increase from the resting rate of 18.3 ml $O_2/min/Kg^{3/4}$ to approximately 29.3 ml $O_2/min/Kg^{3/4}$, an increase of 60%. In contrast, a seal resting on a haul out never has to expend extra energy to stay warm.

From the stand point of energy conservation it is advantageous for the harbor seal to maximize the time spent on land, for whenever it enters the water in Oregon it will use more energy to stay warm than it does while on land.

Harbor seals conduct two important activities in the water; feeding and copulation. Only feeding will be discussed here as the extent to which copulation influences hauling behavior has already been discussed. Also copulation is not felt to be as important a factor as feeding, since the time that a seal spends engaged in copulatory behavior is brief compared to the time that it spends searching for food.

The conflicting demands of energy conservation and feeding lead one to expect the numbers of seals at the haul outs to be high when food availability is high. Conversely, when food availability is lower, the numbers of seals at the haul outs would be expected to be lower also because individual seals will be spending proportionally more time in the water searching for food.

Seasonal food availability then, has the potential to influence harbor seal haul out attendance. A discussion of food abundance in the Coos Bay area may help explain the seasonal variation of local haul out useage.

In 1980 Oregon Department of Fish and Wildlife (ODFW) conducted a fish abundance survey based upon extensive beach seining done in the Coos Bay estuary. Their findings confirm the widely held contention that summer (June, July) is the time of greatest fish abundance in Coos Bay (R. Bender pers. comm.).

The time of greatest fish abundance can be inferred using another method; given that selection pressure influences the timing of reproduction so as to maximize the survival of the offspring, the birthing, and particularly the weaning of seal pups should be closely associated with the time of maximum food availability. The harbor seal nurses for a relatively short period of time, and weaning occurs 5 - 6 weeks after birth (Bigg 1969). Since the Coos Bay pupping peak occurs in the first part of May, the weaning time (the time of maximum food availability) should fall at the beginning of July.

It is noteworthy that the time of greatest food abundance, as noted by the ODFW beach seining program, and as inferred by the time of weaning, coincides with the time of greatest haul out attendance (July). The abundant supply of fish during the summer months could help to explain the summer time peak of haul out useage.

Many species of fish come to the estuarine and coastal zone, use it as a spawning area in the spring and summer months, then leave to spend the rest of the year in the offshore zone. This study shows that when these fish are present, seals use them as food (see Table 2). The absence of these fish supports the idea that a seal must spend a greater portion of its time searching for food during the winter months. Thus lower winter food availability could explain why fewer seals were counted on the haul outs during the winter months.

Diet Studies.

It was the original intent of this study to collect diet information from all seasons, as a diet study using large comparable seasonal samples had not been conducted for the harbor seal. Unfortunately this study was unable to fulfill this intent. The supply of scats at the Pigeon Point haul out dwindled to all most nothing during the winter months (see Fig. 4). The paucity of scats in the winter is likely the result of individual seals having to spend more time off the haul outs searching for food. It should be kept in mind that the feeding study data represents the diet of the harbor seal during the five months of May to September only.

Because the harbor seal diet includes spawning fish, such as herring (see Table 2), that occur in the nearshore and estuarine zones only briefly each year, caution should be used when interpreting the results of any diet study. Some authors have presented sweeping statements about the harbor seals annual intake of seasonally available fish (such as salmon) based on gut samples collected largely when the species in question were present in the coastal zone (Spalding 1964, Havinga 1933). Others, such as Fisher (1952) were aware of this problem and were hesitant to make statements about the annual harbor seal intake of any particular fish species.

The results of the 1980 Oregon Department of Fish and Wildlife seining program are not at this date fully tabulated, but staghorn sculpins, shiner surf perch and young English sole appear to have been among the most abundant species of fish in the Coos Bay estuary. Pacific herring and smelts inhabit the bay for shorter time periods, but are abundant fish during their spawning runs.(R. Bender pers. comm.).

The extent to which seals hauling out at Pigeon Point and North Spit feed in the bay cannot be quantitatively determined from this study, but it is noteworthy that the above named fish comprise 67% of all the prey items found in the seal scats. Seals were observed feeding on staghorn sculpins on several occasions within the bay, though these observations do nothing more than confirm that some fish are eaten there.

Table 2 indicates a wide variety of prey species were eaten, but of 45 fish species involved, 33 species made very small individual contributions to the diet. Each species in this group contributed only one percent or less to the total number of prey items.

