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Hawaiian monk seal diving behavior

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Diving behavior of Hawaiian monk seals was studied to gain an understanding of their use of the marine habitat. Radio tags and maximum-multiple-depth recorders (MMDR) were attached with anklets to seven adult male monk seals at Lisianski Island. 24-h automatic monitoring of radio tags provided a detailed record of hauling out activity on the island's beaches. Over 4800 individual dives by six animals were recorded by the MMDR system. The majority (59 %) of dives were in the 10—40 m depth range, the remaining dives were to depths generally greater than 40 m, with 13 dives to at least 121 m. Monk seal prey items were identified from examination of seal scat and included fish otoliths, cephalopod beaks and invertebrate exoskeleton fragments. The prey assemblage was benthic; the majority of prey were shallow water forms and a smaller number of species were deep water forms. The depth at which the prey were taken generally agreed with the distribution of monk seal dive depths recorded. This information indicated that Hawaiian monk seals depend entirely upon the food resources found over the reef surface and slopes while at rookery islands during the breeding season.

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1. Introduction

The endangered Hawaiian monk seal *Monachus schauinslandi* has breeding populations restricted to atolls of the Northwestern Hawaiian Islands. The species appears to have declined in numbers by about one-half between 1958 and 1978 and the center of abundance has shifted from the atolls in the western portion of the range to those at the eastern extreme of the breeding range (Johnson et al. 1982). Conservation efforts by the U.S. National Marine Fisheries Service include consideration of designating critical habitat under terms of the U.S. Endangered Species Act. The rookery beaches were to be included as part of critical habitat. The fact that monk seals are known to feed on benthic or reef-dwelling fishes and invertebrates argued for including marine habitat within the critical habitat, but no information existed on the depths to which monk seals commonly dive in search of prey. The need to preserve an abundant prey assemblage for monk seals was countered by an intense interest in developing commercial fisheries in the inner reef and reef slope waters. The seaward extension of the boundary of critical habitat became a major point of contention with commercial fisheries interests not wanting to be excluded from fishing any nearshore waters and resource managers recognizing that the protection of food resources within critical habitat would be essential to recovery of the endangered monk seal.

Our study was an attempt to obtain a series of dive records from feeding monk seals to provide a data base from which a seaward boundary of critical habitat could be designated. In addition we were interested in testing radio tags for determining the proportion of time animals spend ashore. This was needed to adjust census figures as an estimation method for population size.

2. Materials and methods

The study was conducted at Lisianski Island (26°02'N, 174°04'W) from 4 May through 11 June 1980. Adult male seals were selected for instrumentation because they remain on or near the rookery islands during most of the pupping season which extends from March through June. Males normally go to sea in the evening, feed during

the night, and return to the island in early to mid-morning. By instrumenting only adult males we were assured that some portion of the dives would reflect the depths where animals search for food or were actually feeding. Futher, since the males are forced to return to land to obtain access to females we had a high probability of being able to recover instruments.

Seven adult males were captured by physical restraint with a canvas restraining device, a hoop net, and black bag. The canvas restraining device consisted of a heavy canvas stretcher with wooden poles which we placed over sleeping animals. Physical restraint was necessary only for instrumenting the animals and subsequent adjustment of one anklet.

Each seal was equipped with a radio transmitter on one ankle and a depth-of-dive recorder on the other. Radio transmitters were purchased from the Cedar Creek Bioelectronic Laboratory of the University of Minnesota. The transmitters were 2/5 × 8 cm cylindrical package weighing approximately 50 g in air. They transmitted on 164 MHz, were powered by a lithium battery sufficient for one to two months life, and were encapsulated in electrical casting resin. Transmitters were attached by means of an anklet of machine belting 12 mm wide and 3 mm thick, covered with 20 mm diameter latex surgical tubing. The belting was connected using a one-eighth inch brass machine bolt with brass flat washers and a steel lock washer and nut. The bimetallic combination provided certain release of the anklet should it not be recovered from the animal.

Instruments were removed with a knife blade set at the back of a stainless steel hook attached to a 1.2 m wooden handle. The point of the hook was slipped under the anklet and tugged sharply cutting both the surgical tubing and machine webbing, freeing the anklet.

The radio-tagged animals were monitored with a 4-element Yagi antennae and programmable scanner-receiver connected to an Esterline Angus strip-chart recorder. Two antennae were mounted on a 9-m high mast located on the highest point of the island and oriented along the long and short axis of the island.

Multiple maximum depth recorders (MMDR) were attached in the same manner as the radio transmitters. The units used were 2.3 cm in outside diameter by 9.5 cm long and weighed 95 g in air. The MMDR basically was a series of pressurse transducers and a time circuit which monitored depths of dives which were processed in eight storage registers for data readout (Kooyman et al. 1982). A potentiometer made it possible to set the span on the pressure range from 0—500 psig. The pressure ranges correspond to specific water depth ranges. Anytime a dive exceeded the threshold of a counter, the dive was added to that register's count and stored. The end result was a frequency distribution of all dives made by the seal over the period of time the MMDR was attached. The data stored in the recorder was determined by connecting the unit to a digital processor. Each register was read separately.

To assess food habits of monk seals during the study, we collected fresh scats which were soaked for 12 to 24 h in sea water to which was added ca. 1 g liquid detergent. The liquified scat were then run through a set of two nested testing sieves measuring 2.36 mm and 0.71 mm. Mard parts such as fish otoliths, bone, teeth, and scales, cephalopod beaks, and exoskeleton of lobster were removed from the sieves and stored in alcohol for later identification. Fish otoliths were identified by John E. Fitch, California Department of Fish and Game, and cephalopod beaks by Clyde Roper, U.S. Museum of Natural History, Smithsonian Institution.

