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The Emergence of an Important Hawaiian Monk Seal (*Monachus schauinslandi*) Pupping Area at Kalaupapa, Moloka'i, in the Main Hawaiian Islands

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Abstract

The Hawaiian monk seal (*Monachus schauinslandi*) is one of the most endangered marine mammals on earth, with the majority (90%) of the population found in the relatively uninhabited Northwestern Hawaiian Islands (NWHI) and the remaining 10% in the heavily developed main Hawaiian Islands (MHI). Since 1998, the total population has declined 4%/y to ~1,100 animals. Despite this trend, the population in the MHI is increasing, with monk seals pupping at Kalaupapa National Historical Park on the island of Moloka'i. Long-time human residents in Kalaupapa indicated that monk seals rarely used the beaches prior to 1997, and no births had been observed since at least 1941. Since 1997, a total of 53 pups have been born, with births increasing at an average annual rate of 26.6%. Reproductively active females born at Kalaupapa exhibited a 55.6% site fidelity. Spatially, monk seal density was higher on sandy beaches (2.0 monk seals km^{-1}) than basalt (0.3 monk seals km^{-1}) habitat. Temporally, monk seal density was highest during the late spring and early summer due to the presence of mother-pup pairs. After weaning, monk seals also used adjacent basalt habitat and typically moved away from Kalaupapa at the onset of winter; since 2009, monk seal sightings have increased throughout the year. Explanations for the emergence of the pupping area include suitable habitat characteristics (e.g., protected shallow water habitat, high prey abundance, and low predator/competitor abundance), reduction of human activities (e.g., elimination of cattle in 1985, sparse [3.4 people km^{-2}] and declining [90% since 1900] human population, and low public visitation [8,494 people y^{-1}]), and a supportive community. Current management actions include habitat-use surveys, population studies, community presentations, and law enforcement patrols. Kalaupapa has become a productive pupping area for monk seals in the MHI, and the establishment of a birthing area provides hope for the survival of this endangered species.

Key Words: Hawaiian monk seal, *Monachus schauinslandi*, pupping, habitat, Kalaupapa

Introduction

The Hawaiian monk seal (*Monachus schauinslandi*) is one of the most endangered marine mammals on earth and the only marine mammal whose range is located entirely within the United States. The majority (90%) of the population resides in the relatively uninhabited Northwestern Hawaiian Islands (NWHI), with a small population found in the heavily developed main Hawaiian Islands (MHI) (National Marine Fisheries Service [NMFS], 2007). In the MHI, aerial surveys and shoreline sightings have found monk seals concentrated at more remote locations on the islands of Ni'ihau, Kaua'i, O'ahu, and Moloka'i. Monk seals have been documented less commonly on the islands of Lāna'i, Maui, Kaho'olawe, and the big island of Hawai'i in the southeastern portion of the archipelago (Baker & Johanos, 2004).

This species is protected under the Marine Mammal Protection Act of 1972 and was listed in 1976 as endangered under the U.S. Endangered Species Act of 1973 (NMFS, 2007). Federal and state agencies, such as the National Marine Fisheries Service (NMFS), Marine Mammal Commission, U.S. Fish and Wildlife Service, and the State of Hawaii, Division of Aquatic Resources, have supported monk seal research and management efforts in the NWHI and MHI. Over the past decade, the total monk seal population declined from ~1,400 animals to 1,100, with the decrease occurring primarily in the NWHI at an annual rate

of approximately 4% (Baker et al., 2011). It appears that the primary factor contributing to this decline is food limitation and the resulting low juvenile survival rate (Antonelis et al., 2006; Baker, 2008).

