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EFFECTS OF TAGGING ON WEANED HAWAIIAN MONK SEAL PUPS

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Flipper tagging is a valuable technique in research and management of pinnipeds, providing such information as abundance, movement, age-specific survivorship, and age at first reproduction. Although this technique is usually considered to have no effect on subsequent behavior or survival of pinnipeds, some evidence exists that tagged animals are disturbed during capture and restraint and possibly by the continued presence of the tag. For example, northern fur seal (*Callorhinus ursinus*) pups suffered increased mortality for up to 1 week after capture and tagging (Roppel et al. 1963). Mammals that are prey to carnivores may react to disturbances, particularly capture and restraint, with a complex suite of behavioral and physiological responses, including "freezing" and marked bradycardia (Smith and Johnson 1984).

Even if capture and restraint are not harmful, the presence of marking devices may affect subsequent behavior or survival. Behavioral changes due to markers have been documented in birds (Burley et al. 1982, Jackson 1982) and ungulates (Queal and Hlavachick 1968, Beale and Smith 1973), but capture alone had no effect on subsequent reproductive success of adult female deer (Hamlin et al. 1982). Tags that affect foraging ability may cause increased mortality, an effect difficult to detect or to attribute to tags unless a control group is tested. Northern fur seal pups tagged and then marked with flipper notches had a lower survival rate over 2 years than did animals that were only marked (U.S. Natl. Mar. Fish. Serv. [NMFS] 1970).

Counts of the Hawaiian monk seal (*Monachus schauinslandi*) indicated a population decline of about 50% since 1958 (Johnson et al. 1982). Human disturbance, including biological research, is one of several factors contributing to this decline (Kenyon 1972). In the 1950's, some nursing pups and their mothers were tagged, and the pups were weighed periodically (Kenyon and Rice 1959, Wirtz 1968), but the extent to which these procedures affected the seals is not known. Because of potentially adverse effects of "hands-on" research, our study assessed the combined short-term effects of capture, restraint, and tagging on behavior and survival of weaned monk seal pups.

STUDY AREA AND METHODS

The study was initiated in spring 1982 on Lisianski Island, a low, sandy, 1.8-km^2 area about 1,700 km northwest of Honolulu, Hawaii. Beaches and rocky ledges comprise the island's 5.25-km perimeter. The island and surrounding shoals were inhabited by a relatively closed population of about 215 monk seals (Stone 1984). Pups were born from February to July, with peak births occurring from March to May.

Marking and Tagging

In 1982 we marked monk seal pups with identifying numbers on their pelage by commercial hair bleach (LeBoeuf and Peterson 1969). Bleach was applied 1–4 days after weaning while the pups were asleep, causing no apparent disturbance. Three pups that had weaned before the field party's arrival on 18 March were marked on 20–21 March. One or 2 days after bleach-marking, we also tagged 50% of the marked pups with a dark green plastic Temple Tag® between the fourth and fifth digit of each rear flipper. Tagging required capturing and restraining the pups by hand for 5–15 minutes. Tagging procedures followed Gilmartin et al. (1986), except that we inserted a metal screw through the trailing portions of the tag, a pro-

cedure that required most of the restraint time. We defined marking dates as the dates of tagging for tagged pups and of bleaching for untagged pups. Pups were classed by time after marking into 16 successive, 2-week strata, and data were analyzed by strata. The last pup to wean was marked on 27 July and was in stratum 4 (8–10 weeks after marking) when the study was completed. Thus, all pups contributed to observations through stratum 4, with progressively fewer pups observed at the later strata. We assigned randomly every other pup weaned to the tagged or untagged group, and the next pup to wean was assigned to the opposite group without regard to sex of pups in tagged versus untagged groups. Twenty-six pups survived to weaning on Lisianski Island in 1982 (Stone 1984); 13 (7 M, 6 F) were marked and tagged, and 13 (8 M, 5 F) were marked only. The Mann-Whitney *U*-test (Conover 1971) was used to determine whether tagged and untagged pups were marked at similar or dissimilar sites.

Presence and Location on Island

We determined locations of pups during 21 March–13 September and 26 October–22 November by ≥2 observers walking the perimeter of the island at least twice daily (i.e., min. of 4 circuits, except for single circuits on 3 separate days). The daily time of circuits varied, but generally occurred from early daylight to dusk. We divided the perimeter into 49 sectors of about equal length, and considered the daily location of each pup to be the sector in which it was first sighted. Pups not seen were assumed to be at sea until resighted. The Chi-square test was used to test for differences in number of days that tagged and untagged pups were present on the island.

Statistical tests between the 2 groups of seals were applied separately by stratum because observations at different strata are not independent of each other. This procedure, however, is analogous to multiple sampling, a process in which statistically significant results may arise because of chance when any test is repeated many times.

