PACIFIC ISLANDS FISHERIES SCIENCE CENTER

Report of the Hawaiian Monk Seal Captive Care Workshop
Honolulu, Hawaii
June 11–13, 2007

Compiled and Edited by

Jason D. Baker and Charles L. Littnan

March 2008

Administrative Report H-08-02

About this report

Pacific Islands Fisheries Science Center Administrative Reports are issued to promptly disseminate scientific and technical information to marine resource managers, scientists, and the general public. Their contents cover a range of topics, including biological and economic research, stock assessment, trends in fisheries, and other subjects. Administrative Reports typically have not been reviewed outside the Center. As such, they are considered informal publications. The material presented in Administrative Reports may later be published in the formal scientific literature after more rigorous verification, editing, and peer review.

Other publications are free to cite Administrative Reports as they wish provided the informal nature of the contents is clearly indicated and proper credit is given to the author(s).

Administrative Reports may be cited as follows:

> *Author. Date. Title*. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-*XX*-*YY*, *xx* p.

For further information direct inquiries to

Chief, Scientific Information Services
Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
2570 Dole Street
Honolulu, Hawaii 96822-2396

Phone: 808-983-5386
Fax: 808-983-2902

Pacific Islands Fisheries Science Center
Administrative Report H-08-02

Report of the Hawaiian Monk Seal Captive Care Workshop
Honolulu, Hawaii
June 11–13, 2007

Compiled and Edited by

Jason D. Baker and Charles L. Littnan

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
2570 Dole Street, Honolulu, Hawaii 96822-2396

March 2008

STATEMENT OF PURPOSE

The Hawaiian Monk Seal Captive Care Workshop was convened by NOAA Pacific Islands Fisheries Science Center (PIFSC) to develop the framework for preparing a 10-year plan to salvage and preserve the reproductive potential of juvenile female Hawaiian monk seals as a priority action to mitigate the population decline and enhance the potential for recovery. The scope of the workshop considered a diverse range of capture-related interventions, including on-site captive care for nutritional support, direct translocation, treatment and rehabilitation in the main Hawaiian Islands and any aspect of captive care pertinent to such interventions. NMFS will use this document in formulating future plans for captive care, but as our knowledge base, enhancement tools and potential strategies evolve, then final decisions may vary from the recommendations of this report.

EXECUTIVE SUMMARY

The abundance of Hawaiian monk seals in the Northwestern Hawaiian Islands (NWHI) is declining about 4% per year. Analyses indicate that juveniles are failing to thrive, and only about one of every five juvenile monk seals live to reach maturity. The population decline will continue indefinitely unless survival of juvenile monk seals improves. Hence, immediate and aggressive intervention is needed to enhance recovery of the species. "Captive care," defined to include a variety of activities and treatments, has been identified as a potential means for increasing juvenile female survival. The Hawaiian Monk Seal Captive Care Workshop was convened from June 11 to June 13, 2007 to provide NMFS with essential information to support the development of a 10-year prospective plan for future captive care projects. The workshop was attended by NOAA Fisheries' researchers and managers, animal care specialists, and a variety of stakeholders.

The goal of captive care will be to substantially increase the survival of treated animals over natural survival rates. The biggest impact may be achieved at locations where natural survival is lowest, such that the ability to predict where and when survival is likely to be low would be valuable. Some physical and biological correlates with juvenile monk seal survival have been identified, but the desired predictability of those rates has not been achieved.

Captive care projects for this began in the early 1980s. Approaches varied from protecting weaned pups from sharks and aggressive male seals at Kure Atoll and translocating healthy weaned pups, to bringing undersized pups and juveniles from French Frigate Shoals to Oahu for treatment and nutritional support prior to releasing them at sites where natural survival was relatively high. These efforts were halted after an eye disease spread among the pups collected in 1995. Since 2003, modest captive care efforts have resumed, most recently with an in situ project at Midway Atoll during 2006–2007. The success of the programs implemented to date has been variable, but it is clear that any new captive care initiative will benefit from the lessons learned during these earlier endeavors.