In contrast to the downward trend in the NWHI, the monk seal population in the MHI is increasing (Baker & Johanos, 2004; Baker et al., 2011), with an increasing proportion of births occurring on the islands of Ni'ihau, Kaua'i, O'ahu, and Moloka'i. Since 1981, when NMFS first began tagging pups in the NWHI (Gerrodette & Gilmartin, 1990), the first pup documented to wean in the MHI occurred in 1988. In 1997, a single female began pupping at Kalaupapa on the island of Moloka'i on a near annual basis and, since that time, her progeny and other females have given birth on two beaches within Kalaupapa National Historical Park. The purpose of this study was to document the emergence of the monk seal pupping area on the Kalaupapa Peninsula and to gain a better understanding of some of the factors possibly contributing to this increasing pupping trend.

Materials and Methods

Kalaupapa National Historical Park (KALA) is located on the north central coast of the Island of Moloka'i, Hawai'i (Figure 1). The island is fifth in size (671 km^2) among the eight main Hawaiian Islands. The park encompasses 809 ha of water within the boundary that extends 0.4 km offshore down to a depth of 42 m and includes 20.7 km of coastline. The Kalaupapa Peninsula was designated by King Kamehameha V of the Hawaiian Kingdom in 1865 as a quarantine settlement for people with leprosy (Hansen's Disease) (Moran, 2007). The settlement has been managed in succession by the Kingdom, the territory of Hawaii, and now by the State of Hawaii, Department of Health, which oversees the care of the remaining patients.

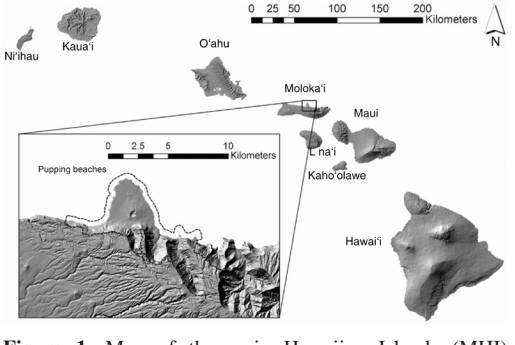

Figure 1. Map of the main Hawaiian Islands (MHI) showing Kalaupapa National Historical Park (KALA) and the location of monk seal pupping beaches; the park boundary is delineated in the inset as a dashed line.

The historic Kalaupapa Settlement and the surrounding area were incorporated into the National Park System in December 1980. Most of the land within the park boundaries is not owned by the National Park Service (NPS) but is managed by NPS through cooperative agreements with various state and federal agencies as well as private entities. Visitation to the park is tightly controlled and limited to 100 people per day by state law. Visitors must either participate in the patient run tour or be sponsored by one of the residents. Park facilities include a collections museum that houses patient oral histories, which were reviewed to document monk seal habitat use over the past century.

NMFS started tagging pups at Kalaupapa, with assistance from the NPS, since the first documented pup was born there in 1997. Pups born at Kalaupapa were typically tagged within 2 wks of being weaned, according to NMFS protocol and records (Henderson & Johanos, 1988). Tagging consisted of plastic livestock ear tags (Temple Tag™, Temple, TX, USA) attached to the dorsal webbing of the hind flippers, DNA samples collected from the flipper tissue plugs, insertion of a pit tag under the skin in the hind quarter, and measurements of the length and girth. Resighting data were cataloged in a population assessment database used to generate values for site fidelity, number of pups per female, and lineage. Birth records in the MHI have been documented since 1962 by NMFS using information collected from the public and cooperating agencies such as the park service (Baker & Johanos, 2004). Pupping site fidelity was defined as the percentage of female pups born at Kalaupapa that returned to give birth after reaching sexual maturity (>3 y old). For the purposes of this study, resight history was used to estimate survival; and if a female had not been observed anywhere in the MHI or NWHI since 2007, then she was removed from the survival pool. Three years was arbitrarily chosen as a cutoff period based on previous resight histories and current survey effort levels. If females were later seen alive, then the pupping site fidelity estimate was back-corrected to reflect that the monk seals were alive in previous years.

