SEASONAL MOVEMENTS AND HAULING SITE FIDELITY OF HARBOR SEALS, *PHOCA VITULINA RICHARDSI*, TAGGED AT THE KLAMATH RIVER, CALIFORNIA

by

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We certify that we have read this study and that it conforms to acceptable standards of scholarly presentation and is fully acceptable, in scope and quality, as a thesis for the degree of Master of Arts.

_____ Major Professor

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Approved by the Graduate Dean

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ABSTRACT

Hauling site fidelity, movement patterns, and the proportion of harbor seals hauling out were examined for one year by radiotagging 12 seals in the Klamath River, California. Hauling site fidelity was highest during the spring and summer months, with 42% of the tagged seals traveling from nearby hauling grounds to forage in the river. The majority of seasonal movements and dispersals originated during winter months, with subadult seals exhibiting a greater tendency for movement than adults. Seasonal movements coincided with the abundance of common prey items, pupping, breeding, and moulting activities. Tagged female seals made a significantly larger proportion of seasonal and local moves than males. Seals hauled out an average of 56.1 ± 2.8% (standard error) of the days in April and 63.6 ± 5.5% (S.E.) in May. Based on resightings, a minimum of 56.4 ± 3.1% (S.E.) and 65.1 ± 12.8% (S.E.) of the study area harbor seal population hauled out daily in April and May. The maximum recorded count corrected for the proportion of animals hauled out suggests that from 522 to 778 harbor seals were present in the study area at the peak of the season in May 1983.

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INTRODUCTION

Harbor seals are considered non-migratory, exhibiting local movements associated with tidal fluctuations, prey abundance, reproductive behavior, and seasonal weather variations (Scheffer and Slipp 1944; Fisher 1952; Bigg 1969; Divinyi 1973; Bonner and Whitthames 1974; Johnson and Jeffries 1977; Vaughn 1978; Boulva and McLaren 1979; Sullivan 1979; Alcorn and Fancher 1980; Roffe 1980; Bowlby 1981; Graybill 1981; Beach *et al*. 1982; Brown and Mate 1983; Jeffries 1983; Stewart and Yochem 1983). Use of specific hauling areas by harbor seals varies both seasonally and daily, with seals exhibiting a unique hauling pattern at each site determined by tide, site topography, and disturbance factors (Fisher 1952; Sullivan 1979; Bowlby 1981; Stewart 1981; Miller *et al*. 1983b). The maximum number of seals hauled out at a particular site may vary considerably from day to day (Sullivan 1979; Alcorn and Fancher 1980; Stewart 1981).

Direct observations and aerial counts provide only indices of population size since the relationship between the maximum number of seals hauled out on any given day and the total number of seals that use a particular site is often unknown and difficult to determine (Smith *et al*. 1973; Eberhardt *et al*. 1979). Individual harbor seals may not haul out on consecutive days, but may remain in the water to rest

or forage (Sullivan 1979; Stewart 1981; Pitcher and McAllister 1981; Brown and Mate 1983; Jeffries 1983; Stewart and Yochem 1983). Some individuals travel to alternate hauling areas on a daily or seasonal basis (Sullivan 1979; Pitcher and McAllister 1981; Brown and Mate 1983; Jeffries 1983; Stewart and Yochem 1983). Seals that consistently use a particular hauling area are said to have a high degree of site fidelity (Divinyi 1973; Boulva and McLaren 1979; Calambokidis et al. 1979; Pitcher and McAllister 1981; Brown and Mate 1983; Stewart and Yochem 1983). Additional information regarding the seasonality of movements, hauling site fidelity, and the population proportion hauled out at a particular time is needed to enhance the accuracy of harbor seal counts.

Radio telemetry studies have been conducted to evaluate site fidelity, the proportion of tagged seals hauled out, and seasonal and diurnal movements of harbor seals in the Wash, East Anglia, England (Bonner and Whitthames 1974); the Kodiac Islands, Alaska (Pitcher and McAllister 1981); the southern California Channel Islands (Stewart and Yochem 1983); and the Oregon and Washington coasts (Brown and Mate 1983; Jeffries 1983). Varying degrees of site fidelity have been reported by Divinyi (1973), Knudtson (1974), Reijnders (1976), Boulva and McLaren (1979), Calambokidis et al. (1979), Pitcher and McAllister (1981), and Stewart and Yochem (1983). Localized and long range movements also have

been reported (Bigg 1969; Haaften 1972; Bonner and Whitthames 1974; Vaughn 1978; Drescher 1979; Pitcher and McAllister 1981; Brown and Mate 1983; Jeffries 1983; Stewart and Yochem 1983). Tagging studies conducted in conjunction with analysis of food habits suggest that some seasonal movements may be a response to seasonal prey abundance (Brown and Mate 1983; Jeffries 1983). Localized prey abundance may be the reason for local movements and the observed seasonality of hauling site fidelity (Roffe 1980; Brown 1981; Miller *et al*. 1983b).

The ability to develop optimal management policies for California's pinniped populations, minimizing depredation of economically important fisheries and limiting incidental mortality associated with these interactions, rests upon accurate assessment of population statistics and long term trends in abundance. The California Department of Fish and Game (CDFG) is currently conducting repetitive statewide aerial counts of harbor seals in California to assess the status of their populations.

River mouths and bays provide ideal hauling areas for harbor seals by offering proximity to seasonally abundant prey species such as anadramous fish (Fisher 1952; Brown and Mate 1983; Jeffries 1983). Fish moving into and out of these areas are confined in narrow channels, embayments, and shallows with limited escape routes from predators (Brown

and Mate 1983). Harbor seal foraging efficiency is reportedly high in such areas (Roffe 1980; Bowlby 1981; Brown and Mate 1983). The Klamath River in northern California typically experiences a high rate of pinniped depredation on free-swimming and netted salmonids during the spring and summer (Bowlby 1981; Boydstun and Buelna 1982; Hart 1983; Herder 1983). Depredation rates of over 13% of the fall gill net harvest (Herder 1983) and from 12 to 16% of the seine caught salmonids (Hart 1983) were reported for 1981. Harbor seals are present at the river mouth year round with seasonal peaks in abundance coincident with early spring runs of lamprey eels (*Lampetra tridentata*) (Bowlby 1981), and mid-fall salmonid runs and the accompanying decrease in sport fishing activity (Bowlby 1981; Herder 1983). The accessibility of hauling areas and the documented parallels between seasonal increases in abundance of seals and their prey suggest the Klamath River is an ideal location for studying movements and site fidelity of harbor seals.

This one year radio telemetry study of harbor seals at the Klamath River was conducted to assess hauling site fidelity and to document movements. Hauling patterns, variability in site use, and estimation of the proportion of the regional seal population hauled out at a particular time were analyzed to help clarify the results of aerial counts

and increase the reliabilty of population estimates from the CDFG statewide aerial harbor seal census.

This study was conducted under contract to the National Marine Fisheries Service as a portion of a larger study to assess pinniped populations on the Pacific coast and develop optimum management policies.

STUDY AREA

The Klamath River is joined by the Shasta, Scott, Salmon, and Trinity Rivers in northern California before draining into the Pacific Ocean 27 km south of Crescent City, in Del Norte county, California. Harbor seals were captured in the Klamath River estuary (lat. 47 32.7'N). The estuary bottom is primarily gravel with mud flats over most of the shallow areas. River mouth hauling areas are located on two sandspits (Figure 1), where harbor seals hauled out during night and early morning hours.