A range of prospective strategies for increasing juvenile survival were discussed at the workshop, including captive care in the NWHI, care of NWHI animals brought to a centralized facility in the main Hawaiian Islands (MHI) and subsequent release back in the NWHI, a variety of direct translocation scenarios (within the NWHI or from the NWHI to the MHI or Johnston Atoll), and in situ antihelminthic treatment. Each approach entails its own advantages and challenges, the latter ranging from logistical and cost-related to sociopolitical. However, these general categories seem to encompass the range of strategies currently conceived for captive care.

The most effective means of improving juvenile survival is uncertain. It was agreed, however, that the focus should be on improving juvenile female survival, with captive care or treatment of juvenile males undertaken primarily where doing so offers a significant opportunity to improve understanding of treatment methodologies. One key consideration is the best age at which to bring animals into captive care and what age to release them. This will entail a balance between the number of animals available for treatment, the potential

survival benefit that can be conferred, and age-specific reproductive value (v_x). Moreover, uncertainty remains regarding factors such as animal condition at admission, duration of captivity, and timing, method and location of release. These uncertainties can only be resolved by using a carefully designed experimental approach with a diligent project assessment. Experimentation inherently entails risks to the individual seals involved and the broader wild population. Hazards can be minimized but not eliminated, making contingency planning and an adaptive approach crucial for precluding these occurrences. We must be prepared to respond to failures and change course appropriately. Of course, a failure to act entails its own, and potentially greater, risks.

A captive care program entails a number of other significant requirements. The NWHI are extremely remote and, therefore, transportation and logistics are very costly and difficult to arrange. A new Marine Mammal Protection Act/Endangered Species Act research and enhancement permit will also be required, as will other permits. Personnel and supporting infrastructure will be needed. A key missing component is a captive care facility in the MHI capable of supporting animals requiring care. The funding required to launch and sustain a captive care program cannot be accurately estimated at this time, as costs will vary enormously depending on such factors as how plans for the MHI captive care facility develop, where candidate animals in the NWHI are located, duration of captivity, and scale of the program. Institutional structures, expertise and capacity are critically important for initiating an efficient and sustained captive care program. NMFS requires partners with expertise in captive marine mammal care, captive care facility design and management, and a number of other areas. It is proposed that a consortium of partners be established among NMFS, nongovernmental organizations, and other contributing agencies and institutions to design and execute a Hawaiian monk seal captive care program.

CONTENTS

CONTENTS (Cont'd)

BACKGROUND

The Hawaiian monk seal (*Monachus schauinslandi*) was listed as endangered under the U.S. Endangered Species Act (ESA) in 1976. Over the last three decades, significant efforts have been made to enhance its recovery, but after a period of relative stability during the 1990s the population has declined at a rate of about 4% per year between 2000 and 2005. Demographic analysis indicates that juvenile survival rates have declined with only about one out of every five seals surviving to sexual maturity (i.e., 4 – 6 years of age). It is apparent that the decreasing trend in total population will continue indefinitely unless survival of juvenile monk seals improves. Hence, immediate and aggressive intervention is needed to enhance recovery of the species.

Actions currently thought to have potential for improving monk seal survival include:

- Mitigating marine debris entanglement by disentangling seals and removing debris from the species' marine and terrestrial habitats.

- Mitigating shark predation by removing predatory sharks, deterring shark predation and translocating weaned pups from areas of high predation risk.

- Mitigating mortality from adult male aggression by intervening to stop life-threatening interactions, treating wounded pups, and removing habitually aggressive males.

- Mitigating pup mortality through a variety of means (reuniting separated mother-pup pairs, fostering unpaired lactating females and prematurely weaned pups, etc.).

- Bringing young seals (principally females) into captive care and release programs. From 1981 to 1995 various rehabilitation and translocation efforts were conducted and are collectively termed "captive care" for the purposes of this workshop. Previous activities produced varying levels of success and are thought to be a potentially effective means of improving survival. The initiation of similar projects in the future will rely heavily on information gleaned from these earlier projects and from efforts conducted during the past 5 years.

