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Short Note

Hawaiian Monk Seals (*Monachus schauinslandi*) at Kure Atoll: Some Life History Effects Following Effort to Enhance Pup Survival

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Counts of Hawaiian monk seals (*Monachus schauinslandi*) were first conducted at Kure Atoll in the Northwestern Hawaiian Islands (NWHI) in the late 1950s (Kenyon & Rice, 1959; Rice, 1960). The highest of several monk seal beach counts (excluding pups) were 105 (1957) and 117 (1958) seals, and minimum pup births in these 2 y were 23 and 25.

Kure Atoll is located at the northwest end of the Hawaiian Archipelago (Figure 1). The atoll contains one permanent island (Green Island) and three ephemeral islets. In 1960, the U.S. Coast Guard (USCG) began construction of a 20-person LORAN station on previously unoccupied Green Island. The facility continued in operation until it was dismantled in 1992. In the first thorough assessment of monk seal births at Kure Atoll, 32 pups were observed in 1964 and 30 pups in 1965 (Wirtz, 1968). All but one of these pups died or disappeared within 60 d of birth.

By 1968, the mean count of seals on the beaches at the atoll had declined by over 40% (including and excluding pups), and spatial hauling patterns had changed (Kenyon, 1972). In the 1950s, prior to human occupation, the mean proportion of seals hauled on atoll beaches using Green Island was 70%; in 1968, that fraction had dropped to 16%, and the change was attributed to human disturbance of the seals by USCG station personnel (Kenyon, 1972). Adult females near birth and prior to weaning their pups are extremely sensitive to disturbance, much more so than males or immature seals, with pups showing little to no response to human presence near them. Pups may even approach people. Almost daily, seals encountered humans and their dogs and vehicles on Green Island beaches, and adult females retreated from these preferred pupping and hauling sites to the ephemeral islets where pup survival was highly affected by wave wash-over and flooding of the islets, shark predation, and adult male seal attacks (Kenyon, 1972; Gerrodette & Gilmartin, 1990).

In 1977, 20 y after the initial seal counts at Kure Atoll, counts of Green Island beaches and the atoll islets showed mean counts of 14 and 17 seals, respectively, and a total of 10 births, a population decline of *ca.* 70% (Johnson et al., 1982). This population decline and the U.S. Endangered Species Act listing of the monk seal in 1976 led the USCG to concede to three modifications of their Kure activities to reduce disturbance of seals. Approximately 700 m of the beaches at the northeast end of Green Island were placed "off limits" to most station personnel; recreational use of vehicles was not permitted on any beach; and dogs were removed from the island.

In 1980, the National Marine Fisheries Service (NMFS) initiated a recovery program for Hawaiian monk seals, which included the appointment of a recovery team charged with drafting a recovery plan (Gilmartin, 1983). The Hawaiian Monk Seal Recovery Team's initial highest priority recommendation was rebuilding the seal populations at the western end of the archipelago, and Kure Atoll became the focal point for the recovery effort.

The exact cause of pup deaths at Kure was not known during the 1960s and 1970s because the atoll's seals were only observed by scientists during brief annual visits. However, based on the observations from the mid-1960s (Wirtz, 1968) and a few subsequent accounts (Johnson et al., 1982), pup losses were believed to occur near weaning, and certainly during the first year, because few yearlings were sighted in any year.

In an attempt to mitigate these pup losses, A. M. Johnson suggested to one of us (WGG) that *in situ*