Trips at sea that overlapped strata were assigned to the stratum with the majority of trip days. If 2 strata included equal numbers of trip days, we assigned the trip to the later stratum. Data on length and number of trips from the island were constrained temporally (min. trip length = 1 day, max. No. of trips/stratum = 7) and were not normally distributed. The Wilcoxon nonparametric test (Conover 1971) was used to test for differences in median number of trips and median trip length between tagged and untagged pups.

Number of sectors between marking and haul-out locations could be determined because locations of pups were recorded. We considered such distances to represent the shortest distance along the island's perimeter. The actual movement of pups cannot be inferred from successive locations because specific routes were not known. Thus, these data reflect only the distance from a hauling site to a marking site, with the maximum distance being half of the island perimeter (i.e., approx 24 sectors). Like the trip data, these values are not normally distributed. We used the Wilcoxon test to test for differences in distance from marking sites to haul-out sites between tagged and untagged pups.

Behavior and Mortality

We observed behavior of pups on alternate days from 24 March to 13 September. Individual pups could not be identified in the nearshore water at night; hence, all observations were conducted during daylight hours. Three 2-hour observation periods (0900–1100, 1230–1430, 1600–1800) were established, each divided into 4 observation windows of 15 minutes each. We used the remainder of each period to locate particular pups. Because 3 observers simultaneously worked each period, 12 windows/period were available. For each period, pups were assigned randomly to a particular observer and window. We first observed pups marked <2 weeks earlier; pups marked ≥2 weeks earlier filled the remaining windows. Midway through the study, pups marked >10 weeks earlier were excluded from behavioral observations because they were frequently at sea.

Any pup not located by the assigned observer during the assigned window could be observed during any window in the period by any observer. Pups not located during the entire period were scored as "not found," and the numbers of tagged and untagged pups so scored were compared through stratum 5 using the Chi-square test.

Observers used stopwatches to measure the duration of 14 behavioral categories describing the pups' activity ashore and in inshore reef areas. Aquatic categories included investigating potential forage items, interacting with conspecifics, and other nondirected swimming. Categories ashore included movement, attempted nursing, awake but not moving, and asleep. We considered an awake animal to have begun sleeping when its eyes were closed for at least 30 seconds, and vice versa for a sleeping animal. Proportion of time spent per behavioral category was calculated for each pup, and values were normalized with an arcsine square-root transformation. We made no a priori assumptions as to which behaviors might differ between groups, and all behavioral categories were compared simultaneously by Hotelling's T^2-test (Harris 1975).

We used the Chi-square test to test any differences in numbers of deaths or disappearances between tagged and untagged seals.

RESULTS

Movements and Behavior

We saw pups on the island >90% of the days within 9–10 weeks after marking; then the percentage dropped notably (Fig. 1). The

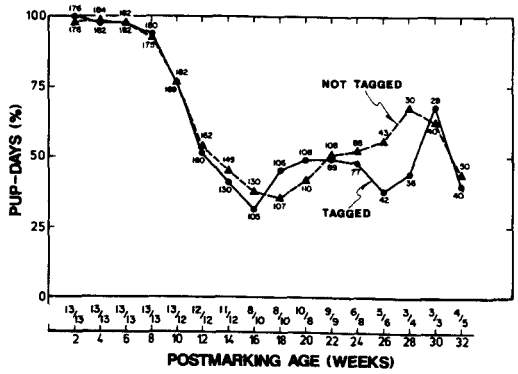

Fig. 1. Percentage of pup-days (presence of tagged and untagged Hawaiian monk seal pups) on Lisianski Island, Hawaii, March–November 1982. Points are means; numbers are total pup-days. Number bar indicates numbers of tagged (top) and untagged (bottom) pups contributing to data.

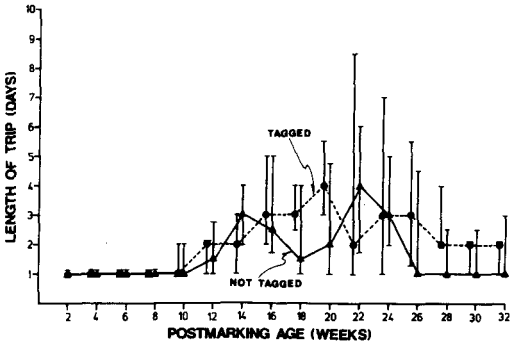

Fig. 2. Duration of trips from Lisianski Island, Hawaii, by tagged and untagged Hawaiian monk seal pups, March–November 1982. Points are medians; bars are 25–75 percentiles.

numbers of pup-days (days when seals were present on the island) for each 2-week stratum did not differ ($P > 0.07$) between tagged and untagged pups. Comparison of pups scored as "not found" during behavioral observations indicated that both groups were equally likely to be away from the island ($P = 0.83$ for strata 1–5).