In August 2005, KALA staff initiated shoreline surveys to document spatial and temporal patterns that might be present in monk seal habitat use. Sampling frequency was generally weekly, but depended on personnel availability. Surveys consisted of a 3.2 km linear track that traversed two different intertidal habitat types: (1) basalt rock and (2) carbonate sandy beach. Data collected included the date, habitat type, start and end time within each habitat type, location, number of monk seals (mother-pup pairs were recorded as two monk seals), identity of monk seals if discerned,

photographs to aid in identification, monk seal sex, and personnel involved. At the onset, surveys did not cover all locations and missed the month of September 2005. Beginning in December 2005, surveys became more consistent with an average of four surveys every month. The trend in pupping at Kalaupapa was assessed using a linear regression model with the number of births per year as the dependent variable. For comparative purposes, the pupping trend for the MHI (excluding Ni'ihau) from 1962 to 2010 was examined using a polynomial regression. The pupping data for the MHI from 1962 to 2001 was obtained from Baker & Johanos (2004) and extended to 2010 with more recent observations.

Fish and benthic data from the NPS Inventory and Monitoring (I&M) program were evaluated from 2004 to 2009 to characterize the subtidal habitat assemblage. The geographical range of the data included hard and soft bottom habitat within a 1- to 25-m depth range around the peninsula and extended 1 to 2 km on either side of the east and west park boundaries. Methods have been described elsewhere in Friedlander et al. (2007), Beets et al. (2010), and Brown et al. (2007, 2010). Substrate data are expressed as percent cover and fish assemblage characteristics as species richness, density, and biomass.

To examine habitat use patterns by season (winter, spring, summer, fall), a general linear model repeated measures ANOVA was used with monk seal density km^{-1} as the dependent variable and habitat type (basalt rock, sandy beach) as the independent factor. Data were ln(x+1) transformed to meet the assumptions of normality and homogeneity of variances (Zar, 1999). Only data from the summer of 2005 through the summer of 2010 were used in the analysis. Winter months for a given year were categorized as contiguous months from the end of that calendar year through the first two months of the subsequent year. For example, December 2006, January 2007, and February 2007 were grouped into the 2006 winter season.

Results

Oral histories and archived documents in the KALA collections museum indicated that patients and workers had not observed any monk seals prior to the 1990s, and only a few (~3 to 5) hauled out intermittently during the 1990s. In addition, conversations with long-time residents who made observations extending back to at least 1941 yielded no evidence of monk seals pupping at Kalaupapa (P. Harada, pers. comm., 6 November 2006). No births were recorded at Kalaupapa in either the historical documents or the scientific literature prior to 1997.

Since 1997, when the first pup was recorded at Kalaupapa, a total of 53 pups have been born on the peninsula, 26 females and 27 males. All pupping has occurred on the two carbonate sandy beaches, Īlio pi'i (0.53 km in length) and Papaloa (0.83 km). The number of pups born annually increased at an average rate of 26.6% ± 11.4% SE. The annual birth rate at Kalaupapa has accounted for 35.8% ± 3.5% SE of the increase in pupping documented across the MHI, excluding Ni'ihau, which appears to be an area of high pup production, but actual numbers are unknown. The linear regression model explained a significant portion of the variation in number of births across years for Kalaupapa (Number of births = -1,083.81 + 0.54*x, $r^2 = 0.92$, $p < 0.001$) (Figure 2). The regression model for the MHI was Number of births = -58,902.17 – 59.57*x + 0.02*x^2.

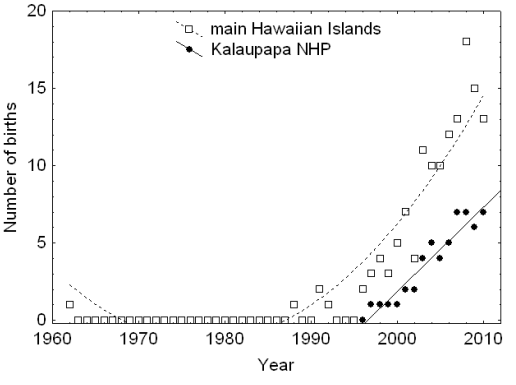

Figure 2. Annual number of births in the MHI (excluding Ni'ihau) and at KALA from 1962 to 2010; the regression equation used to model the trend was linear for KALA and polynomial for the MHI.