There is no evidence at this time to indicate whether the harbor seals of Coos Bay preferentially select any species of prey. As further fish abundance data from the 1980 seining studies becomes available, analysis may show otherwise. Presently the wide variety of fish, and the dominance of the most abundant available species, indicates that the seals are opportunistic feeders; as they swim about in search of food they take any fish they encounter, regardless of its type. Further the seals in Coos Bay have no apparent preference for mid water species over bottom dwelling fish. Several authors have suggested that the harbor seal is an opportunistic feeder (Imler and Sarber 1944, Fisher 1952, Pitcher 1980).

Cephalopods were the fifth most frequently encountered prey in the scats. Pitcher (1980b) found that beaks in scats probably under represent the importance of cephalopods in the diet of the harbor seal. He was unable to quantify these findings but they suggest that this prey group is even more important than the results show (see Table 2).

It should be noted that the items occurring most frequently in the scats are small fish species. Fish otoliths and vertebrae from animals substantially larger than these species made up a very small part of the food remains. Certainly it takes fewer larger fish to satisfy the caloric needs of a seal, and unless large fish were preferentially selected, their remains would not be expected to be the most numerically abundant. The frequency that large fish occur in the scats can on the other hand provide some index of their importance in the diet.

Pitcher (1980b) observed that harbor seals often fragment large fish while eating them, usually discarding the head. He states, "Thus studies of feeding habits based on scat analysis (which requires the presence of otoliths) probably under represent large fishes...". Even if large fish heads, and hence the otoliths, are not eaten, whole vertebrae are likely to be consumed. Fish vertebrae were typically more abundant in the scats than otoliths. Vertebrae with centra as small as 1mm often passed virtually undigested, many with the delicate neural and hemal arches still intact. Large vertebrae were also found in a well preserved state though the neural and hemal spines had been broken off, presumably to allow passage through the gut.

Pitcher only briefly mentions fish vertebrae, as his principle concern was the species of fish involved, and otoliths serve to identify species much better than vertebrae. Since the concern here is more whether any large fish, regardless of species, are eaten, the presence of a large vertebrae in a scat is an adequate indication that a large fish was eaten (Wise 1980).

After considering the discussion above, the occurrence of otoliths or vertebrae from large fish was so low that they could not be considered a preferential item. Their occurrence in the scats is more likely the result of the seals having a fortuitous encounter with a large fish, than the result of a selective search for them.

Opportunism is compatible with the energetic model outlined earlier in the discussion. If a seal disregards certain prey items in preference to others it will have to spend more time in the water searching for food. Given that a preferred item is not much larger, preferential prey selection can be regarded as requiring greater energy output than opportunistic feeding.

Many fishermen are concerned that seals eat the small down stream migrants of salmon known as smolts. Coos Bay does not have an exceptionally large native population of salmon but it is the location of two of Oregons recently developed salmon ranching operations. Both

Oregon Aqua Food Inc. and Anadromous Inc. were on line in 1980, both releasing hundreds of thousand salmon smolts into Coos Bay. The release site of Oregon Aqua Foods is on the North Spit and is less than 1 Km from the North Spit seal haul out. Smolt salmon otoliths were measured before the study began and seive sizes were selected to ensure that otoliths of these fish would be retained. Although salmon smolts were being released during the time of the diet study surprisingly few salmon otoliths were found.

The density of persistant food remains in the Pigeon Point haul out substrate was low and it appears that material from the substrate influenced the diet study findings very little. Therefore it is felt that the scat samples collected at Pigeon Point represented the diet of the seals at the time of their collection.