Radio telemetry checks from shore stations were conducted over the 50 km of exposed rocky coastline from the mouth of Redwood Creek (site 407) north to Castle Rock (site 418 - Castle Island of Griswold 1985) near Crescent City (lat. 41 45.6'N) (Figure 2). This was the ground survey portion of the study area. Site names and numbers were adopted from Miller _et al_. (1983b). Nine distinct hauling areas, composed of more than 50 offshore rocks, each measuring less than 20 m in diameter, serve as hauling sites for harbor seals. Most are steep-sided, flat-topped, rocky shoals and are exposed only at low tides. Two reefs extending from shore, as well as a flat sandy beach (Scat Beach, site 416 - Easy Beach of Griswold 1985) were used as seal hauling areas. On the shoreward side of Castle Rock (site 418), an island and a series of rocky shoals provide

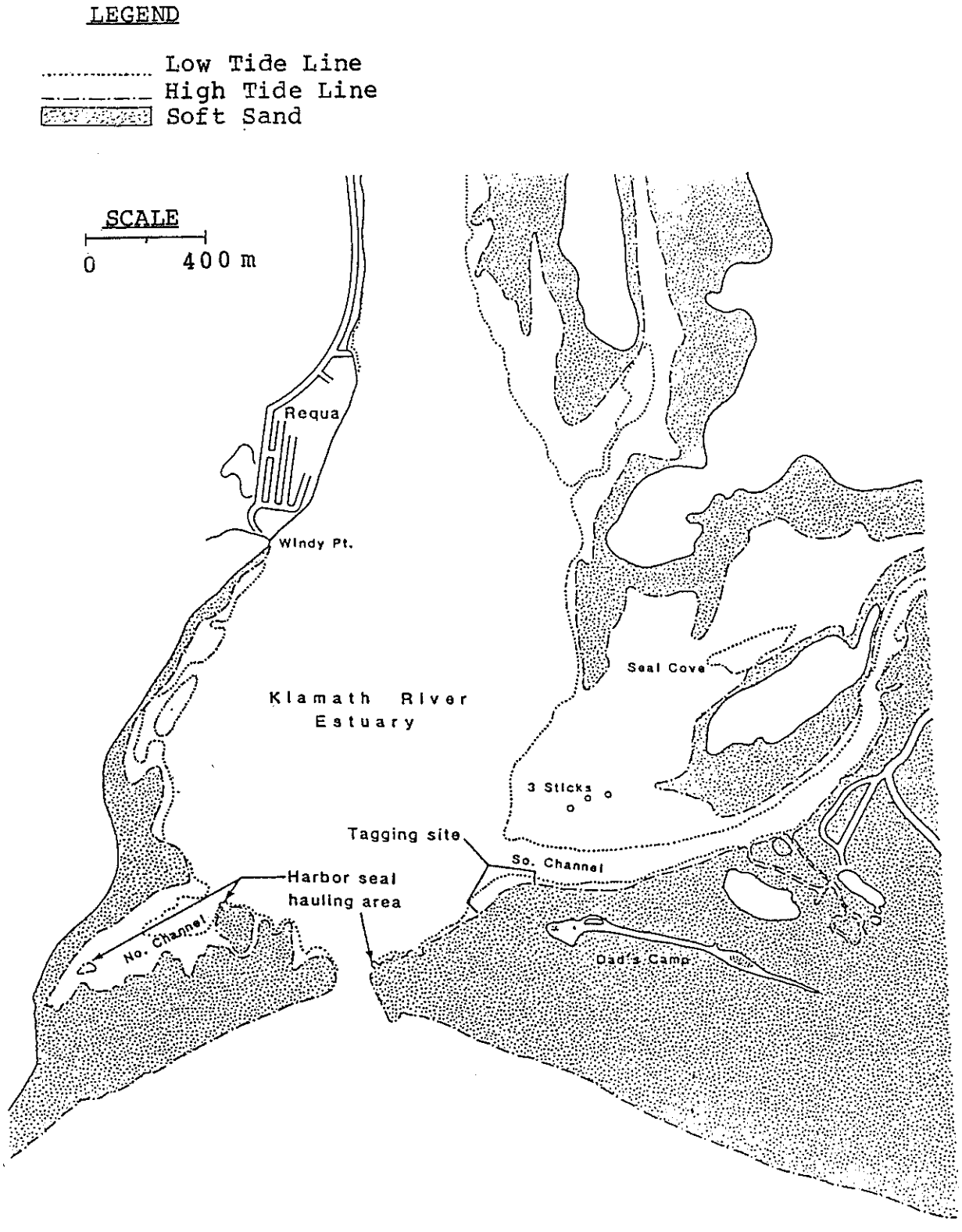

Figure 1. Mouth of the Klamath River showing harbor seal hauling areas.

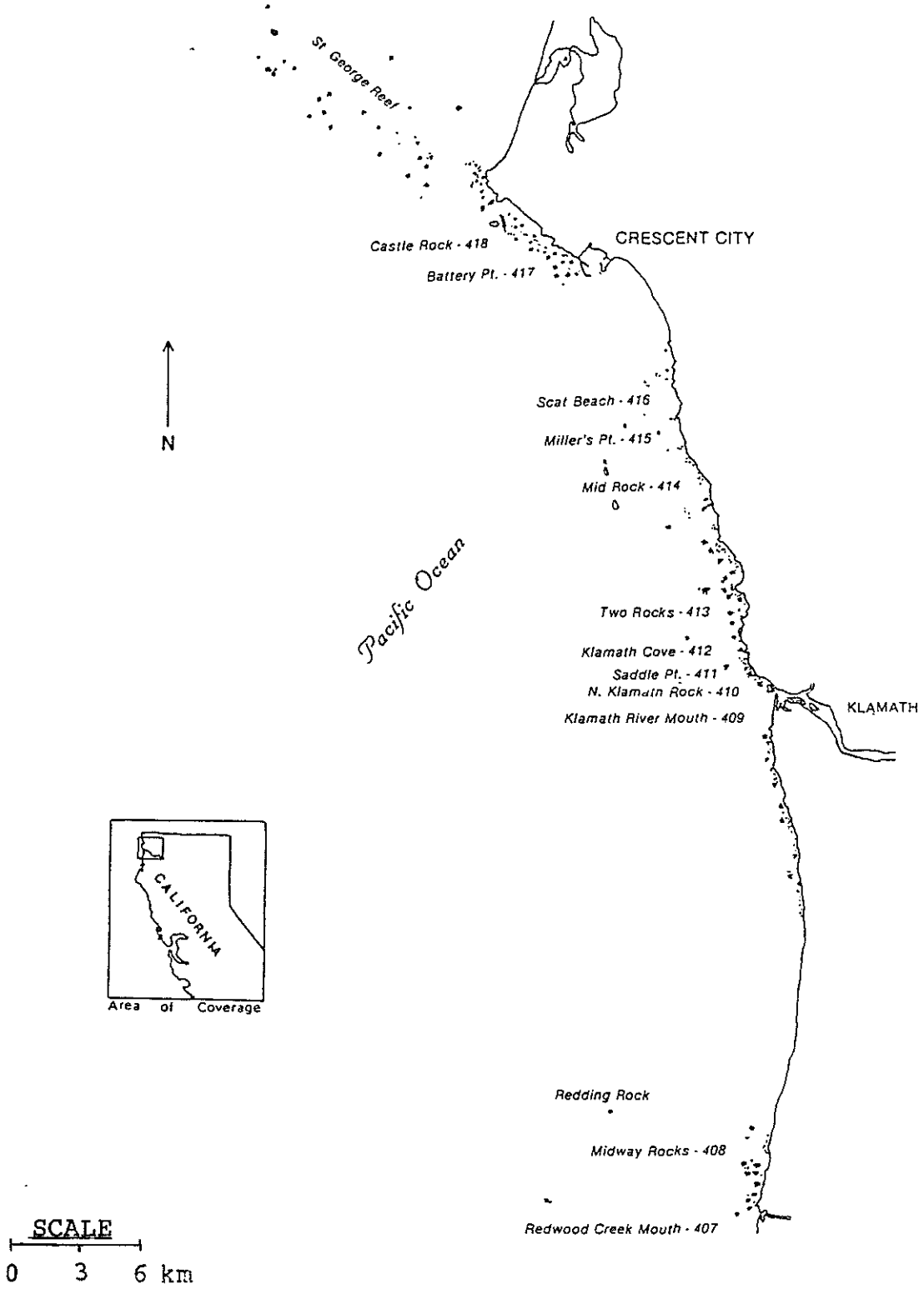

Figure 2. Harbor seal hauling areas monitored by ground radio telemetry checks.

hauling substrate for 200+ harbor seals, 400 - 500 California sea lions (Zalophus californianus), 80+ Stellar sea lions (Eumetopias jubatus), and an occasional elephant seal (Mirounga angustirostris). Harbor seals also compete for space with other pinniped species at Klamath Cove (site 412). Scat Beach (site 416) and Two Rocks (site 413) are the only known rookery / pupping areas within the ground survey area. All sites within the ground survey area are isolated from main roads and, with the exception of Castle Rock (site 418), were accessibe only by trail.

Aerial radio telemetry surveys covered the area from the Eel River, California (lat. 40 37.5'N) to Rogue Reef, near Gold Beach, Oregon (lat. 42 27.0'N), and occasionally as far north as Yaquina Bay, Oregon (lat. 44 48.8'N) (Figure 3). Some 100 or more offshore rocks serve as hauling grounds for seals between Crescent City, California and Gold Beach, Oregon. As with the ground survey areas, seal hauling sites were generally found on the shoreward side of offshore rocks. Harbor seals commonly used three sites on the sand spits at the mouth of the Eel River as hauling grounds. Four sites on the mud flats of Humboldt Bay, near Eureka, California (lat. 40 47.1'N), serve as harbor seal rookeries.