Of the 26 females born at Kalaupapa, 14 likely were sexually mature by 2010. Six of them were not observed after 2007 and were excluded from the pupping site fidelity estimate. Five of the remaining eight females returned to Kalaupapa at least once to give birth (pupping site fidelity 55.6%) (Table 1). RY30, born in 1998, had the most pups (8); followed by RQ21 (7), born in 1997; RI15 (2), born in 2004; RI25 (1), born in 2004; and RV11 (1), born in 2005. These females have only been observed pupping at Kalaupapa, and it was presumed that all pupping events in the MHI (excluding Ni'ihau) were documented. All but one of these females descended from the initial mother R006, including one offspring (RI15) from RY30. RI15 is also the youngest (4 y old) mother on record for this species.

A total of 243 surveys were conducted from August 2005 to August 2010. Monk seal density

Table 1. Pupping history of female monk seals at Kalaupapa from 1997 to 2010; mothers born at KALA are listed in the "Birth year" column with the exception of RH44 who was born on Kaua'i. Monk seals listed in the "Year first identified" column have an unknown birth year.

Mother ID	Birth year	Year first identified	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
R006		1996	X	X	X	X	X	X	X	X		X	X	X	X	
RQ21	1997								X	X	X	X	X	X	X	
RY30	1998								X	X	X	X	X	X	X	X
RH44	2000*												X	X	XX	X
R011		2001					X	X		X	X		X			
R016		2003								X	X	X	X	X	X	
RI15	2004													X		X
RI25	2004															X
R017		2003							X			X	X	X	X	X
RV11	2005															X
R308		2009													X	X

*Born on Kaua'i

= No pupping recorded; X = Pupped at KALA; XX = Pupped elsewhere; = Dead

was significantly higher on sandy beaches (2.0 seals km^{-1} ± 0.3 SE) than the basalt rock (0.3 seals km^{-1} ± 0.3 SE) habitat ($F_{1, 3}$ = 22.9, p = 0.01, power = 0.87). Seasonally, monk seals preferred sandy beaches during the late spring and early summer months ($F_{20, 60}$ = 6.8, $p < 0.001$, power = 1.00), although this relationship varied by habitat over the course of the observation period ($F_{20, 60}$ = 4.6, $p < 0.001$, power = 0.99; Figure 3). This pattern was primarily attributed to mother-pup pairs that used the sandy beaches for nursing in the spring and summer. Then, after weaning, monk seals began to also haul out on adjacent rocky intertidal areas and were resident throughout the leeward coastline until the fall. Monk seals typically moved away from Kalaupapa at the onset of winter and the strong winter swells, although recently monk seal sightings have increased on a year-round basis (Figure 3). This is shown by the upsurge in density during the winter months and the higher overall density in 2009 and 2010. It should be noted that pupping has extended into the later months due to consecutive years of pupping by the same mothers, and so weaned pups remain into the fall/winter months before dispersing.

Subtidal community data from the NPS I&M program indicated a relatively stable coral community with a minor (0.3%) decline in coral cover from 2006 to 2009 ($F_{3, 42}$ = 3.4, p = 0.03, power = 0.73; NPS, unpub. data). Even though this change was statistically significant, it was not considered biologically relevant (Brown, 2004). In comparison to published values from around the MHI, Kalaupapa had low percent coral cover (9.3% ± 0.8% SE), a low incidence of coral disease/bleaching (0.6 % ± 0.2% SE), moderate percent macroalgae cover (19.1 % ± 1.7% SE), high fish species richness (24.5 species, 125 m^{-2} ± 1.7 SE), moderate fish density (15.4 fish ha^{-1} × 1,000 ± 3.1 SE), and high fish biomass (2.1 metric tons ha^{-1} ± 0.2 SE) (Friedlander et al., 2008). The fish community at Kalaupapa had a higher level (0.13 metric tons ha^{-1} vs 0.04 metric tons ha^{-1}) and higher percentage (7.6% vs 5.9%) of apex predator biomass compared to other locations around the MHI (for comparative values, see Friedlander et al., 2007, 2008).