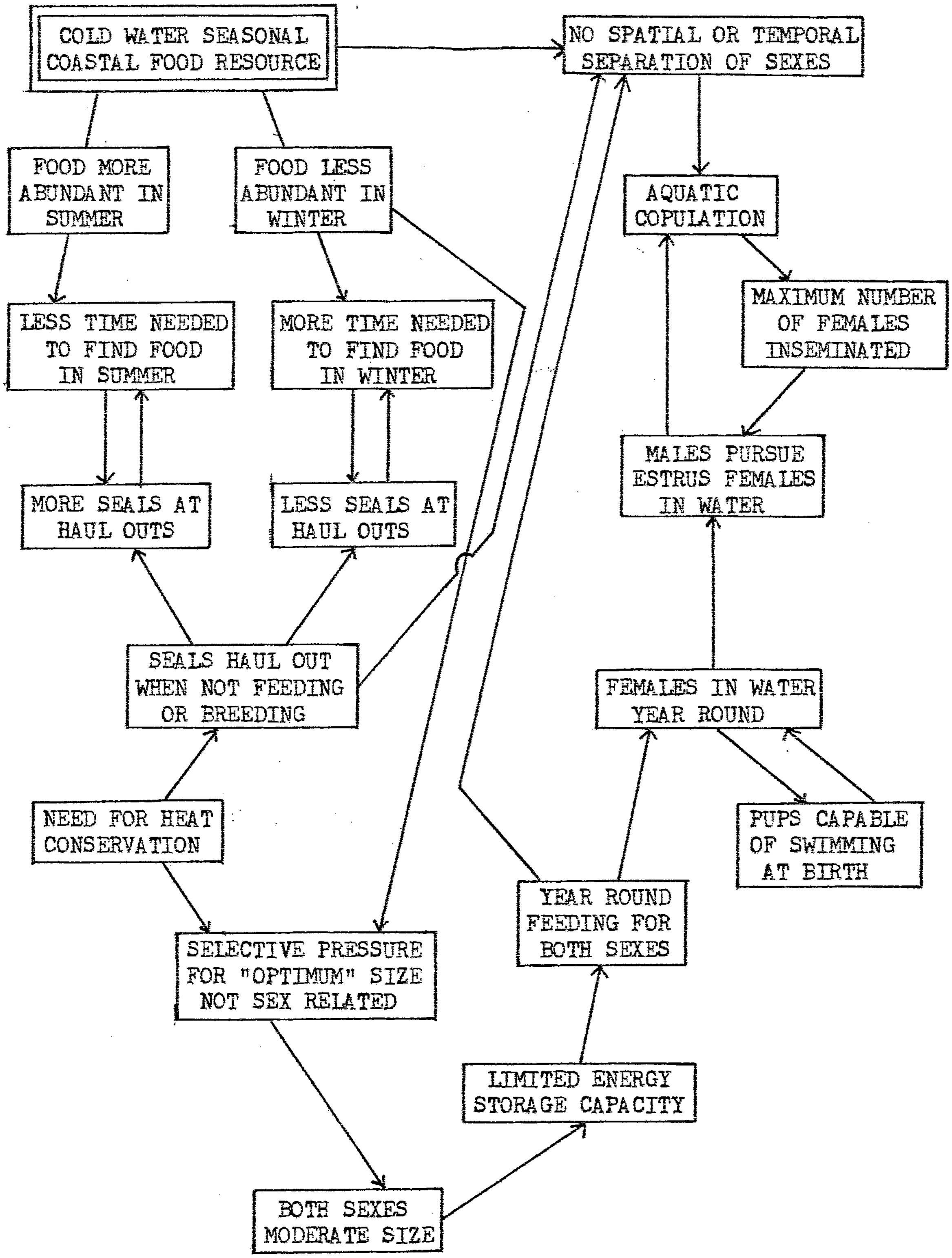
SUMMARY

So far the results of the diet study and the censuses have been discussed as separate topics. In an attempt to synthesize these findings a model that accounts for observations of these and other harbor seals is presented. The model (Figure 5) was inspired by a model presented by Bartholomew (1970) to explain the evolution of pinniped polygyny. Bartholomews model is based on the contention that pelagic dispersal and terrestrial copulation are the two key determinants leading to polygyny and sexual dimorphism in some pinnipeds, noteably California sea lions, Steller sea lions, Northern Fur seals (*Callorhinus ursinus*) and Northern elephant seals.

It is interesting to note that the harbor seal is unique among pinniped species frequenting the Oregon coast, in that it does not frequently copulate on land (Venables and Venables 1956, Newby 1973), and it is not known to have a pelagic dispersal phase (Fisher 1952, Bigg 1969). If the above behavioral observations are compared to the fundamental elements of Bartholomews model, it is apparent that his model does not apply to the evolution of harbor seal behavior. The model presented here is an attempt to explain the evolution of the biology, ecology and social behavior of harbor seals.

One of the unique features just mentioned is that the harbor seal is a rather sedentary species; it spends its life in the nearshore, coastal and estuarine zones. This element is felt to be the key evolutionary determinant responsible for the adaptive features of the harbor seal.

Figure 5. A model for the evolution of behavior in harbor seals.