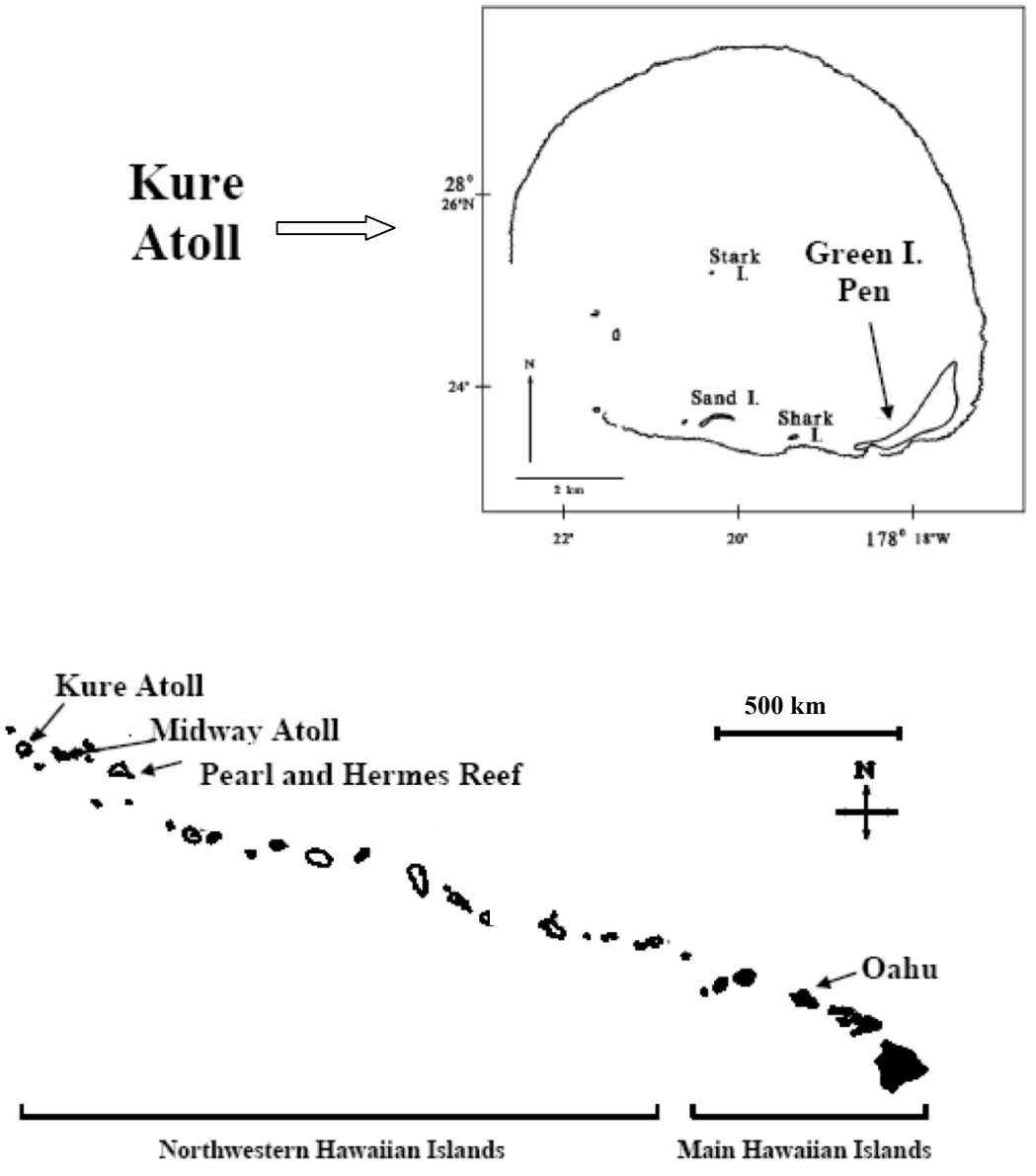

Figure 1. Hawaiian Archipelago and Kure Atoll with location of Green Island shoreline seal pen site

temporary captive maintenance of pups might enhance their survival (pers. comm., 15 May 1980). This recommendation was developed into a recovery project that became known as "Head Start" and was initiated at Kure Atoll in 1981.

In the spring of 1981 and continuing through 1991, all Hawaiian monk seals born at Kure Atoll were flipper-tagged for identification. All female pups, regardless of condition, were collected as soon as possible after weaning and placed into a temporary holding enclosure (35 m × 60 m wire fence, enclosing near equal areas of beach and seawater) on the lagoon side (north) of Green Island (Figure 1). Handling times associated with collecting and moving an animal into the shoreline enclosure were less than 30 min. Water depth at the offshore fence line usually ranged between 1.0 and 1.5 m. Male weaned pups were also flipper-tagged but were not collected for captive maintenance. The probable serial monogamous mating of monk seals makes survival of males far

less critical to the reproductive potential of the population.

Birth dates of all 65 pups (male and female) born from 1981 through 1991 ranged from 26 January to 18 July. During the Head Start project, 32 female pups were born in 9 of the 11 y; no female pups were born in 1983 and 1986. Weaning dates of the female pups ranged from 16 March through 27 August, and the range of pup collection dates for captive maintenance was 16 March through 28 August. The intervals between weaning and collection for 31 of the 32 female pups were known, with most (21) collected within 1 d of weaning; the others were collected within 17 d after weaning.