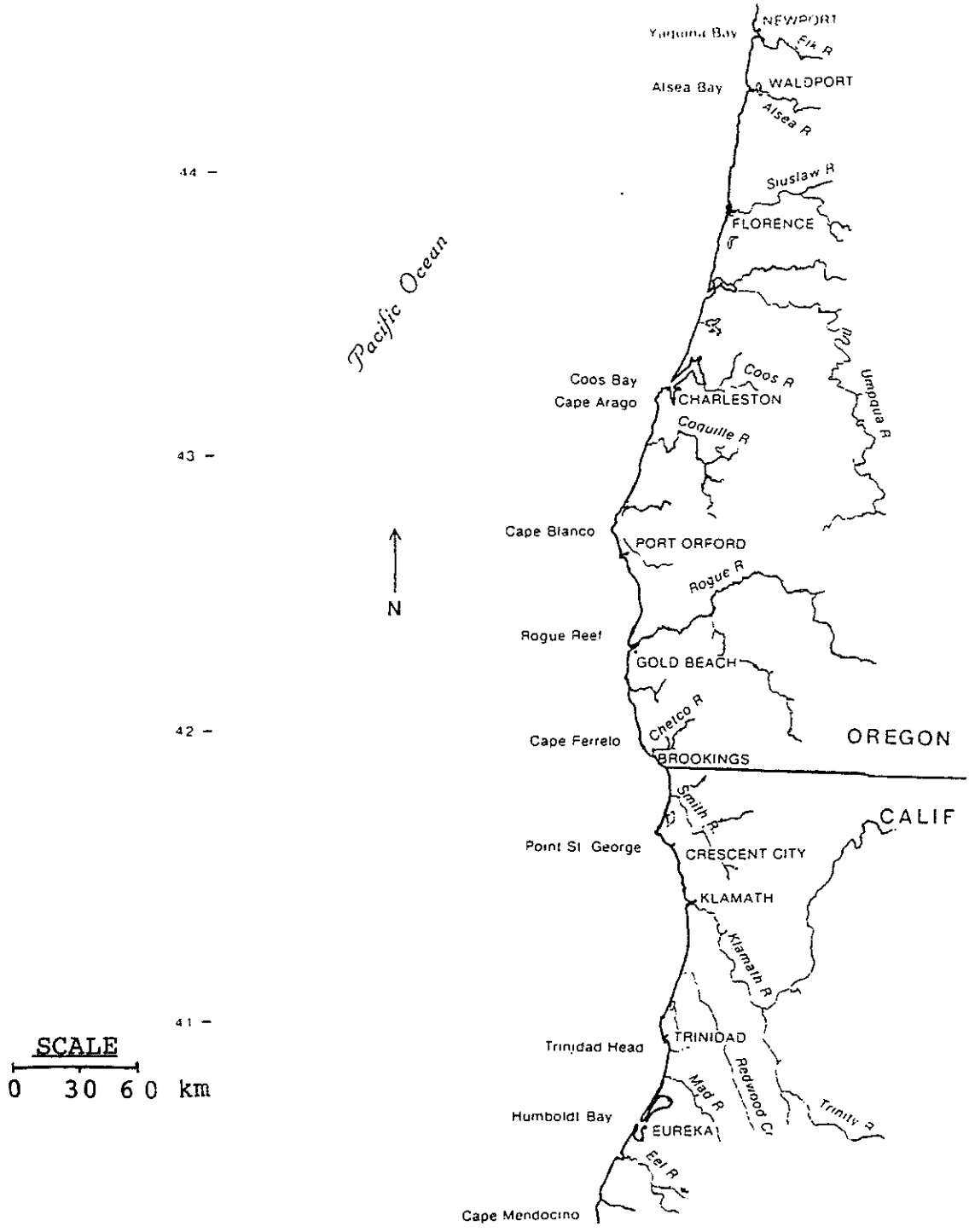

Figure 3. Study area monitored by aerial radio telemetry checks.

METHODS AND MATERIALS

Capture and Handling

Harbor seals were captured for tagging between June 8 and October 14, 1982, at three sites in the Klamath River. Seals remaining in the estuary after fishermen disturbed the river mouth hauling areas in the early morning (Herder 1983) were herded into capture nets using one or more underwater acoustic harrassment devices developed at Oregon State University (Miller et al. 1983a). The capture nets consisted of panels 30 m long by 6 m deep of #36 green nylon with 25 cm mesh. The floatline was a 1.1 cm braided polypropylene line with the floats paired at every other hanging to minimize their entanglement in the mesh. The leadline was a 0.63 cm braided polypropylene lead core line weghing approximately 0.23 kg / m. Net panels were laced together with #18 black seine twine for a total length of 100 m. An additional 70 m net fence, 8 m deep, of the same mesh and line specifications as the capture net was anchored in the river channel. The downriver end of the capture net was fixed to an onshore log. The upriver end was tied and laced to the near end of the anchored fence net (Figure 4A). The capture nets were loosely set, allowing for a "U" shaped enclosure with a 50 m opening at the upriver end. The anchored fence net was set to extend the mouth of the enclosure to 100 m offshore. A quick release mechanism,

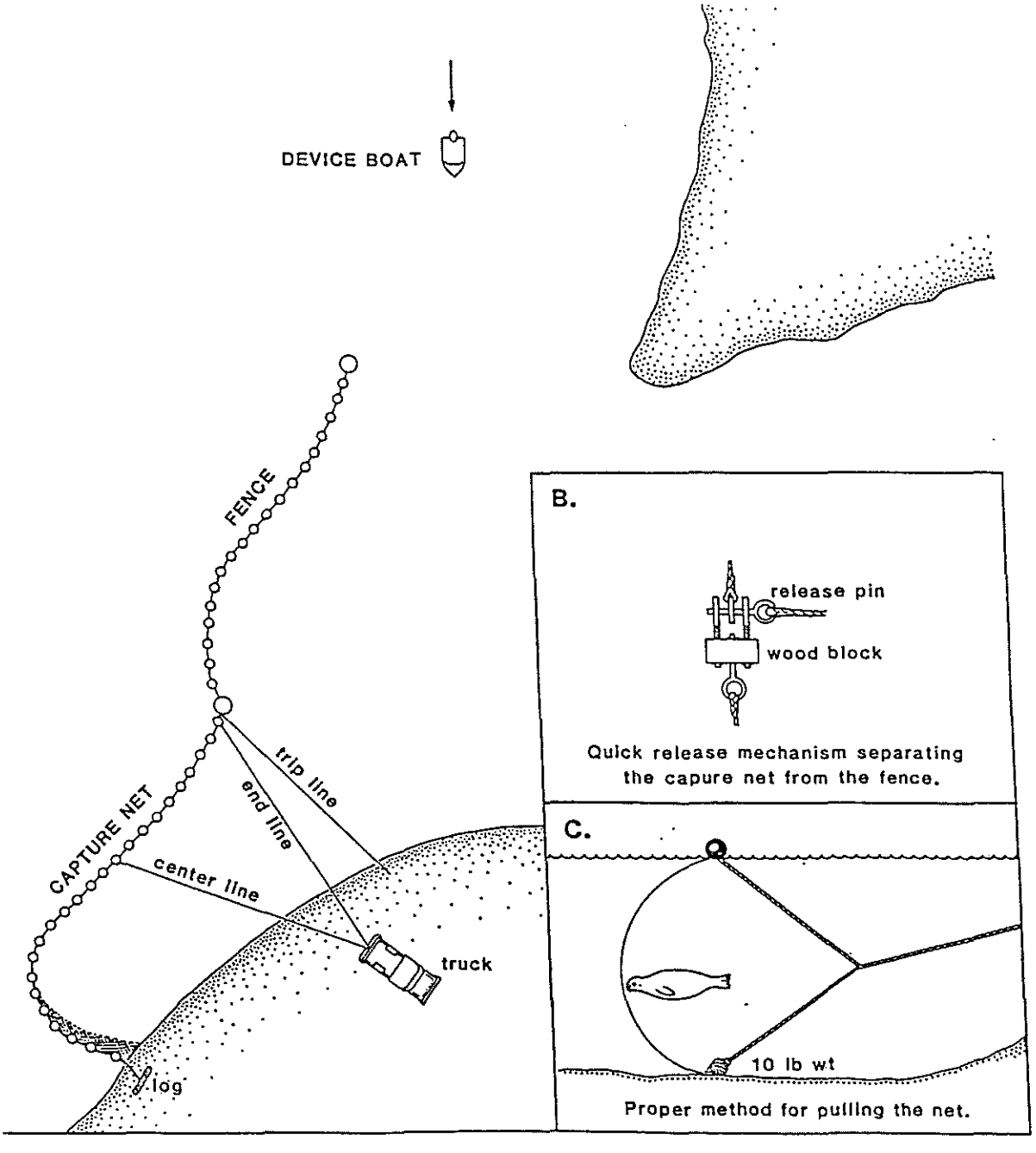

Figure 4A. Net lay for capturing harbor seals in the Klamath River, 1982.

constructed of four 4.4 cm "eye" bolts in a wooden block (Figure 4B), allowed the shore team to disconnect the capture net from the lines of the fence net. Once disconnected in this manner, the capture net could be pulled onto the beach.