HAWAIIAN MONK SEAL POPULATION STATUS, TRENDS, AND PREDICTABILITY

Introduction

The Hawaiian monk seal population in the NWHI is declining at approximately 3.9% per year. The proximate cause of this decline is reduced juvenile survival. For the species to recover, survival rates must increase. Figure 1 shows expected age-specific survival rates for each of the six main NWHI subpopulations based on the most recent 3 years of data (2004–2006). Note the dramatic decline in survivorship during the first few years.

The goal of envisioned captive care efforts is to increase juvenile survival to levels above those currently occurring in the wild population. The magnitude of improvement in survival achieved will be the difference between natural survival and survival of treated seals. Thus, the biggest difference may be achieved at sites and locations where natural survival is lowest, such that the ability to predict where and when survival is likely to be low would be valuable. This section summarizes information about temporal and spatial variability in juvenile monk seal survival, and, importantly, predictability of survival rates.

Variability in Juvenile Survival

Survival from birth to weaning is estimated by simply dividing the number of pups known to have weaned by the number known born. Survival during the typical 5–6-week nursing period tends to be quite high (> 0.90) at all sites except French Frigate Shoals (FFS), with occasionally lower rates at some sites (Fig. 2). At FFS, survival to weaning has been generally declining since at least the early 1990s, with many losses attributed to Galapagos shark predation in recent years.

A thorough analysis of monk seal survival rates is presented in Baker and Thompson (2007), and much of the following is drawn from that work. Baker and Thompson (2007) grouped consecutive ages that had equivalent survival rates so as to better characterize spatial and temporal variability. They found that individual subpopulations revealed similar patterns in age-specific survival, characterized by relatively low survival rates from weaning to age 2 yrs, intermediate rates to age 4 yrs, and then relatively high “mature” survival rates until age 17 yrs, after which a senescent decline was observed. Juvenile, subadult, and adult survival rates all varied significantly over time. Trends in survival among subpopulations were coherent with their relative geographic positions, suggesting regional structuring and connectedness within the archipelago. Survival rates for different age classes tended to be positively correlated, suggesting that similar factors may influence the survival for seals of all ages.

The temporal-spatial patterns found are depicted in Figure 3, which shows that for most age groups temporal trends in survival at FFS were geographically distinct. Laysan Island (LAY) and Lisianski Island (LIS) tended to group together (except the youngest age group at LIS), and Pearl and Hermes Reef (PHR), Midway Atoll (MDY) and Kure Atoll (KUR) tended to vary in synchrony.

For the purpose of designing interventions to improve survival, it may be more appropriate to examine each subpopulation and the first 2 yrs post-weaning separately. Figure 4 shows capture-recapture estimates of survival for the six main NWHI subpopulations from weaning to age 1 yr and from weaning to age 2 yrs. It is clear that annual variability in juvenile survival rates is high and can vary dramatically from one year to the next. The result of this variability over the long term has been jagged age structures with gaps resulting from poor surviving cohorts (Fig. 5). The 2005–2006 period at LAY is a dramatic indication of how juvenile survival rates can change rapidly. For that period, estimates of survival to ages 1 through 3 yrs were the lowest of any year on record (Fig. 6).

Predictability Using Environmental Indicators

While the variability in juvenile monk seal survival is high, the drivers of that variability have only recently begun to be identified. Cumulative evidence suggests that food limitation is a primary cause of fluctuating rates, but how food availability is mediated over time and space remains largely unknown. Antonelis et al. (2003) found that pups born at LAY and FFS in El Niño years had larger weaning girths than in non-El Niño years. There was also a tendency for pups born in El Niño years at FFS to have higher first-year survival, though this trend was not observed at LAY. More recently, Baker et al. (in press) report a significant relationship between juvenile survival in the western NWHI subpopulations and a large-scale oceanographic feature called the Transition Zone Chlorophyll Front (TZCF). The TZCF separates the vertically stratified, low surface chlorophyll subtropical waters and the vertically mixed cool, high chlorophyll Transition Zone waters. The TZCF annually migrates more than 1000 km in latitude, and its southern extent in winter varies. Baker et al. (in press) hypothesized that when the front migrates southward, it brings colder, more productive waters into monk seal foraging habitat, thereby enhancing the prey base and, consequently, survival. They found a statistically significant nonlinear relationship between the winter position of the TZCF and survival of monk seals through 4 years of age at the most northerly atolls (Fig. 7). Survival was poorer when the front remained farther north. The relationship was strongest following a 1- or 2-year lag, perhaps indicating the time required for enhanced primary productivity to influence the food web and improve the seals' prey base. No such relationship was found at subpopulations located farther south or among adult animals at any site. Variation in ocean productivity may mediate prey availability in monk seal foraging habitat and consequently influence juvenile survival in the northern portion of their range. While this relationship has considerable variability around it (Fig. 7), the time lag involved may be useful in that the position of the TZCF may provide some advanced warning of years when we may expect very low survival at particular sites.