Female pups were held in the beach enclosure for 23 to 188 d. Pups in the enclosure were exposed to a variety of live reef fish species and invertebrates caught locally to allow the pups to feed *ad libitum* because no data were available during these years on which species might be important prey in this transition to foraging post-weaning. Although no rigorous behavioral observations of pup foraging in the enclosure were undertaken, pups were usually observed chasing prey by 4 wks post-weaning, and most pups were catching and at least attempting to consume prey by 8 wks post-weaning.

No health problems were observed while the pups were captive, and pup release dates from the enclosure ranged from 13 August to 21 September. The captive female pups were released from the holding pen in late summer each year by simply removing the fencing from the enclosure.

The wide range of birth and weaning dates and, therefore, captive holding times (ending with a single release date each year for most seals) were due to the normal broad temporal distribution of births for this seal (Johanos et al., 1994). Because trauma from shark attacks was believed to be the primary cause of pup losses during the 1960s and 1970s (Johnson et al., 1982), the scheduling of release of the female pups at the end of the summer months was based on observations that large sharks were not sighted near shore then and that few incidents of adult male sexual aggression toward pups were known at this time of year (Hiruki et al., 1993). Available USCG logistical support and inclement weather also affected seal release date scheduling.

During the period 1976 to 1979, prior to Head Start, only 38% (15 of 39) of the pups born at Kure Atoll were born on Green Island (Reddy, 1989). In 1981, six of ten pups were born on Green Island (Gilmartin et al., 1986); and during the following 8 y, 94% (31 of 33) of the atoll's pups were born on Green Island (Westlake & Gilmartin, 1990). The high number of births on Green Island after initiation of the Head Start project was significantly different from earlier years. Reduction in beach disturbance on Green Island after the Head Start project began was followed by a rapid return of monk seal pupping to the historically preferred pupping beaches on this island. This shift in birth sites back to Green Island and to the same high fraction (95% of atoll births) observed prior to USCG occupation over two decades earlier (Kenyon, 1972) was an important positive change as evidenced by the high survival of the male pups as well—seals that were not protected in the Head Start enclosure—compared to the low pup survival of the 1960s and 1970s (Wirtz, 1968; Johnson et al., 1982).

A similar, striking shift in monk seal hauling to a previously USCG-disturbed beach occurred on Tern Island at French Frigate Shoals (Figure 1) after the USCG ended its LORAN station operation and presence on the island in 1979 (Schulmeister, 1981). Seal counts on Tern Island increased from occasional seal sightings and a highest count of five seals during USCG occupation to a mean of 14 seals and a peak of 28 seals within a year of the USCG's departure.

In some years, Head Start female pups were weighed at the time of collection and at intervals during captive holding; male pups were not weighed. Female pup mass was monitored during the captive period in the years 1981, 1982, and 1988 (Gilmartin et al., 1986; Henderson & Finnegan, 1990; Bowlby et al., 1991). Animals held captive in 1981 were only weighed at the beginning and end of the captive period. Animals held captive in 1982 and 1988 were weighed three to five times while in captivity. Body mass data were available from 45 animal samplings of 12 seals from these years. The initial mean weaning mass estimate for the 12 seals was 77.9 kg (SE = 2.93). Standard regression techniques used to estimate the average change in body mass showed a mean mass loss rate of 0.33%/d (% of initial weight or 0.26 kg/d) during the first 4 to 5 mo post-weaning. Mass change measured in four monk seal pups near weaning at Midway in 1957 showed an average loss rate of *ca.* 0.6% mass/d (Kenyon & Rice, 1959). However, those data were only from the first few weeks post-weaning when the loss rate was higher. During the same early post-weaning period, our data showed a rate of loss (0.5% mass/d) comparable to the 1957 study. Since weaned pups do not begin to forage successfully until at least 2 to 4 mo post-weaning, this rate reflects the mass loss in a fasting animal and was not expected to be different from free-ranging pups.