A skiff with the submerged transducer of the acoustic harassment device passed as close as possible to the shallow resting area in the estuary, attempting to drive seals along the river bank and into the net area. When seals were sighted within the net enclosure, shore observers pulled the quick release trip line to separate the capture and fence nets. Capture nets were pulled both from the end and from the center to retrieve captured seals as quickly as possible. The pull lines were attached at the floatlines and at two 4.5 kg weights tied onto the leadline. This forced the net to bag without lifting off the bottom during the pull (Figure 4C). When possible, a four wheel drive vehicle was used to help pull the nets. Time proved to be a critical factor as some seals were able to escape by swimming towards shore, away from the approaching net, and then turning and jumping the floatline. None of the 22 harbor seals captured were entangled in the mesh, but were pulled ashore in the bag of the net.

Once ashore, seals were removed from the capture nets and held in hoop nets prior to tagging. Hoop nets, similar

to those described by Jeffries (1983), were constructed from 1.0 m diameter hoops of 5.2 cm PVC plastic pipe with a 2.5 m bag of varying mesh size tightly knotted at the distal end. Seals were pulled out of the capture nets by the hind flippers and directed into an open hoop net. Once completely inside, the hoop was twisted two or more full turns , placed back over the animal and staked down. This kept seals tightly confined until tagging procedures could begin.

Four workers were required to tag each animal. Captured seals were removed from the hoop nets hind flippers first and maneuvered so that they were lying ventral surface down on the hoop net. One worker stradled the seal and sat on its back. The animal was pinned by pulling one edge of the hoop net over its' head and applying pressure with the hoop net just posterior to the animal's occipital condyles. A second worker tucked the seal`s fore flippers under the knees of the person straddling the animal, then moved around to hold the hind flippers. Seals were thus immobiilized without the use of drugs. If physical control over the animal was lost, the only escape route was back into the hoop net. Once restrained, seals were tagged by a third worker, and the fourth person served as data recorder.

A 3.8 m wooden tripod with block and tackle was used to weigh seals within the hoop nets on a 136 kg hanging scale. Standard length and girth measurements were recorded whenever possible. Standard length was measured as the

straight line distance, in cm, from the tip of the nose to the tip of the tail (Bigg 1969). Axillary girth was measured as the circumfrence of the animal, in cm, in the axils of the fore flippers. Seals greater than 130 cm standard length and weighing in excess of 60 kg were classed as adults. Adult size and weight limits were based on growth rates for harbor seals three years or older as described by Bigg (1969). Subadult seals were defined as animals between one and three years old, weighing between 40 and 60 kg, and measuring from 110 to 130 cm standard length. Young of the year were identified as pups by their behavior, by standard lengths less than 110 cm, and weights less than 40 kg.

Captured seals were sexed by examination of the external genitalia. Male harbor seals were identified by the presence of a penal opening or penal line (Sullivan 1979). Females seals were identified by the presence of mammary slits (Sullivan 1979).

Tag Attachment Procedure

Radio telemetry packages (5.7 x 3.1 cm), consisting of cylindrical transmitters in the 164-166 Mhz range powered by twelve month lithium batteries, were glued to captured seals. Radio transmitters and colored vinyl streamers were attached along the mid-dorsal surface between the shoulder blades by pouring five-minute epoxy glue into a tag mold. This pelage attachment has been successfully used to tag

grey seals (*Halichoeris grypus*) in the United Kingdom (Sheila Anderson, British Seals Research Unit, pers. comm.) and with harbor seals on the Pacfic coast (Brown and Mate 1983; Jeffries 1983; Stewart and Yochem 1983).

Tag molds were constructed of 6 cm lengths of 7.5 cm diameter PVC plastic pipe. All molds were pre-cut halfway down from the top to facilitate removal from the finished tag. Molds used with radio telemetry packages were notched halfway down from the top to allow the antenna to extend posteriorly. Electrical tape was used to keep the molds from separating prematurely. Two 4 x 18 cm vinyl streamers, color coded for identification of sexes, were sewn onto squares of 3 mm nylon mesh netting, which was stretched tightly over the bottom of the molds and positioned to allow approximately 15 cm of streamer material to extend beyond the mold.

Pelage in the area of the tag attachment was cleaned and degreased with 70% isopropyl alcohol and acetone. The area was then blown dry with low pressure air from a SCUBA tank and regulator. Molds were worked into the pelage until tufts of fur pushed up between the meshes. Tags generaly required 60 to 80 g of five-minute epoxy and ten to fifteen minutes to set. The anterior edge of the transmitter package was pushed downwards into the glue to maintain the antenna at approximately a 30 angle above the animals' back. This

angle permitted the tip of the antenna to extend above the water level when the seal surfaced.

Head tags, resembling a smaller version of the pelage tags, were made from 3 cm diameter plastic film cannisters, 2 x 6 cm colored vinyl streamers, and the same 3 mm nylon mesh netting used with the pelage tags. Head tags were designed to facilitate identification of seals surfacing in the river. Concern over the effects of the high temperature (120°F) attained by the hardening epoxy and for the safety of researchers handling such small tags near the animals' face led to the discontinuance of their use after only three were placed.

Standard cattle jumbo roto tags were attached between the second and third inter-digit webbing of both hind flippers. Six colors were alternated to permit recognition of sexes and individuals. Colored vinyl streamers were pinned between the roto tags and the webbing to allow for continued visual monitoring even after the pelage tags were shed during the moult.

Ground and Aerial Monitoring

Radio tagged harbor seals were monitored with a Telonics TR-2 scanning receiver. Seals used river mouth hauling grounds extensively during night and early morning hours (Bowlby 1981; Hart 1983; Herder 1983). Radio telemetry

checks and haulout counts were begun at first light at these sites. All other sites were considered low tide hauling areas with maximum use during afternoon low tides when mild sea conditions prevailed (Sullivan 1979; Stewart 1981; Miller et al. 1983b). These sites were monitored from 1.5 hours before to 2.0 hours after daytime low tides, the optimal low tide windows described by Miller et al. (1983b).

Ground radio checks were conducted an average of seven times each month throughout the one year study, though severe storms and an extended rainy season restricted the number of such checks made from November through May. Observers checked each transmitter frequency for a period of three to five minutes to detect seals in the water that surfaced infrequently. Harbor seals at each known hauling area from the Klamath River north to Castle Rock (site 418) were counted before and after each radio telemetry check. A day of tracking effort was defined as any day when at least one radio check was conducted during the low tide window at any of the study area hauling sites. A Questar-7 parabolic reflector telescope, a 20 to 40 power zoom spotting scope, and 7 x 35 power wide angle binoculars were used to check haulouts for streamer tagged animals and during counts.

Weather permitting, aerial radio checks were made at least once each month within the same low tide windows used during ground surveys. A Cessna 185 (CDFG) with a two-

element Yagi antenna mounted on each wing strut was used to monitor hauling grounds from the Eel River, California, to Rogue Reef, Oregon. An observer-controlled switch provided for directional location of radio transmitters by selectively receiving signals from either or both antennae. The U.S. Coast Guard provided additional opportunities for aerial telemetry surveys from their search and rescue helicopters. All surveys were flown at altitudes from 180 to 200 m to optimize count photography while minimizing disturbance to the hauling areas.

Radio tag frequencies were continuously scanned for three seconds each throughout aerial telemetry surveys. Sighting data and visual estimates of the number of seals hauled out were recorded with the time and location. Additional observers provided double-blind counts and assisted with oblique (CDFG Cessna) and vertical (U.S. Coast Guard helicopters) photography. A 35 mm SLR camera with an 80 to 300 mm zoom lens was used to photograph all hauling sites within the ground survey area according to procedures developed for aerial census of pinniped populations (Johnson and Jeffries 1977; Mate 1977; Everitt and Braham 1980; Miller _et al_. 1983b). High speed color film, ASA 200 or 400, and shutter speeds of 1/500 or faster were necessary to reduce blurring caused by airspeed (95 - 120 kts. for CDFG Cessna; 25 - 90 kts for U.S. Coast Guard helicopters). Photographs were later examined and all harbor seals were

counted for estimates of the regional population within the ground survey area.