Indicators from Monk Seal Parameters

Girth

Average girth and length of monk seal pups at weaning is another potentially useful but variable parameter (Figs. 8a,b). Craig and Ragen (1999) demonstrated a significant relationship between body condition at weaning and subsequent survival of monk seals. They also found that this relationship varied over time and between sites. Analyses currently underway with larger datasets from all six main NWHI subpopulations confirm Craig and Ragen's (1999) findings. In short, pups that wean larger (best indicated by girth measurements) have higher post-weaning survival, and this relationship has no upper asymptote within the range of weaning sizes observed. However, it should be noted that as Craig and Ragen (1999) found, this relationship varies over time and space. That is, we can conclude that a larger pup will have a better chance of surviving than a smaller pup in the same subpopulation in the same year. But that is not to say that given a pup's girth measurement, we can predict its survival rate reliably. Even less certain is predicting cohort survival given mean pup girth. Figure 9 shows scatter plots of cohort mean weaning girth versus cohort survival from weaning to age 1 yr. While in most cases some positive correlation is evident, these relationships are noisy and have weak predictive value.

Autocorrelation

Analysis of autocorrelation indicates how correlated a time series is with itself after increasing time lags. Figure 10 shows autocorrelation plots of survival from weaning to age 1 yr for all six NWHI subpopulations. The autocorrelation coefficient (ρ) varies between 0 and 1 (analogous to the correlation coefficient, r) and equals 1 when the time lag is zero. Figure 10 indicates that post-weaning survival to age 1 in a given year is a poor predictor of how the next year's cohort will fare. The highest autocorrelation was observed at FFS, and this is likely a result of the long-term general decreasing trend in survival at that site.