Beach counts of seals on all islands at Kure were conducted two to three times per week during the late spring and summer months. During these

counts, size, sex, hauling site, identities, and other data were recorded (Johanos et al., 1987). Similar data were collected at the nearby atolls of Midway Islands and Pearl & Hermes Reef (Figure 1) and the other major NWHI breeding islands to provide additional information on interatoll movement patterns, reproduction, and survival of 1981 to 1991 Kure-born seals. The sighting data were used to calculate annual survival based on the first and last sighting of an individual. Animals not seen for an entire year were assumed to be dead. The dates between the first and last sighting were used to calculate the number of days survived by an individual. For animals that were determined to have died subsequent to the last sighting within a year, the animal was assumed to have died at the end of the day of last sighting. This is clearly a conservative approach and would tend to negatively bias estimates of annual survival. Animal-days were pooled across all animals of a given age class or cohort to determine the fraction of days survived. The fraction of days survived was converted to an annual estimate of survival by raising the estimate to the 365.25 power; and a confidence interval for the survival estimate was derived using a binomial model, which assumes animal-days are independent events (DeMaster & Drevenak, 1988).

Pooled first-year survival (summed data over years, weaning to sighting in second summer) of female pups that had been temporarily held in the beach enclosure (1981 to 1991) was 0.849 (95% CI = 0.703-0.946). Pooled first-year survival of male pups was 0.889 (95% CI = 0.788-0.970) during these same years, not significantly different from female survival. Annual survival of all Kure-born seals (1981 to 1991 cohorts) remained high through 2000 after the USCG's departure, with no significant difference between the sexes (females age 1 to 19: 0.967 [0.945-0.984] and males age 1 to 19: 0.947 [0.917-0.973]).

The improvement in survival over the previous two decades (1960s and 1970s) at Kure Atoll resulted in Kure being one of the NWHI locations with the highest survival rate of young seals (Gilmartin et al., 1993). Among the five primary NWHI monk seal breeding sites during 1981 to 1987, first-year survival (weaning to age 1) at Kure was 0.88, second only to French Frigate Shoals at 0.90.

Although the numbers of adult females and births were increasing as a result of the higher female survival (Van Toorenburg et al., 1993), by the late 1980s, it was apparent that the high survival rates of the Head Start females and their male non-penned counterparts were similar (Gilmartin et al., 1993) and that temporary captive holding of the females alone was not responsible for their higher survival. At that time, the need to continue the temporary holding of females was reconsidered; however, the Hawaiian Monk Seal Recovery Team strongly recommended continuation of the project based on concerns that female pups might be more sensitive than male pups to the continuing, albeit reduced, level of human–seal disturbance on the beaches and the possibility that some other threats could be operating (e.g., aggressive male attacks on pups) that would reduce female survival (Wirtz, 1968; Banish & Gilmartin, 1992; Hiruki et al., 1993; Johanos et al., 2010). The Recovery Team believed discontinuing the project and attempting to assess the relative importance of any threats in these first few months would put the female pups at unnecessary risk. Additionally, since the shoreline enclosure and NMFS staff were to be at the atoll to facilitate another project (Gilmartin et al., 2011), no additional costs would be incurred in continuing Head Start.

The seal beach census sighting data were also used to assess interatoll migrations. Of the 32 females, seven (22%) were sighted at another atoll at least once as of 2000. Three of the females were seen at Midway Islands (110 km east of Kure), two were sighted at Pearl & Hermes Reef (275 km east of Kure), and two were seen at both Midway and Pearl & Hermes Reef. Seven of the 33 males (21%) that were weaned in the same years also were sighted at least once on another atoll as of 2000. Three males were identified at Midway Islands, one was seen at Pearl & Hermes Reef, two were seen at both Midway Islands and Pearl & Hermes Reef, and one was seen at Lisianski Island (550 km southeast of Kure).

These movements of Kure-born seals indicate that neither the probability of being resighted (female rate = 0.22 vs male rate = 0.21) nor the average distance moved (average distance of female movement = 204 km [SE = 33 km] vs average distance of male movement = 244 km [SE = 60 km]) differed by gender. These movement data are likely negatively biased due to a relatively low effort to resight tagged animals at some locations (e.g., Midway Islands, where resighting effort was inconsistent until 1997) and because of the limited beach survey effort outside of the pupping season at most islands/atolls. These migration patterns were important to document as other management tools considered for promoting monk seal recovery at Kure included translocating young seals to Kure (Gilmartin et al., 2011), an action that could have resulted in higher emigration rates than normal.