Sequential Haulout Counts

Site fidelity and daily fluctuations in the proportion of tagged seals using hauling areas were monitored by counting seals at all ten ground survey sites from the Klamath River mouth (site 409) to Castle Rock (site 418). Observers counted all seals hauled out and conducted radio telemetry checks for tagged animals at each site in sequence. All sites were checked within the low tide windows described above. Sequential haulout counts conducted from the ground counted seals observed in the water but did not incude these in haulout totals. This reduced bias for comparison with aerial surveys which typically miss animals in the water (Mate 1977; Eberhardt _et al_. 1979; Miller _et al_. 1983b). All sequential haulout counts were conducted from aerial surveys from August 1982 through March 1983. In late March, the addition of a second radio reciever made sequential haulout counts from the ground possible using two teams of observers. Four low tide series, one in April and three in May were extensively monitored for evidence of movements of resident tagged seals, site fidelity, and daily fluctuations in the number of animals hauling out.

Movements

Movements were recorded when a tagged seal was resighted more than two km from its last known location. Movements by seals of from two to twenty-five km were considered short range or local. A resident was defined as a tagged seal that was observed in the study area during the pupping and breeding season (March through June). Seasonal movements were recorded when moves appeared to be associated with seasonally abundant food items or with pupping or breeding actvities. Seals that traveled more than 25 km to alternate hauling areas and did not return within the study period were considered to have dispersed (Bonner and Whitthames 1974).

Estimates of the number of seals hauling out are based on the methods outlined by Eberhardt _et al_. (1979) and those applied by Stewart and Yochem (1983). The proportion of tagged seals present each day was averaged over the sample period and used to develop a comparative estimate of the proportion of seals hauled out.

RESULTS

Twenty-two harbor seals were captured and tagged between June 8 and October 14, 1982. All 22 received double plastic flipper tags with colored vinyl streamers. Three seals were tagged 3.3 km upriver and were outfitted with head tags that included a colored streamer. The remaining 19 animals were captured and tagged at the river mouth. None of these seals received head tags. Pelage attached radio transmitters were mounted on 12 harbor seals (Table 1.)

Three weeks after tagging, one of the seals (RT-556a) became entangled in a salmon gill-net and drowned. The seal's head-first orientation to the net indicated that the pelage tag did not contribute significantly to its entanglement. The pelage tag, which was still firmly attached to the animal's back, was cut away and subsequently used to tag another seal (RT-556b). Three weeks after the transmitter was redeployed, the seal carrying it was resighted. The pelage tag was intact but was not transmitting. Transmitter failure was probably a result of damage to the unit during removal from the first seal to carry it. One other seal (RT-722) lost its radio telemetry package and was resighted and identified based on the colors of the hind flipper streamers. Only remnants of epoxy glue remained where the pelage tag had been attached.

Table 1. Tag application by sex and age group of 22 harbor seals tagged at the Klamath River, 1982.

MALES

	ADULT	SUBADULT	PUP	TOTAL
TAG APPLICATION				
Radio Tagged	6	1	1	8
Head Tagged and Radio Tagged	0	1	0	1
Pelage Streamer and Flipper Tagged Only	4	5	0	9
Totals	10	7	1	18

FEMALES

	ADULT	SUBADULT	PUP	TOTAL
TAG APPLICATION				
Radio Tagged	2	0	0	2
Head Tagged and Radio Tagged	0	2	0	2
Pelage Streamer and Flipper Tagged Only	0	0	0	0
Totals	2	2	0	4

The majority of the 22 seals captured were male (82%). Only a few were female (18%). Twelve of the captured seals were adults (55%), nine were subadults (40%), and one was a pup of the year (Table 2).

Captured adult male harbor seals averaged 6.1% longer and 10.9% heavier than the adult females captured. Length values are comparable to those reported for British Columbia harbor seals, where males averaged 9% longer and 34% heavier than females (Bigg 1969). Differences in weight are probably due to the small sample of adult females at the Klamath River. Subadult males and females were similar in length and weight, averaging 126.3 cm standard length and 47 kg. This is consistent with Bigg's (1969) observations that the growth rate is approximately equal for both sexes until age five.

Site Fidelity and Movements

A total of 303 radio telemetry surveys were conducted from August 31, 1982, through August 4, 1983. These surveys were conducted over 82 days of tracking effort. The number of tracking days was limited by inclement weather, heavy surf, and tidal conditions considered sub-optimal for seal counts. Thirteen aerial surveys were conducted, seven from the CDFG Cessna and six from U.S. Coast Guard helicopters. A total of 33 telemetry surveys, including one aerial survey,

Table 2. Standard length, girth, and weight of harbor seals tagged at the Klamath River, 1982.
RT = Radio Tag, FT = Flipper Tag

MALES

AGE CLASS	TAG NO.	STANDARD LENGTH (cm)	AXILLARY GIRTH (cm)	WEIGHT (kg)
Adult	RT-622	164	126	107
Adult	RT-556	152	128	109
Adult	FT-945	150	106	77.1
Adult	FT-956	145	103	71.2
Adult	RT-668	140	62	48.5
Adult	RT-656	138	106	63.5
Adult	FT-189	136	107	86.2
Adult	RT-634	135	-	70.3
Adult	RT-579	134	107	68.0
Adult	FT-181	-	-	-
Subadult	FT-151	130	-	-
Subadult	FT-108	128	97	47.6
Subadult	FT-126	123	104	51.6
Subadult	RT-722	114	100	58.9
Subadult	RT-610	114	88	-
Subadult	FT-183	-	-	-
Subadult	FT-957	-	-	-
Pup	RT-703	106	85	34.0

FEMALES

AGE CLASS	TAG NO.	STANDARD LENGTH (cm)	AXILLARY GIRTH (cm)	WEIGHT (kg)
Adult	RT-596	136	100	71.2
Adult	RT-585	135	92	-
Subadult	RT-556	128	90	52.5
Subadult	RT-601	124	84	-

were conducted over eleven days of tracking effort from July 1 to Septemeber 30, 1982. There were 76 surveys, including two aerials, conducted during 24 days of tracking effort from October 1 through December 31, 1982, the fall sample period. During the winter sample period from January 1 through March 31, 1983, inclement weather limited telemetry surveys to 43 in 14 days of tracking effort. Three aerial surveys were conducted during the winter. Conditions improved in the spring sample period from April 1 through June 30, 1983, with 124 telemetry surveys completed in 27 days of tracking effort. Six aerial surveys were conducted during the spring. From July 1 until August 4, 1983, when the moulting period was well under way, 27 telemetry surveys were conducted, including two aerial surveys, in six days of tracking effort.

Transmitter signals were strong and continuous when seals were hauled out. Signals became noticeably weaker as tagged animals descended into freshwater and were immediately absent as the antenna was submerged in saltwater. Under optimum conditions, line of sight signals were detected from as far away as seven km.

All 12 radio tagged seals were resighted at least once during the study period. Eleven of those resighted (92%) used at least one hauling area other than the river mouth. Four seals (33%) used three different sites and two seals

hauled out at four or more sites. During the study a total of 37 movements were recorded for all of the tagged seals.

Five seals were consistently resighted within 25 km of the tagging site and were considered resident animals because of their presence during the breeding season. Three of these resident seals were adult males (RT-579, RT-634, and RT-656), one was a subadult male (RT-722), and one was an adult female (RT-596). Over 86% of the movements by resident seals consisted of travels between the river mouth and one other hauling site.

Two seals (18%) traveled to hauling grounds more than 40 km from the tagging site, stopping at least once along the way to haul out. Of these, one was a large subadult male (RT-668) that was resighted two to three weeks prior to the breeding season (May and June) at a known rookery site 80 km south of the Klamath River at Humboldt Bay. The other seal, an adult female (RT-596), traveled 29 km north of the tagging site in December and was resighted in March at Scat Beach (site 416), a known pupping site within the ground survey area. Both seals were resighted at the river mouth by June.

Long range movements, or dispersals, were noted for three seals. One, a subadult female (RT-585), traveled over 300 km to Alsea Bay, Oregon, where she was resighted in mid-January (Peter Stoel, California State Univ., San Francisco,

pers. comm.). A subadult male (RT-622) was resighted in the water 2 km north of Rogue Reef, Oregon, more than 150 km north of the tagging site. One of the tagged seals (RT-610), a subadult male, was identified from the colored streamer tags by a fisherman approximately 100 km south of the Klamath River in December.