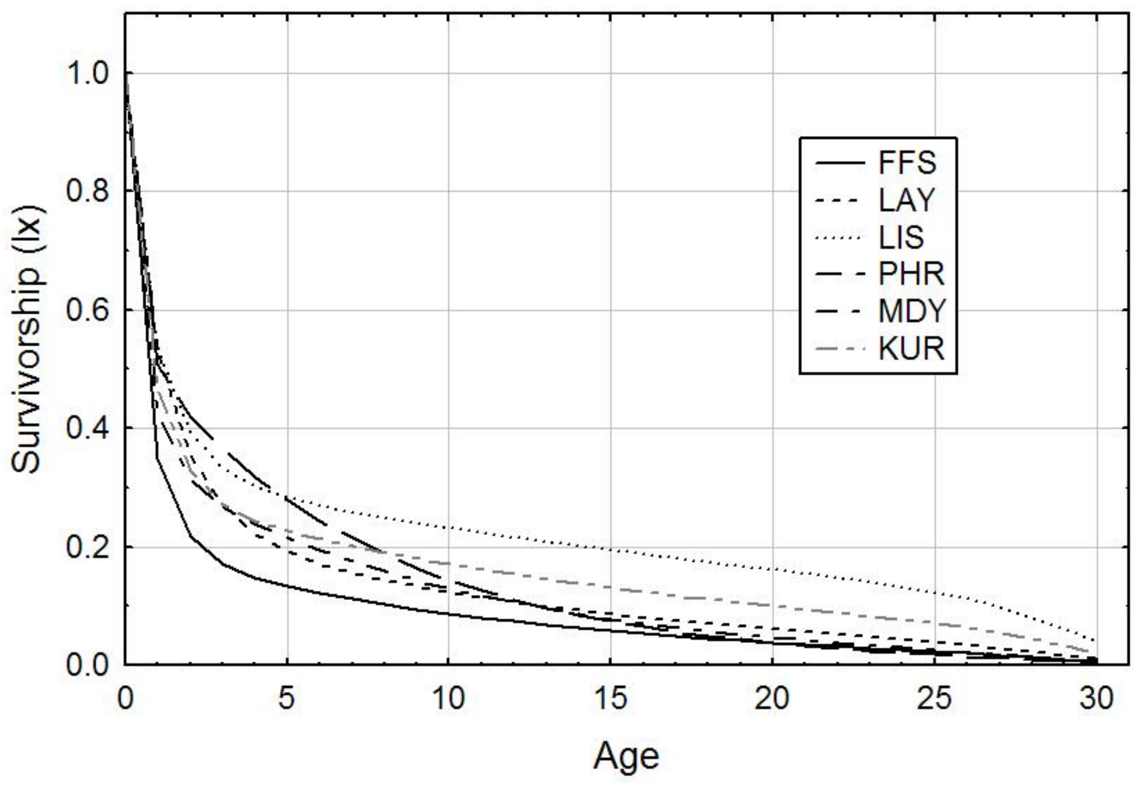


Figure 1.--Expected survival to age (l_x curves) for monk seals at the six main NWHI subpopulations based on 2004–2006 mark-resighting data.

Conclusions

Variable, but recently low, juvenile survival rates are driving the decline of monk seals in the NWHI. There is evidence of regional structuring of the environment and connectedness among proximate subpopulations. Some environmental factors and body condition correlates to juvenile survival rates have been identified, but the desired level of predictability of those rates at all sites has not been achieved.