The human population at Kalaupapa is currently 117, which equates to 3.4 people km^{-2} within the county (U.S. Census Bureau, http://quickfacts.census.gov/qfd/states/15/15005lk.html). The population has declined 32% since 1969 when the State of Hawai'i lifted the quarantine policy on Hansen's Disease patients and 90% since 1900 when the population was at its peak. Annual visitor statistics from 2002 to 2010 show a mean visitor count of 8,494 people y^{-1} ± 688 SE, which is substantially less than

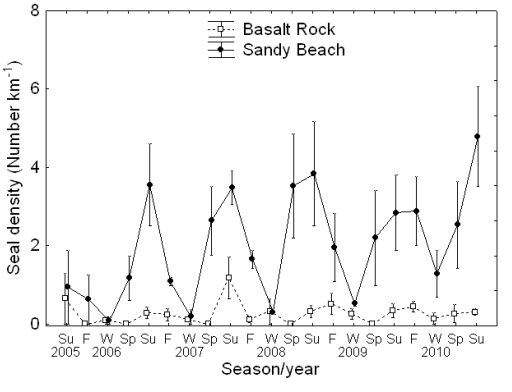

Figure 3. Mean monk seal density (number km^{-1}) by season on basalt rock and sandy beach habitats along the leeward peninsula of KALA from 2005 to 2010; season codes are as follows: W = Winter, Sp = Spring, Su = Summer, F = Fall. Error bars are ± 1 SE of the mean.

the number allowed by law in the settlement (State of Hawai'i, Department of Health, unpub. data).

Discussion

This study has documented the emergence of a monk seal pupping area at Kalaupapa, Moloka'i, since 1997. Some of the possible explanations for the success of the pupping area include suitable physical and biological characteristics of the monk seal habitat at Kalaupapa and the reduction of human activities which would positively influence monk seal behavior patterns (Ragen, 1999).

Several characteristics of the physical and biological environment are noteworthy. First, and perhaps most important, Kalaupapa has pupping site attributes such as extensive (~0.4 km^2) shallow water (< 1 m in depth) habitat adjacent to the pupping areas, short (0.53 km and 0.83 km in length) carbonate beaches, and emergent boulders near the shoreline. Westlake & Gilmartin (1990) identified these same primary attributes at preferred pupping sites in the NWHI, and they theorized that these features limited shark access to the beaches. Second, the benthic marine resources in more remote areas of the MHI such as Kalaupapa are faring considerably better than reef systems adjacent to heavily populated regions. Even though coral cover is low at Kalaupapa, it is relatively stable and appears healthy in contrast to the impacted reefs with declining coral cover and heavy fishing pressure (Friedlander et al., 2008). Third, the high biomass of potential prey species around the peninsula provides food resources in higher abundance than elsewhere around the MHI (NPS, unpub. data from 2005 to 2010). In addition, immature monk seals from KALA have been documented using offshore foraging areas such as Penguin Bank, which is only 45 km from the peninsula (Brillinger et al., 2008; C. Littnan, pers. comm., 9 February 2011). Fourth, the high abundance and large size of apex predators (e.g., jacks and sharks) in comparison to other sites around the MHI would be considered a detriment to monk seal recovery since these large fish have been hypothesized to be direct competitors to monk seals in the NWHI (Baker & Johanos, 2004; Parrish et al., 2008). The apex predator biomass at KALA, however, is still less than levels found in the NWHI (Friedlander & DeMartini, 2002; Friedlander et al., 2008). Fishery catch statistics from remote areas such as KALA indicate that fishing pressure is evident, with fishers catching jacks (Carangidae) and occasionally pelagic apex predators such as tuna (Scombridae) (University of Hawai'i–Hilo, unpub. data from 2009-2010). Consequently, the depressed apex predator population coupled with the low intraspecific competition (Baker & Johanos, 2004) could potentially benefit monk seal recovery.