Tagged harbor seals exhibited a strong seasonality in their movements apparently related to pupping and breeding activities and to prey species abundance. Prior to the completion of the fall salmonid runs (November), ten of the twelve radio tagged seals (83%) were consistently resighted within 2 km of the Klamath River mouth, an indication of strong site fidelity. After the salmonid runs had ended, nine of the radio tagged seals (75%), including three that made long range dispersals, moved away from the river mouth. Two seals (RT-596 and RT-688) (18%) were resighted on Castle Rock (site 418) in mid - December, a move that may have been in response to the abundance of Pacific herring (*Clupea harengus*) in nearby Crescent City harbor. Both seals returned to the Klamath River after the herring runs ended in March.

The frequency of resightings of radio tagged seals varied seasonally. From October through December 1982, tagged seals were resighted an average of 33.6% ± 7.2% (S.E.) of the 24 days of tracking effort. From January

through March, 1983, resightings dropped to an average of 0.7% ± 2.2% (S.E.) of the 14 days of tracking effort. Resighting frequency increased to an average of 14.0% ± 13.0% (S.E.) of the 27 days of tracking effort from April through June, 1983, and then declined to 11.0% ± 10.5% (S.E.) from July through August 1983 of 6 days tracking effort. This decline in resighting frequency is most likely due to transmitter loss with moulting. The average resighting frequency was 16.4% ± 7.2% (S.E.) of the days of tracking effort when pooled with resightings of the same period for the previous year.

Seasonal movements and dispersals were significantly more common during the fall and winter months than during the spring (Fisher's exact test, $p = 0.004$) (Table 3). All three dispersals (100%) and six of the seven (86%) recorded long range seasonal movements were initiated between November and March. The remaining seasonal movement (14%) was that of a large subadult male (RT-668) returning to the river from a rookery area in June.

Local movements occurred throughout the year but increased significantly during the spring months (Fisher's exact test, $p = 0.004$). Five resident seals traveled from alternate hauling areas to forage at the river mouth 16 times from April through June. This comprised 59% of all local movements detected for all tagged seals throughout the

Table 3. Seasonal variation in types of movements made by harbor seals tagged at the Klamath River, 1982.

NUMBER OF MOVES DURING THE PERIOD:		DISPERSAL	SEASONAL	LOCAL
SEASON				
Fall	Oct - Dec	1	3	3
Winter	Jan - March	2	3	3
Spring	April - June	0	1	16
Summer	July - Sept	0	0	5

study period. Three short range movements (10%) were recorded during the fall, three during the winter, and five (21%) were noted during the summer.

Subadult seals showed a greater tendency for seasonal movements and dispersals than adult animals. Subadult seals made six of the seven (86%) recorded seasonal moves. The ratio of local moves made by adults to those by subadults approached unity (Table 4).

Radio tagged female harbor seals made significantly more seasonal and local moves than males ($G = 0.711$, $p < 0.05$, 1 df).

Regional Population Counts

A total of 45 region-wide population counts were made during the study period August 31, 1982 to August 4, 1983. These surveys included 32 sequential haulout counts and 13 aerial counts. Harbor seal populations within the ground survey area were declining when the surveys began in August 1982, reaching their lowest point in October with an average of 81 animals. The number of seals increased to a peak in December, averaging 176 animals, then declined to a low of 102 in February 1983. The regional population peaked in June when counts averaged 337 animals (Figure 5). The maximum number of seals recorded within the ground survey area was 407 in late May.

Table 4. Variation in types of movements made by tagged harbor seals by sex and age class.

AGE CLASS	NO. SEALS	DISPERSAL	SEASONAL	LOCAL
Adult	12	1	1	14
Sub-Adult	9	2	6	13
Pup	1	0	0	0
Totals	22	3	7	27

SEX	NO. SEALS	DISPERSAL	SEASONAL	LOCAL
Male	18	2	1	7
Female	4	1	6	16
Totals	22	3	7	27

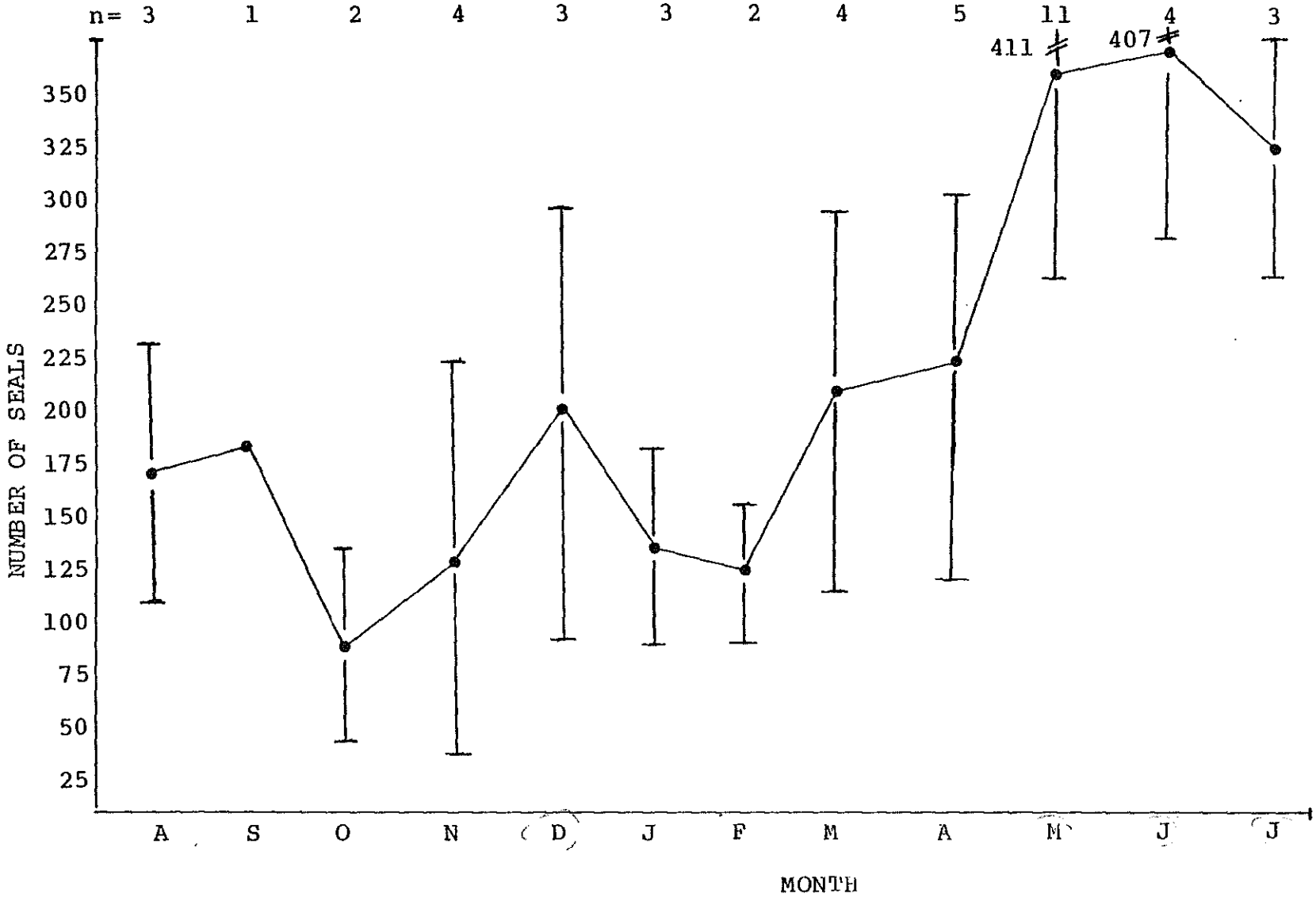

Figure 5. Mean and range of the number of harbor seals hauled out by month within the ground survey area.

The number of harbor seals hauled out at each site varied considerably from month to month. However, counts from most sites were consistent with the regional totals. The only exceptions were found in December, when counts at all sites except Castle Rock (site 418) continued to decline to winter lows in January or February. Castle Rock counts increased to a winter peak of 134 animals in December, over 75% of all the animals found within the study area (Figure 6).