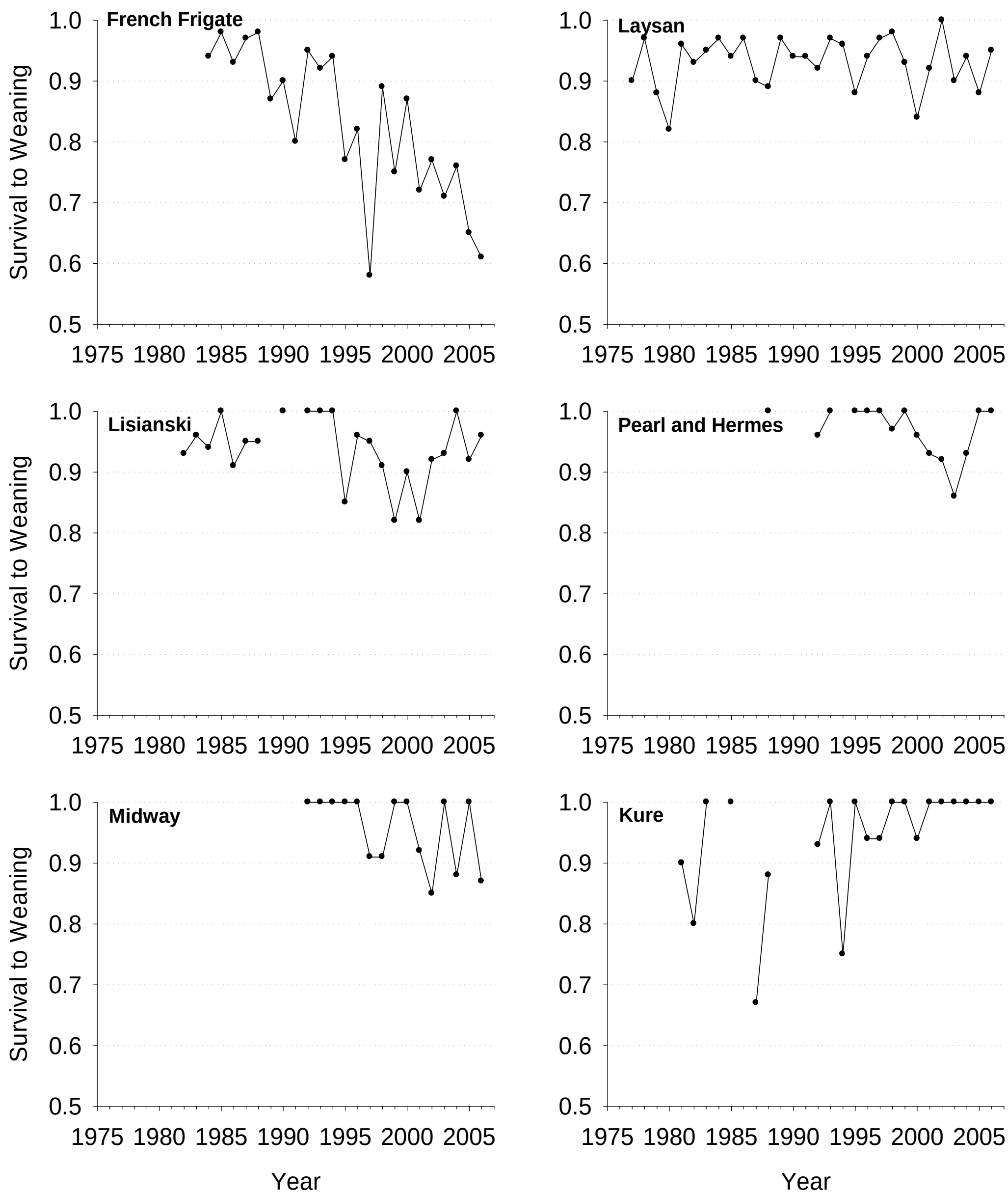


Figure 2.--Survival rates of monk seal pups from birth to weaning at six NWHI subpopulations

.

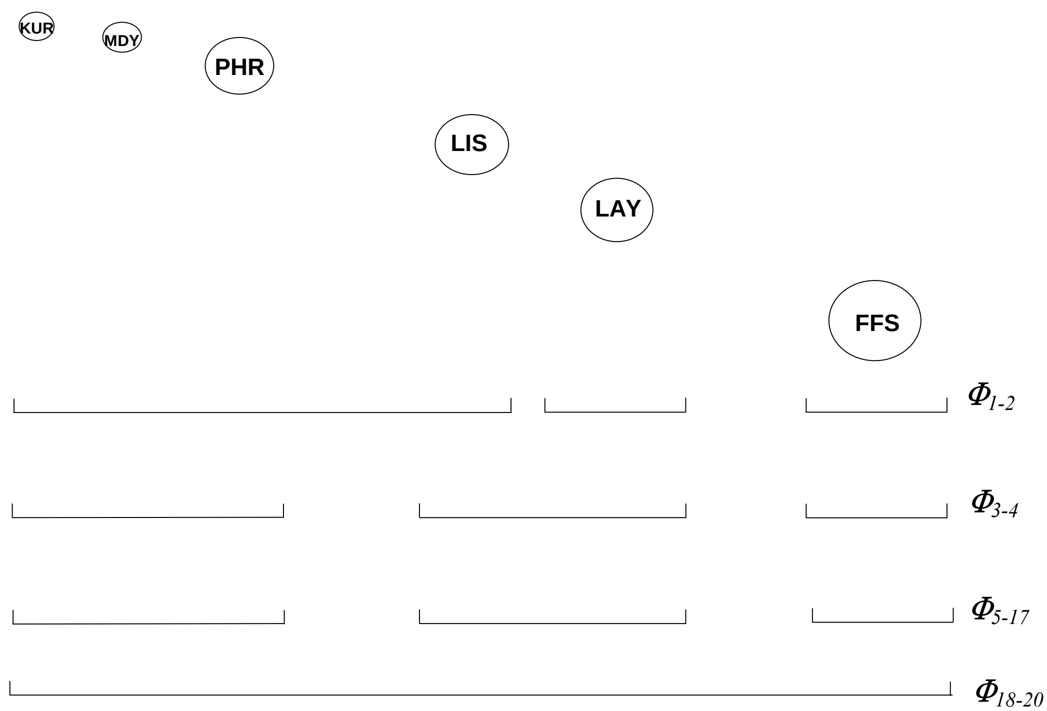


Figure 3.--Spatial patterns in survival of Hawaiian monk seals at six Northwestern Hawaiian Islands subpopulations (based on Baker and Thompson, 2007). Brackets indicate subpopulation/age group combinations with indistinct survival rate trends. Survival rate (Φ) subscripts indicate age groups. FFS = French Frigate Shoals, LAY = Laysan Island, LIS = Lisianski Island, PHR = Pearl and Hermes Reef, MDY = Midway Atoll, KUR = Kure Atoll.