Median trip length did not differ between tagged and untagged pups ($P > 0.08$ for all strata) (Fig. 2). The median number of trips did not differ between groups ($P > 0.17$ for all strata).

During the first 2 weeks after marking, tagged pups hauled out farther from their marking site than did untagged pups ($P = 0.01$) (Fig. 3). Conversely, tagged pups hauled out closer to their marking site ($P < 0.01$) 12, 14, 18, and 20 weeks after marking. No significant differences existed at the other 10 strata. Location of marking sectors about the island did not differ between groups ($P = 0.57$).

Behavioral observations of pups totaled 447 hours (223 hr for tagged pups, 224 hr for untagged pups). Behavior of tagged pups did not differ from that of untagged pups ($P > 0.25$) (Fig. 4). However, we observed 2 cases of interspecific behavior relating to the presence of tags. In both instances a swimming pup was harassed briefly by a great frigatebird (*Fregata minor*) that dove at the pup and picked at the tags. The only response by each pup was an open-mouthed threat toward the bird.

Mortality, Disappearance, and Tag Loss

No mortality of tagged pups occurred during or immediately following tagging. One animal died 88 days after tagging; it was found 2 hours after being observed and was being vigorously defended by an adult male. Postmortem examination did not reveal the cause of death, although fat vacuoles noted during histological examination of liver tissue suggested protein malnutrition. A second tagged seal disappeared in late September or early October, about 7 months after tagging (Stone 1984). As of August 1987, this seal had not been resighted at any location and was presumed dead (Southwest Fish. Cent. Honolulu Lab., NMFS, unpubl. data).

The remaining 11 tagged seals were resighted in 1983 (Johanos and Kam 1986) and as recently as 1986 (R. L. Westlake, Southwest Fish. Cent. Honolulu Lab., NMFS, unpubl. data). All 13 of the untagged seals survived for >1 year (Johanos and Kam 1986), at which

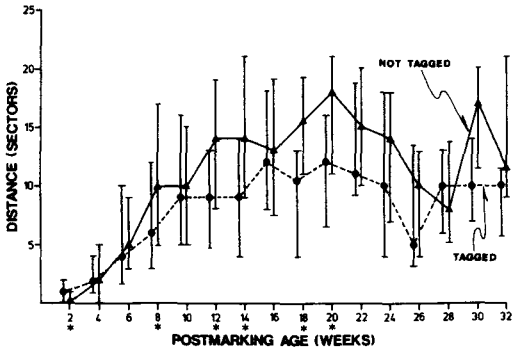

Fig. 3. Distance from marking site to haul-out site of tagged and untagged Hawaiian monk seal pups on Lisianski Island, Hawaii, March–November 1982. Points are medians; bars are 25–75 percentiles (* $P < 0.05$).

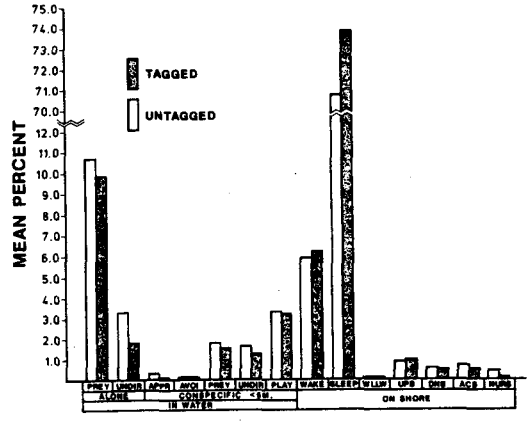

Fig. 4. Behavior of tagged and untagged Hawaiian monk seal pups on Lisianski Island, Hawaii, March–September 1982. Bars indicate percentage of time observed in each behavioral category. PREY = investigating potential forage; UNDIR = nondirected swimming; APPR = approaching conspecific; AVOI = swimming away from conspecific; PLAY = grasp, roll, or mock-fight with conspecific; WAKE = awake, unmoving; SLEEP = asleep; WLLW = wallowing in sand; UPB, DNB, ACB = move up, down, or across beach; NURS = attempt to nurse.

time they molted the pelage bearing the identifying bleach marks. The Chi-square test of equal mortality revealed no difference between the tagged and untagged groups ($P > 0.10$).

Of the 26 tags applied (2 each for 13 pups), one was lost during the study, and one was lost in 1985 (D. J. Alcorn, Southwest Fish. Cent. Honolulu Lab., NMFS, unpubl. data). Both tags had pulled through the flipper webbing, leaving a healed tear in the tissue.