Proportion of the Population Hauled Out

Five resident seals remaining in the study area during April and May were monitored closely to determine the proportion of tagged seals hauled out during a specific low tide period. One seal (RT-722) was resighted without the radio transmitter and was repeatedly observed and reidentified based on the colors of the hind flipper streamers. These five seals were observed on three of the eight sites monitored from the Klamath River mouth to Castle Rock, Crescent City (sites 409 through 418). Observations indicate that these animals were traveling to the river mouth to forage at least twice each week and then returning to their respective hauling areas. Two low tide hauling

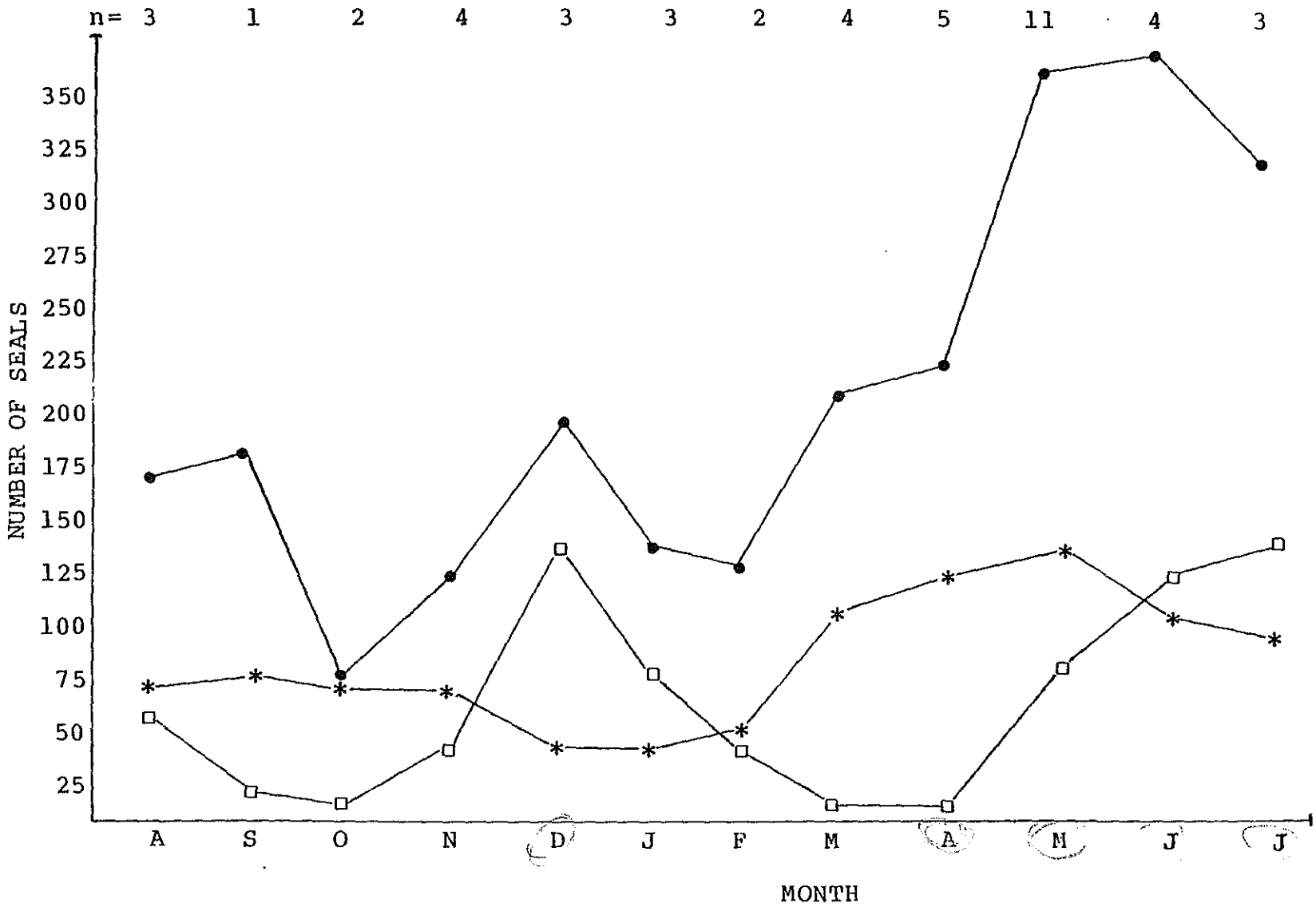

Figure 6. Mean number of harbor seals hauled out by month at Castle Rock, the mouth of the Klamath River, and the entire ground survey area. Castle Rock = □; Klamath River = *; Ground Survey Area = ●

areas, Two Rocks (site 413) and Scat Beach (site 416), were consistently used by the five resident seals. All resightings of the tagged residents were made either at the river mouth or at one of these two sites, an indication of site preference.

Data from 16 days of sequential haulout counts in April and May 1983, suggest that not all Klamath River harbor seals haul out every day. Tagged seals hauled out an average of 56.1% ± 2.8% (S.E.) of the days in April and 63.6% ± 5.5% (S.E.) of the days in May. The difference between the proportion of days seals hauled out in April and May is not significant ($t = -0.72$, $p < 0.1$). The frequency with which tagged females hauled out (43.7%) was similar to that of tagged males, (49.8% ± 3.6% S.E.).

Estimates of the proportion of tagged seals hauling out each day were made from the same 16 days of sequential haulout counts conducted in April and May 1983. A minimum of 56.4% ± 3.1% (S.E.) and 65.1% ± 12.8% (S.E.) of the tagged seal population hauled out each day in April and May respectively (Table 5). The proportion of tagged animals hauled out in April is not significantly different from that of May ($t = -0.81$, $p < 0.1$).

Table 5. Proportion of resident tagged harbor seals hauled out daily in April and May 1983.

APRIL

TAG NO.	DAYS TRACKED	DAYS RESIGHTED	PROPORTION RESIGHTS
RT-579	5	3	.60
RT-596	5	3	.60
RT-634	5	3	.60
RT-656	5	4	.80
RT-722	5	2	.40

MAY

TAG NO.	DAYS TRACKED	DAYS RESIGHTED	PROPORTION RESIGHTS
RT-579	11	9	.82
RT-596	11	6	.55
RT-634	11	8	.73
RT-656	11	8	.73
RT-722	11	3	.27

DISCUSSION

Site Fidelity and Movement Patterns

Harbor seals tagged at the Klamath River showed evidence of strong site fidelity during the fall at the mouth of the river, and again in the spring at two hauling areas less than 10 km to the north. This distinct seasonality to hauling site fidelity is supported by higher resighting frequencies observed in fall and spring than in either winter or summer. Salmon fishing typically decreases dramatically during the fall (Hubbell 1985), lessening disturbance of river mouth hauling areas (Herder 1983). Observations of foraging behavior in the river mouth and surf zone (Bowlby 1982, Herder 1983) and increased abundance of lamprey eels (*Lampetra tridentata*) (Bowlby 1982, Herder 1983) suggest that the Klamath River is a hub of foraging activity. Seals foraging at the Klamath River mouth and estuary probably enjoy increased foraging efficiency by preying on fish that enter the narrow river channels, estuarine and surf zone shallows, and those entangled in nets. Harbor seals may immigrate seasonally to areas such as the Klamath River where food is abundant and foraging efficiency is high. The dual site fidelity observed among tagged seals may have resulted from increased disturbances that forced harbor seals to use alternate hauling areas and commute to the river to forage. Some seals may have altered

their hauling patterns by switching from day to night hauling at the mouth of the river. Changes from day to night hauling patterns have been observed among harbor seals on the Channel Islands in California (Brent Stewart, Hubbs Sea World Research, San Diego, CA, pers. comm.).

Varying degrees of hauling site fidelity have been reported for harbor seals in other areas. Pitcher and McAllister (1981) reported that of 31 tagged seals resighted, 23 (74%) were found only at the capture site on southwest Tugidak Island, Alaska. Observations of recognizable individuals returning to the same hauling areas day after day have been reported by Knudtson (1974), Reijnders (1976), Boulva and McLaren (1979), Sullivan (1979), and Stewart and Yochem (1983).

The majority of detected movements originated during the late fall and early winter months. Shorter days and inclement weather may decrease the number of seals hauling out (Fisher 1952; Bigg 1969; Brown and Mate 1983; Jeffries 1983; Stewart and Yochem 1983). This seasonal cycle of low abundance has been reported in Washington (Johnson and Jeffries 1977; Jeffries 1983), Oregon (Roffe 1980; Brown 1981; Brown and Mate 1983), and California (Herder 1983; Stewart and Yochem 1983). Jeffries (1983) documented movements of tagged harbor seals into the Columbia River in response to the winter abundance of eulachon (Thaleichthys

pacificus). Seasonal and local movements in response to changes in prey abundance have been reported by Roffe (1980), Brown (1981), Bowlby (1982), Brown and Mate (1983), and Jeffries (1983).

Inclement weather conditions and low prey abundance near the Klamath River in December and January may necessitate foraging farther from prefered hauling areas. The 1982-1983 winter counts of harbor seals hauling out on Castle Rock (site 418), 29 km north of the Klamath, indicate an increase in abundance in November and December, with a decline in numbers hauled out through April. This divergence from the usual low winter abundance observed elsewhere may indicate an aggregation of seals that coincides with large spawning runs of herring in Crescent City harbor (Pat Collier, CDFG, Eureka, CA, pers. comm.). Herring gill-netters reported over $2400 damages in lost revenue and equipment due to pinniped depredation in Crescent City harbor in 1981 (Miller et al. 1983a). Two of the seals tagged in this study were resighted on Castle Rock in early December.