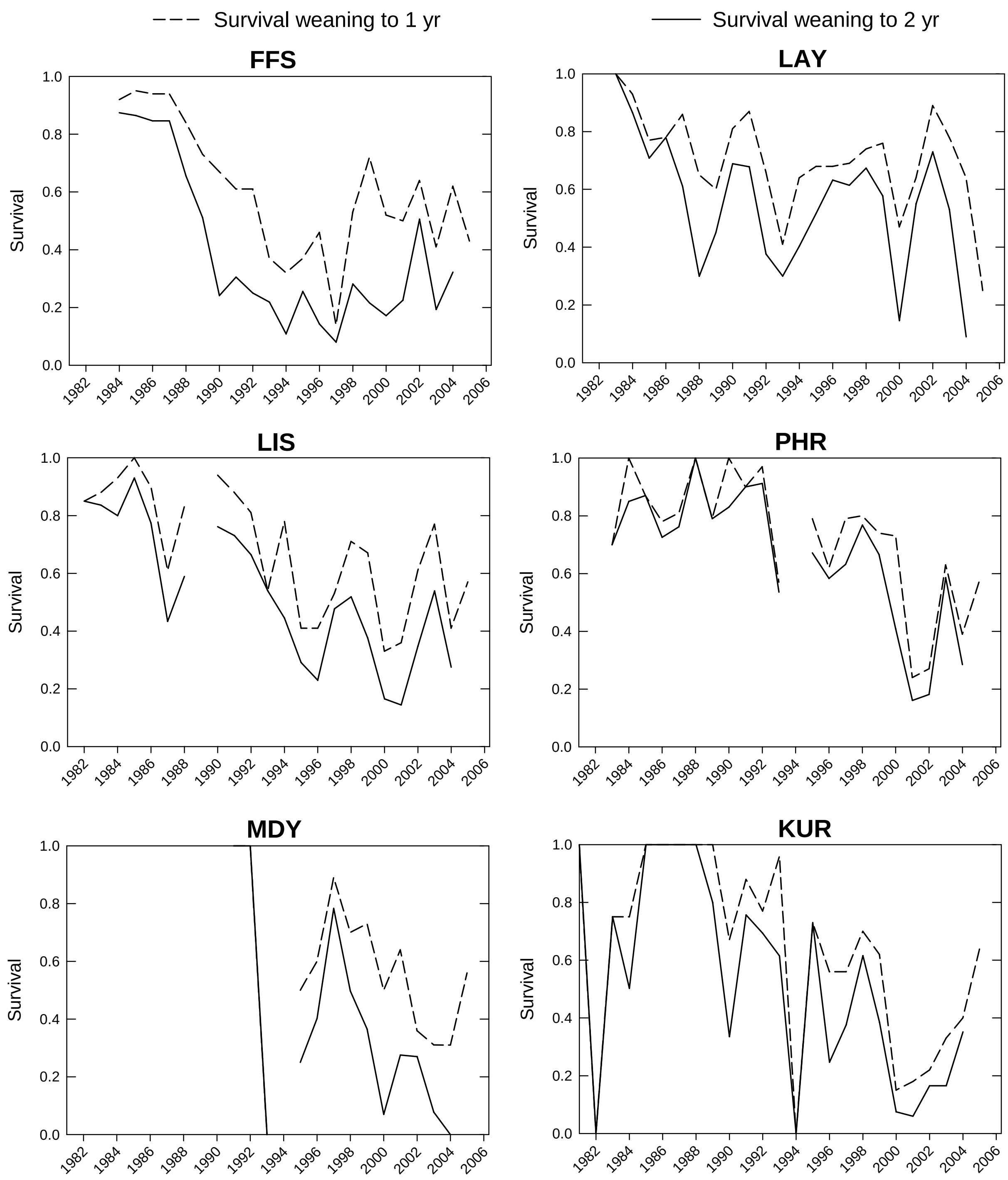


Figure 4.--Cohort survival of monk seals from weaning to ages 1 and 2 years.