COLD WATER SEASONAL COASTAL FOOD RESOURCE
NO SPATIAL OR TEMPORAL SEPARATION OF SEXES
FOOD MORE ABUNDANT IN SUMMER
FOOD LESS ABUNDANT IN WINTER
AQUATIC COPULATION
MAXIMUM NUMBER OF FEMALES INSEMINATED
LESS TIME NEEDED TO FIND FOOD IN SUMMER
MORE TIME NEEDED TO FIND FOOD IN WINTER
MALES PURSUE ESTRUS FEMALES IN WATER
MORE SEALS AT HAUL OUTS
LESS SEALS AT HAUL OUTS
SEALS HAUL OUT WHEN NOT FEEDING OR BREEDING
FEMALES IN WATER YEAR ROUND
NEED FOR HEAT CONSERVATION
PUPS CAPABLE OF SWIMMING AT BIRTH
YEAR ROUND FEEDING FOR BOTH SEXES
SELECTIVE PRESSURE FOR "OPTIMUM" SIZE NOT SEX RELATED
LIMITED ENERGY STORAGE CAPACITY
BOTH SEXES MODERATE SIZE

Year round residency in the coastal zone appears to have influenced most aspects of the harbor seals life.

The temperate coastal zone has been discussed earlier as being a seasonally variable food resource. The harbor seals moderate size and lack of sexual dimorphism appear to be a consequence of its dependence on this seasonal supply of food. Boulva and M^cClaren (1979) state that harbor seals feed throughout the year, and there does not appear to be anytime of fasting in this species as is often seen in other pinniped species. They further state that harbor seals maintain a relatively constant blubber reserve suggesting that the seals do not regularly depend on their fat reserves to get them through a time of low food abundance.

That harbor seals were present on Coos Bay area haul outs throughout the year implicitly states that at least some seals are capable of satisfying their caloric needs regardless of the season. This statement is substantiated by the earlier discussion of oxygen consumption of seals in air and water. This suggests that seals should haul out when not feeding or breeding because they will expend less energy doing so. That some seals are capable of satisfying their caloric needs during the time of least food abundance also indicates that the caloric needs of the seal can be met more quickly during the times of greater food abundance. Seasonal variations in the food supply stands as an explaination for the seasonal variations in haul out attendance.

Bartholomew (1970) and Harrison and King (1965) state that cold water temperatures have served as a selective force leading to a large size in marine mammals. The complete dissociation of whales from the gravitational forces of the terrestrial environment has enabled this selective force to generate animals of the greatest size. Pinnipeds, on the other hand, have retained a terrestrial phase and are still subject to the constraints of terrestrial locomotion and gravity. The necessity of terrestrial locomotion is given as the reason why pinnipeds have not been able to attain the size of whales.

If cold water promotes large size in marine mammals some opposing selective factor must be responsible for the fact that not all pinnipeds are the same size. All pinnipeds, even the 7m Southern elephant seal, Mirounga leonina are capable of terrestrial locomotion, yet some species, like the harbor seal, are much smaller than this. Terrestrial locomotion cannot be the major selective force limiting the size of these smaller pinnipeds.