Reduction in human activities has been identified as a primary factor contributing to the successful reestablishment of some monk seal pupping and haulout areas (Gerrodette & Gilmartin, 1990). At Kalaupapa, the elimination of cattle on the peninsula in 1985 (Agness et al., 2001), sparse and declining human population, low public visitation, and a supportive community may have contributed to the success of the pupping areas. The removal of cattle was hypothesized to be beneficial because cattle would often wander down on the beaches and potentially disturb the monk seals (P. Harada, pers. comm., 21 January 2006). Several of the patients at Kalaupapa commented on seeing monk seals haul out intermittently beginning in the 1990s, but before that time there were no observations (N. Chang, pers. comm., 12 February 2011). Another element that may be important in the recovery is the minimal human presence on the peninsula, which has been declining over time. The other islands and counties in Hawai'i have all experienced population growth from 307 to 1,547% since 1900 (U.S. Census Bureau, http://quickfacts.census.gov/qfd/states/15000lk.html) and an increase in visitor traffic from 60,436 to 6,420,448 people per year since 1952 (State of Hawai'i Visitor Statistics, http://hawaii.gov/dbedt/info/visitor-stats/visitor-research). It is important to note, however, that changes in monk seal behavior from the reduction in human activities are difficult to quantify since no human-use data are available prior to 2005. In addition, monk seals are now being sighted at heavily trafficked beaches such as Waikīkī as the MHI monk seal population expands. Finally, the Kalaupapa community has been receptive to monk seal conservation efforts. This attitude was especially evident during the relocation of a captive monk seal to Kalaupapa by the NMFS Protected Resources Division. During this event, the community welcomed the transfer in comparison to other areas around the state, which have voiced opposition to seal translocations (Clark & Wallace, 2002).

The emergence of the pupping area at Kalaupapa raises the question of whether this is a new occurrence or a reestablishment of a previously existing population. 'Īlio pi'i, which is one of the beaches that monk seals use at Kalaupapa, means "climbing dog" in Hawaiian (Pūkui et al., 1974) and the name appears to have been in use since at least 1862 (Ka Nupepa Kuokoa, 1862). The Hawaiians call the monk seal *'Īlio holo i ka uaua*, which roughly translates to "dog that runs in rough [seas]" (Pūkui & Elbert, 1957). This term has been used to describe monk seals since

at least the mid-1800s (e.g., Ka Nupepa Kuokoa, 1865). Because Polynesians often named places with significant meanings, it is possible that monk seals used this beach at one time to haul out, but that was certainly prior to the patient-recorded history available to us. As indicated previously, patient oral histories and other documentation rarely mentioned the presence of monk seals at Kalaupapa, and there are no records of any births in this area for at least 56 y.

Although the history of indigenous species in the Hawaiian archipelago is frequently one of decline and extinction, there are some notable examples of threatened and endangered species that have recovered. They include the green sea turtle (*Chelonia mydas*) and the humpback whale (*Megaptera novaeangliae*); both of these marine species have made substantial recoveries in Hawai‘i over the past 30 y with legal protection and significant management action (Balazs & Chaloupka, 2004; Calambokidis et al., 2008). Now the human community at Kalaupapa, with monk seal management activities conducted by KALA staff (e.g., weekly habitat use surveys, population studies, community presentations, and law enforcement patrols) and NMFS (e.g., guidance, support personnel, and establishing a monk seal stranding response), has seen the establishment of a productive pupping area for monk seals in the MHI, providing hope for this endangered species.

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