DISCUSSION

Tagged pups were present the same percentage of days as untagged pups, indicating handling did not cause increased time at sea. Numbers and lengths of trips from the island also were equal between groups, suggesting that tagging did not affect the normal pattern of foraging trips at sea and haul-out ashore.

Disturbance induced by tagging might cause pups to avoid the area of capture, and any such effect would be expected to occur shortly after tagging. Such avoidance may account for the differences observed during the first 2 weeks after marking. Nevertheless, any effects were short term because the haul-out distance from marking sites was equal for tagged and untagged pups 4 weeks after marking. We cannot explain the finding that tagged pups hauled out closer to their marking sites at 12, 14, 18, and 20 weeks after marking. Because marking and tagging sites did not differ between groups, any consistent haul-out at a particular location by the aggregate of weaned pups would not produce the observed difference.

Systematic, detailed observations of pup behavior on shore and in the nearshore reef shallows revealed no differences between tagged and untagged groups. Behavioral changes would be expected to include attempts to remove tags or movement of the tagged flipper if irritated which, in turn, might also increase the time awake on shore because of shaking, scratching, or other movement of the rear flippers. No such behavior was observed, nor did any apparent infections result from tagging.

It is not known to what extent tagging contributed to the death or disappearance of 2 weaned pups. Both pups weaned before the field party's arrival on the island, so their nursing times or condition at weaning are un-

known. The protein malnourishment of the known dead pup does not imply that tags impaired foraging. Weaned phocids undergo a prolonged fast while learning to feed. During this time, subarctic species, such as the harp seal (*Phoca groenlandica*), rely initially on core reserves of lipids and proteins as energy sources before metabolizing blubber fat later in the fast (Worthy and Lavigne 1983). Temperate species, such as northern elephant seals (*Mirounga angustirostris*), use lipids exclusively from the blubber layer (Ortiz et al. 1978). The duration of the fast is not known for monk seals, although northern elephant seals fast for at least 8–12 weeks (Ortiz et al. 1978).

The postweaning disappearance or mortality of 2 tagged pups during their first year represents 8% of the 26 weaned pups and 15% of the tagged group. The difference in mortality for the 2 groups (2 vs. 0 deaths) was not statistically significant, assuming an equal probability of 2 mortalities among the untagged group. Nevertheless, if the 2 pups had died as a result of tagging, a 15% mortality estimate might be appropriate for any group of pups tagged in the future. First-year mortality for pups tagged in 1983 at Lisianski Island was 12% (D. J. Alcorn, Southwest Fish. Cent. Honolulu Lab., NMFS, unpubl. data) and for pups tagged at Laysan Island in 1983 and 1984 was 5% (Johanos et al. 1987) and 7% (T. C. Johanos, Southwest Fish. Cent. Honolulu Lab., NMFS, unpubl. data), respectively.

Data on first-year mortality of untagged pups are sparse. Johnson and Johnson (1981) observed 14% mortality or disappearance of weaned pups on Laysan Island during the first 6 months of age. Recent beach counts at this island suggested that its population is relatively stable (Alcorn 1984). At French Frigate Shoals, first-year mortality of untagged, bleach-marked pups was about 16% from 1983 to 1984 (J. R. Henderson, Southwest Fish. Cent. Honolulu Lab., NMFS, unpubl. data). This population has apparently leveled off after several years of increase (Johnson et al. 1982). Much higher mortality rates were observed at Kure Atoll in 1964 and 1965 (Wirtz 1968), and have contributed to a subsequent decline in that population (Johnson et al. 1982). About 50% of the weaned pups of northern elephant seals die during the first 7 months after leaving the shore (Reiter et al. 1978).

In our study we attributed the 100% survival of tagged pups during the few weeks immediately after capture to both restraining the pups for a short time and not herding or driving the animals before tagging. The latter procedure caused increased mortality of northern fur seal pups (Roppel et al. 1963).

SUMMARY

This study assessed the combined, short-term effects of capture, restraint, and tagging on weaned Hawaiian monk seal pups. Thirteen pups were tagged and marked; 13 were marked only. Pups were observed for up to 32 weeks after marking. Analyses of percentage of days seen ashore and the numbers and lengths of trips from the island revealed no differences between the 2 groups. A test of 14 behavioral categories revealed no differences in behavior. During the first 2 weeks after marking, tagged pups hauled out in locations significantly farther from marking sites than did their untagged counterparts. This effect disappeared by 4 weeks after marking, and 12, 14, 18, and 20 weeks after marking, tagged pups hauled out closer to their marking sites. First-year survival of both groups was similar, and we observed no mortality attributable to tagging. Tag loss over 4 years was 8%. Flipper tagging is a procedure that does not adversely affect weaned Hawaiian monk seal pups in the short term.

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