Although the sample size was limited, the results suggested interatoll movement may be greater where the distances between atolls are relatively small. About 10% of seals under 10 y of age NWHI-wide were found at locations other than their natal island (Ragen & Lavigne, 1999),

and these results were heavily biased by movements at the eastern NWHI atolls where interatoll distances are greater and populations were larger.

Reproductive data from nine females born at Kure during the period 1981 to 1985 and surviving to reproduce showed the following ages of first births: one seal at age 5 y, four seals at age 6 y, and four seals at age 7 y. The mean age of first birth for these seals was 6.3 y (SE = 0.2). These findings were not unusual. During the years of this project, the youngest age of first birth observed for Hawaiian monk seals at any site was 5 y, and the mean age of first birth was about 7 y at Laysan Island and 1 to 2 y later at French Frigate Shoals (Ragen & Lavigne, 1999).

We believe the increased and comparable survival of female and male pups and the return of birthing to Green Island beginning in 1981can be explained by a reduction in human beach disturbance. Visits to the atoll by other biologists in earlier years included warnings regarding the sensitivity of seals to human disturbance, but no change in the behavior of the USCG personnel was noticed. Therefore, an unexpected consequence of Head Start was better compliance by the USCG with its own regulations intended to reduce disturbance of seals and its compliance with the additional warnings suggested by the NMFS staff during this project. The NMFS staff presence for an average of over 6 mo each year to conduct the Head Start project and monitor the population while educating the USCG station personnel on the plight of the seals appeared to have had a strong beneficial influence on USCG behavior. Although occasional seal disturbance from USCG activities continued during the course of the project, we believe, based on anecdotal accounts of disturbance from USCG personnel who had been stationed at Kure in years prior to 1981, that the frequency and intensity of disturbance incidents were greatly reduced after 1981.

These findings support the earlier assumption that beach disturbance of monk seals at Kure Atoll in the 1960s and 1970s was sufficient to cause females to abandon preferred pupping beaches on Green Island and that loss of the protection afforded by these sites resulted in high pup mortality (Kenyon, 1972). In a relatively short time after this work began, NMFS project staff at Kure persuaded USCG personnel to reduce disturbance of seals on the beaches, and this change allowed females to return and utilize their preferred birthing beaches on Green Island. An increase in pup survival immediately followed, probably related to reduced environmental threats at the sheltered Green Island birth and nursing sites and more undisturbed time for mothers and pups on the beach that reduced the risk of shark and adult male seal attacks in the water. Therefore, while reduction of disturbance to adult females was the primary factor responsible for increasing pup survival at Kure, the Head Start captive holding effort proved to be an acceptable strategy for short-term protection of pups, in part because of the weaned pups' relative immunity to human disturbance. This work showed that temporary captive holding of pups *in situ* does not seem to affect any important natural history traits and that this tactic could be used at sites where shark attacks and adult male seal aggression threaten weaned pup survival.

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Literature Cited

Banish, L. D., & Gilmartin, W. G. (1992). Pathological findings in the Hawaiian monk seal. *Journal of Wildlife Diseases*, *28*, 428-434.

Bowlby, C. E., Scoggins, P., Watson, R., & Reddy, M. (1991). *The Hawaiian monk seal,* Monachus schauinslandi*, at Kure Atoll, 1982-83* (NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-155). La Jolla, CA: National Oceanic and Atmospheric Administration.

DeMaster, D. P., & Drevenak, J. K. (1988). Survivorship patterns in three species of captive cetaceans. *Marine Mammal Science*, *4*, 297-311. doi:10.1111/j.1748-7692.1988.tb00539.x

Gerrodette, T., & Gilmartin, W. G. (1990). Demographic consequences of changed pupping and hauling sites of the Hawaiian monk seal. *Conservation Biology*, *4*, 423-430. doi:10.1111/j.1523-1739.1990.tb00317.x

Gilmartin, W. G. (1983). *Recovery plan for the Hawaiian monk seal,* Monachus schauinslandi. La Jolla, CA: National Marine Fisheries Service, National Oceanic and Atmospheric Administration.