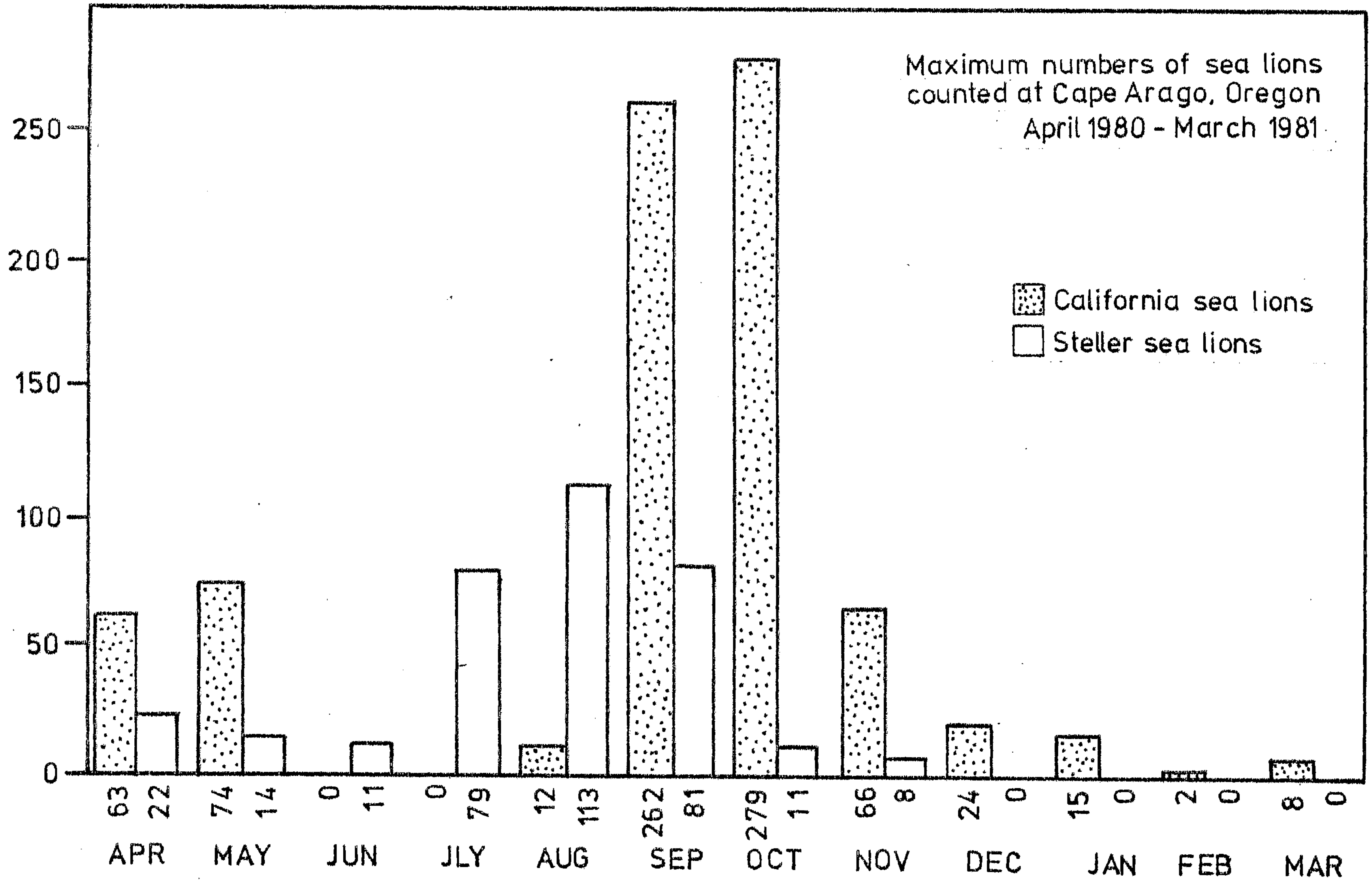
In winter larger pinniped species such as the Caifornia and Steller sea lions leave the Coos Bay haul outs (Appendix 1). The pelagic dispersal of these species in search of food suggests that the winter coastal food resource in Oregon cannot sustain their caloric needs (see Bartholomew 1970).

This study and others,(Scheffer and Slipp 1944, Pitcher 1980a) indicate that the harbor seal is an opportunistic feeder whose diet consists primarily of the most locally abundant fish species. In temperate coastal zones individual prey items become more widely spaced during the winter months. In situations were search time is long a predators yield of energy per prey item will be an inverse function of its size. The energy used while searching for prey is a direct function of the predators size. A large predator will have a larger net caloric comsumption per unit of time than a smaller one, and if prey size is constant the net caloric gain will be greater for a smaller animal.

In light of the previous discussions regarding seasonal prey availability and thermal conservation, the diminished winter food supply is proposed as the major selective force acting to counter cold water selection for larger size. The size of the harbor seal can be viewed as the product of the conflicting selective forces presented by the seals cold water environment, and its diminished winter food supply. Through time these interacting factors have established an "optimum" size for the harbor seal. Because the seal is nonmigratory and because the selective forces for determining size are not linked to the reproductive cycle, sexual dimorphism has never developed in the harbor seal.

Once the factors responsible for determining the size of the seal are understood the unique aspects of the harbor seals reproductive biology can be explained. A small animal cannot store energy to sustain a prolonged period of fasting as well as a large one can (see Bartholomew 1970), and assuming that the harbor seal is approaching or has attained the "optimum" size, it does not appear that it will ever be able to sustain prolonged periods of fasting. Because of its year round feeding habits, reproductive activities such as copulation and pupping have become more water orientated than the polygynous pinniped species.

Appendix 1. A monthly account of California sea lions (*Zalophus californianus*) and Steller sea lions (*Eumatopias jubata*) at Simpsons Reef, Coos County, Oregon from April 1980-March 1981.


Maximum numbers of sea lions
counted at Cape Arago, Oregon
April 1980 - March 1981
California sea lions
Steller sea lions
250
200
150
100
50
0
63 22
74 14
0 11
0 79
12 113
262 81
279 11
66 8
24 0
15 0
2 0
8 0
APR
MAY
JUN
JLY
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR

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