While some seasonal movements are most likely related to prey abundance, the availability of preferred pupping and breeding sites apparently caused two tagged seals to return to the Klamath area rookery sites prior to the breeding season, passing other rookery areas along the way. Harbor

seal counts at non-rookery areas remained low throughout the pupping and breeding season and peaked during the moult in late July and early August. One tagged subadult was observed in April at a rookery area in Humboldt Bay, near Eureka, California, and was resighted at the Klamath River in June. The same animal was observed, partially moulted, in July less than 2 km from the river mouth.

The propensity for movement varies among individuals of different sex and age groups (Roffe 1980; Pitcher and McAllister 1981; Brown 1981; Bowlby 1982; Brown and Mate 1983; Jeffries 1983; and Stewart and Yochem 1983). The dispersal of harbor seals, particularly juveniles, has been widely documented (Mansfield 1967; Divinyi 1973; Haaften 1972; Bonner and Whitthames 1974; Vaughn 1978; Drescher 1979; and Pitcher and McAllister 1981). Two of the seals tagged in this study traveled over 100 km to new hauling grounds, and were not resighted within the study area. One radio-tagged subadult was last observed at the mouth of the Klamath River in December and was not resighted during the remainder of the study. The transmitter may have failed or the seal may have moved out of the aerial survey area.

The proportion of the harbor seal population hauling out each day in the study area averaged 56.4% ± 3.1% (S.E.) in April and 65.1% ± 12.8% (S.E.) in May based on resightings of tagged animals. This represents a minimum

estimate as tagged seals hauling out on days monitored may have been off the haulout at the time telemetry surveys were conducted. Applying the values obtained for May to the maximum region-wide count of 407 during that time period, the harbor seal population in the ground survey area can be estimated at from 522 to 778 animals. Pitcher and McAllister (1981) estimated that the average number of seals hauling out each day from June through September at 35 to 60% of the Tugidak Island population based on resights of tagged individuals. Stuart and Yochem (1983) reported a minimum of 58% ± 4% (S.E.), 54% ± 14% (S.E.), and 41% ± 10% (S.E.) of the San Nicolas Island harbor seal population hauled out each day in May, June, and July respectively. Results obtained at the Klamath River are consistent with these values, however these estimates are more valuable for comparative purposes than for use as census correction factors due to the small sample size (five seals). Differences are probably due to varying environmental conditions that dictate the timing of pupping, breeding, and moulting at the three study sites, as well as differing methodologies.

In theory hauling site fidelity among harbor seals can be used to adjust aerial counts and to correct estimates of the maximum number of seals using a particular hauling area. However, there is considerable variability in site fidelity between areas relative to the hauling substrate and the

physical characteristics of the site (Sullivan 1979; Pitcher and McAlister 1981; Stewart 1981; Brown and Mate 1983). A considerable degree of interchange between sites on a seasonal and even daily basis confuses the interpretation of site fidelity data. This study and others (Sullivan 1979; Stewart 1981; Pitcher and McAllister 1981; Brown and Mate 1983; Jeffries 1983; Stewart and Yochem 1983) suggest that individual harbor seals do not always haul out on consecutive days. Stewart (1981) suggests that the interval between hauling bouts may be two days or more for an individual harbor seal, though considerable variation is evident.

If harbor seals enjoy increased foraging efficiency at the mouths of rivers and bays, and local movements to and from these foraging areas are common, as the dual site fidelity of Klamath River seals suggests, then a more practical approach to population estimation may be to abandon the hauling site as a sampling unit in favor of the foraging region. The ground survey area of this study can be considered a foraging region from early spring, when counts at local hauling sites increase dramatically, to mid - fall, when low prey abundance and inclement weather prompt seasonal emmigration and lower hauling frequencies.

Since estimates of the number of seals using a particular hauling area on a given day do not permit a

determination of the population proportion hauled out, a more practical approach may be to record the maximum count and the number of identifiable individuals for as many consecutive sites as can be covered during the period 1.5 hours before to 2.0 hours after low tide. These sequential haulout counts should begin at least one day before and continue through at least one day after the regional aerial count. This approach can be used to estimate the regional harbor seal population from the proportion of tagged or marked individuals observed while minimizing the effects of local movements. The regional seal population can be estimated by correcting for animals not present on any of the hauling areas at the time of the census. The larger the number of marked individuals the more accurate the estimates will be. This approach has been used by Stewart and Yochem (1983) for the southern California Channel Islands, and by Jeffries (1983) for Washington state and Columbia River harbor seal populations.

The presence of El Niño conditions in California coastal waters during 1982 and 1983, with sea surface temperatures averaging 2 - 3 $^{\circ}$C above normal, may have significantly altered the distribution of prey species preferred by harbor seals. Statewide aerial censuses conducted during this period reflect a decline in the relative abundance of harbor seals of from 10 to 15% over 1981 estimates (Doyle Hanan, CDFG La Jolla, CA, pers.

comm.). This reduction in relative abundance was accompanied by a decline in harbor seal fecundity (Doyle Hanan, pers. comm.), an indication of less favorable environmental conditions such as a decline in availability of preferred prey (Rickleffs 1979). A reduction in the availability of seasonally abundant prey species may have altered harbor seal movements within the study area. Resident seals may have foraged farther from regular hauling areas than normal. Seasonal wanderers may have originated or terminated movements earlier than normal in response to changes in the availability of preferred prey species.

Pelage attached radio transmitters were shed when the animals moulted. As a consequence, only one year of information on harbor seal movements was collected before the tags were lost. The financial constraints of telemetry studies prevented the continuance of the radio tagging into a second year. Although the results presented here are consistent with previous telemetry studies on Pacific coast harbor seal populations, it remains a difficult task to predict long term changes in abundance without large numbers of identifiable individuals and more consistent methods for quantitatively evaluating variability in site fidelity and the proportion of seals hauled out.

CONCLUSIONS

1. Pelage attached radio transmitters are an effective means of identifying and tracking harbor seals. Attachment of this type of tag is slower than conventional ankle collars but transmissions can be recorded when the animal is at the surface of the water and the tag is shed when the animal moults. There was no evidence that this type of tag contributed to entanglements in gill nets. Colored vinyl streamers placed under standard flipper tags provide excellent high visibility marks for identifying hauling individuals from a distance.

2. Klamath River tagged harbor seals exhibited two types of site fidelity. During the fall, tagged seals consistently hauled out at the river mouth only. This is supported by high resighting success and few movements. In early spring, shifts to alternate hauling areas were detected, probably due to increased activity at the river mouth. Tagged seals remained faithful to their new site but periodically returned to the river mouth to forage, occassionally hauling out there over night. Periods of consistent site fidelity occurred coincident with the onset of pupping and breeding activities. During this time resighting success increased and the majority of movements by tagged seals were to river mouth hauling areas.

3. Klamath River tagged seals exhibited a strong seasonality in their movements. The majority of movements exceeding 20 km originated in late fall and winter months, possibly in response to decreasing photoperiod, inclement weather, and/or low prey abundance. Long distance movements, thought to be related to availability of seasonally abundant prey or pupping and breeding activities, were considered seasonal moves. These were characterized by a return to the Klamath River. Seasonal movements were more prevalent among subadults than other age groups. Harbor seals that were resighted over 100 km from the river but which did not return were considered to have dispersed to new hauling areas.

4. The average proportion of tagged or marked indiividuals hauling out each day may be a more useful indicator of population trends than estimates which rely strictly upon site fidelity. Site fidelity varys by season and methods for quantifying it vary among authors. During pupping and breeding periods the number of seals making dispersal moves can be considered negligible. Local movements between sites by seals can be ignored during this period by counting the animals on a region wide basis.

5. The Klamath River appears to be a hub of foraging activity, particularly from early spring to mid - fall. Repeated observations of foraging behavior at the river

mouth suggest that harbor seals may move to alternate hauling areas as a result of disturbances by fishermen and return to the river to forage. This conclusion is supported by the dual site fidelity observed among tagged individuals. The entire ground survey area, from Redwood Creek (site 407) to Castle Rock (site 418) constitutes a geographically identifiable foraging region for counting harbor seals. The harbor seal population for this foraging region can be estimated to be between 522 and 778 animals, based on the maximum counts recorded in May 1983 and corrected for seals off the haulouts. Though consistent with results of related studies, the proportion of the population hauled out reported here may be biased due to a small sample size.

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