3. Results

Dive recorders were attached for 2 to 20 days for an aggregate of 94 days. The dive recorder for one animal was inoperative. Six animals accomplished 4817 dives in 60 day or night periods at sea (Table 1) for an average of 80 dives/period at sea. The majority (59 %) of dives were in the 10—40 or 10—30 meter range, with the remaining 41 % of dives being in depths beyond the 30 to 40 meters upper threshold of the first register to depths up to at least 121 m. Only three animals were away from the island two or more nights and these were the only seals that dove to depths greater than 40 m. Due to an extensive reef system of Lisianski Island, the seals must swim 10—21 km from the island to reach water 40 m deep.

Table 1. Activity of adult male Hawaiian monk seals instrumented with dive recorders and radio tags, Lisianski Island, May—June 1980.

Tag radio freq.	Dive record days	Proportion of daylight hours ashore	At sea (day/night[1])	Dives recorded	
				Number	Depth
164.192	2	0.21	0/2	108	10—40 m
164.130	7	0.20	0/5	11	10—40 m
164.113	10	0.43	0/0	7	10—40 m
164.228	20	0.30	5/13[2]	1193	10—40 m
				133	41—85 m
164.161	18	0.23	2/16[2]	1469	10—40 m
				184	41—85 m
164.099	18	0.40	1/4	Recorder damaged no record	
164.053	19	0.13	6/11[3]	75	10—30 m
				935	31—60 m
				689	61—120 m
				13	121—175 m

[1]Nights are tallied if animal was at sea from dark to midnight, midnight to dawn, or during both periods; days were tallied if animal was at sea from dawn to noon or noon to dark.
[2]Includes 2 absences of a night, day, and another night.
[3]Incluees one absence of 4 successive days and 5 nights, and one absence of a night, day and another night.

Radio tags functioned well and allowed location of instrumented males when they were ashore. The average time ashore during daylight hours for 6 reproductive adult males was 16 % during the hour following dawn, then gradually increased to 35 % between 1100—1200 hours, and decreased to 21 % in the hours preceding darkness. The proportion of time individual reproductive males were ashore varied from 13 % to 40 % of total daylight hours. A single nonreproductive adult male exhibited a pattern unlike the reproductive males. He spent 43 % of total daylight hours ashore but was ashore early morning and late evening and was frequently in the water from 1100—1600 hours. We collected all scat found on the island. We obtained identifiable hard parts from 182 of 232 scat collected. Otoliths of 260 fishes of 11 families, beaks of 71 cephalopods all of the genus *Octopus* and exoskeleton fragments of one lobster were identified. An additional 11 otoliths could not be identified from available reference material and 15 otoliths were too digested to allow identification.

4. Discussion

Lisianski Island is located on the north end of Neva Shoals — an extensive shallow water area which extends primarily south of the island. To reach the 10 meter isobath, the minimum diving depth recorded, animals needed to be from 1 to 13 km from land. Beyond Neva Shoals there are extensive coral flats within the 10—40 meter depth range where male monk seals were diving and feeding. The 40-m isobath generally delineates the outer edge of the reef. A substantial portion of the recorded dives, those beyond 30 m, reflect animals

diving along the reef slope.

These are the first dive records for the Hawaiian monk seals. They suggest a pattern of generally shallow dives, yet the dives in excess of 121 m by one animal are moderately deep for pinnipeds. Several species have been recorded to dive beyond 150 m: a northern fur seal *Callorhinus ursinus* female to 190 m (Kooyman et al. 1976); a California sea lion *Zalophus californianus* male to 250 m (Ridgway 1972); a Weddell seal *Leptonychotes weddelli* to 600 m (Kooyman 1966). When compared to the dive depths accomplished by these species the 121 m (or greater) dives recorded in this study may be considerably less than the maximum diving capability of the Hawaiian monk seal.

The deep dives recorded in this study support a single diving record for the Mediterranean monk seal *Monachus monachus* which was caught on the hook of tuna gear set at a depth of 75 m at Camera de Lobos, Madeira in 1957 (Sergeant et al. 1978). There had been some question as to whether that animal might have been hooked while the gear was being set, but in light of the demonstrated diving capabilities of the Hawaiian monk seal, it is probable that the Mediterranean monk seal was caught while the gear was at depth.

Determination of the proportion of time spent ashore for adult males during daylight hours is difficult because of their tendency to lay between a female and the water's edge with their rear flippers immersed in the water. When the transmitter antenna is in wet sand or under water, the signal is attenuated and no signal is received, yet the male is almost entirely ashore. Therefore, the radio tag record underrepresents the actual proportion of time ashore.

Results of the scat collection indicate that the Hawaiian monk seal feeds heavily on reef fishes. The fish found most frequently and in highest numbers were conger eels (Congridae), surgeon fish (Acanthuridae), and wrasses (Labridae) which prefer shallow, benthic habitats. Less numerous were brotulids (Brotulidae) and cusk eels (Ophididae) which are probably found in both shallow and deep, benthic habitats, and lizard fish (Synodidae) were the only prey species from a deep water, benthic habitat. The habitat depth of the identified prey is consistent with distribution of the monk seal dive depth records. During the breeding season monk seals apparently depend entirely on the food resources found on the coral reefs, sandy flats, and deeper reef slopes. A designation of critical habitat which included all waters from island shorelines to the reef slope edge is justified by the marine habitat utilization data obtained in our study. Setting the seaward boundary of critical habitat at 20 fathoms would include most of those waters and provide a consistent boundary which could be easily detected by vessel operators approaching the rookery islands of the Hawaiian monk seal.

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