Gilmartin, W. G., Johanos, T. C., & Eberhardt, L. L. (1993). Survival rates for the Hawaiian monk seal (*Monachus schauinslandi*). *Marine Mammal Science*, *9*, 407-420. doi:10.1111/j.1748-7692.1993.tb00473.x

Gilmartin, W. G., Morrow, R. J., & Houtman, A. M. (1986). *Hawaiian monk seal observations and captive maintenance project at Kure Atoll, l981* (NOAA Technical Memorandum NOAA-TM-NMFS-SWFC-59). La Jolla, CA: National Oceanic and Atmospheric Administration.

Gilmartin, W. G., Sloan, A. C., Harting, A. L., Johanos, T. C., Baker, J. D., Breese, M., & Ragen, T. J. (2011). Rehabilitation and relocation of young Hawaiian monk seals (*Monachus schauinslandi*). *Aquatic Mammals*, *37*(3), 332-341. doi:10.1578/AM.37.3.2011.332

Henderson, J. R., & Finnegan, M. R. (1990). *Population monitoring of the Hawaiian monk seal,* Monachus schauinslandi*, and captive maintenance project at Kure Atoll, 1988 (*NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-150). La Jolla, CA: National Oceanic and Atmospheric Administration.

Hiruki, L. M., Gilmartin, W. G., Becker, B. L., & Stirling, I. (1993). Wounding in Hawaiian monk seals (*Monachus schauinslandi*). *Canadian Journal of Zoology*, *71*, 458-468. doi:10.1139/z93-066

Johanos, T. C., Becker, B. L., & Ragen, T. J. (1994). Annual reproductive cycle of the female Hawaiian monk seal (*Monachus schauinslandi*). *Marine Mammal Science*, *10*, 13-30. doi:10.1111/j.1748-7692.1994.tb00386.x

Johanos, T. C., Kam, A. K. H., & Forsyth, R. G. (1987). *The Hawaiian monk seal on Laysan Island: 1984* (NOAA Technical Memorandum NOAA-TM-NMFS-SWFC-70). La Jolla, CA: National Oceanic and Atmospheric Administration.

Johanos, T. C., Becker, B. L., Baker, J. D., Ragen, T. J., Gilmartin, W. G., & Gerrodette, T. (2010). Impacts of sex ratio reduction on male aggression in the endangered Hawaiian monk seal (*Monachus schauinslandi*). *Endangered Species Research*, *11*, 123-132. doi:10.3354/esr00259

Johnson, A. M., DeLong, R. L., Fiscus, C. H., & Kenyon, K. W. (1982). Population status of the Hawaiian monk seal (*Monachus schauinslandi*), 1978. *Journal of Mammalogy*, *63*, 415-421. doi:10.2307/1380438

Kenyon, K. W. (1972). Man versus the monk seal. *Journal of Mammalogy*, *53*, 687-696. doi:10.2307/1379207

Kenyon, K. W., & Rice, D. W. (1959). Life history of the Hawaiian monk seal. *Pacific Science*, *13*, 215-252.

Ragen, T. J., & Lavigne, D. M. (1999). The Hawaiian monk seal: Biology of an endangered species. In J. R. Twiss, Jr. & R. R. Reeves (Eds.), *Conservation and management of marine mammals* (pp. 224-225). Washington, DC: Smithsonian Institution Press.

Reddy, M. L. (1989). *Population monitoring of the Hawaiian monk seal,* Monachus schauinslandi*, and captive maintenance project for female pups at Kure Atoll, 1987* (NOAA Technical Memorandum NOAA-TM-NMFS-SWFC-123). La Jolla, CA: National Oceanic and Atmospheric Administration.

Rice, D. W. (1960). Population dynamics of the Hawaiian monk seal. *Journal of Mammalogy*, *41*, 376-385. doi:10.2307/1377496

Schulmeister, S. (1981). Hawaiian monk seal numbers increase on Tern Island. *Elepaio*, *41*, 62-63.

Van Toorenburg, R. A., Gilmartin, W. G., & Henderson, J. R. (1993). Composition of the Hawaiian monk seal population at Kure Atoll, 1990. *Pacific Science*, *47*, 211-214.

Westlake, R. L., & Gilmartin, W. G. (1990). Hawaiian monk seal pupping locations in the Northwestern Hawaiian Islands. *Pacific Science*, *44*, 366-383.

Wirtz II, W. O. (1968). Reproduction, growth, and development, and juvenile mortality in the Hawaiian monk seal. *Journal of Mammalogy*, *49*, 229-238. doi:10.2307/1377979