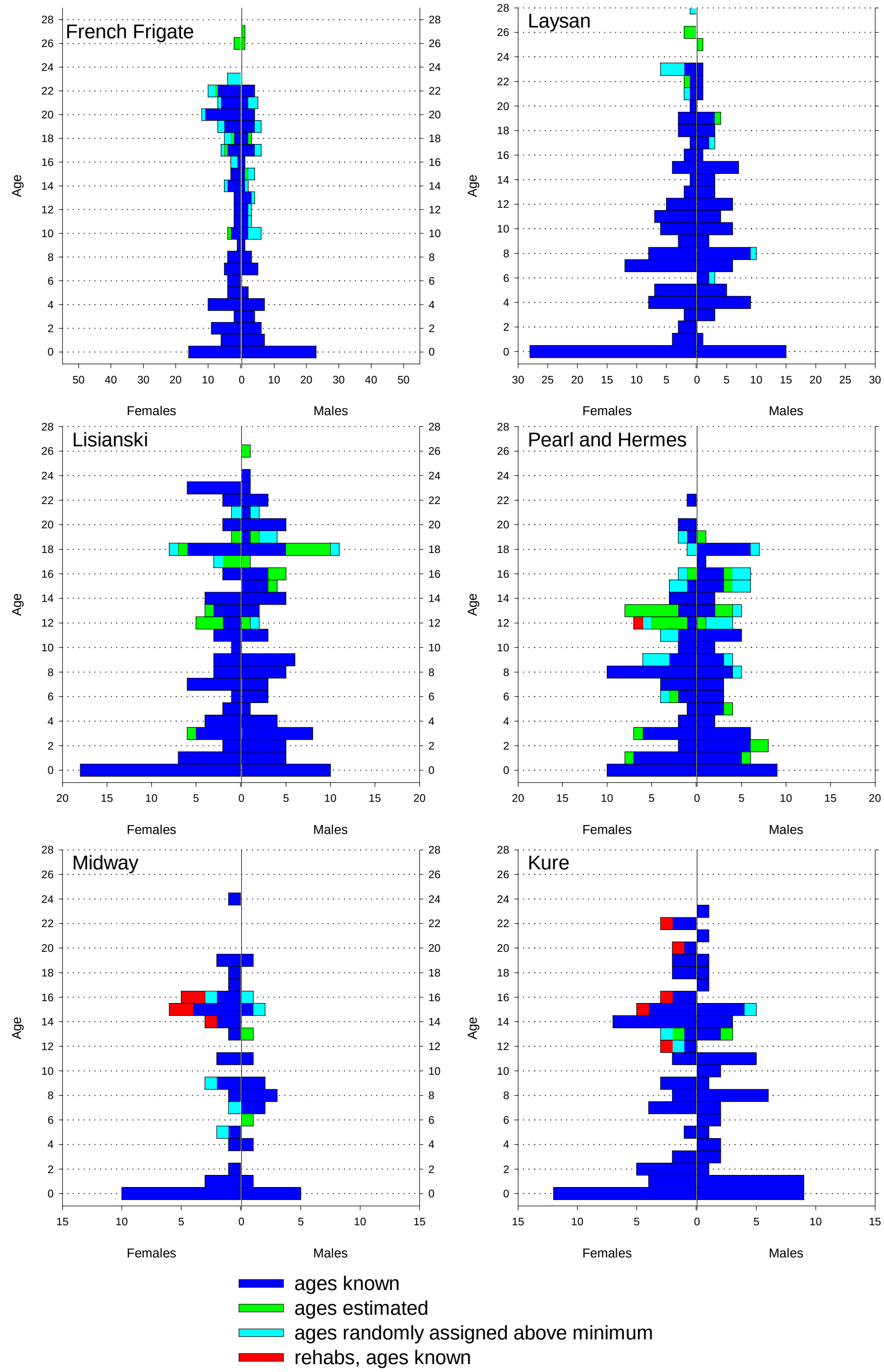


Figure 5.--Age structure of Hawaiian monk seal subpopulations in 2006.

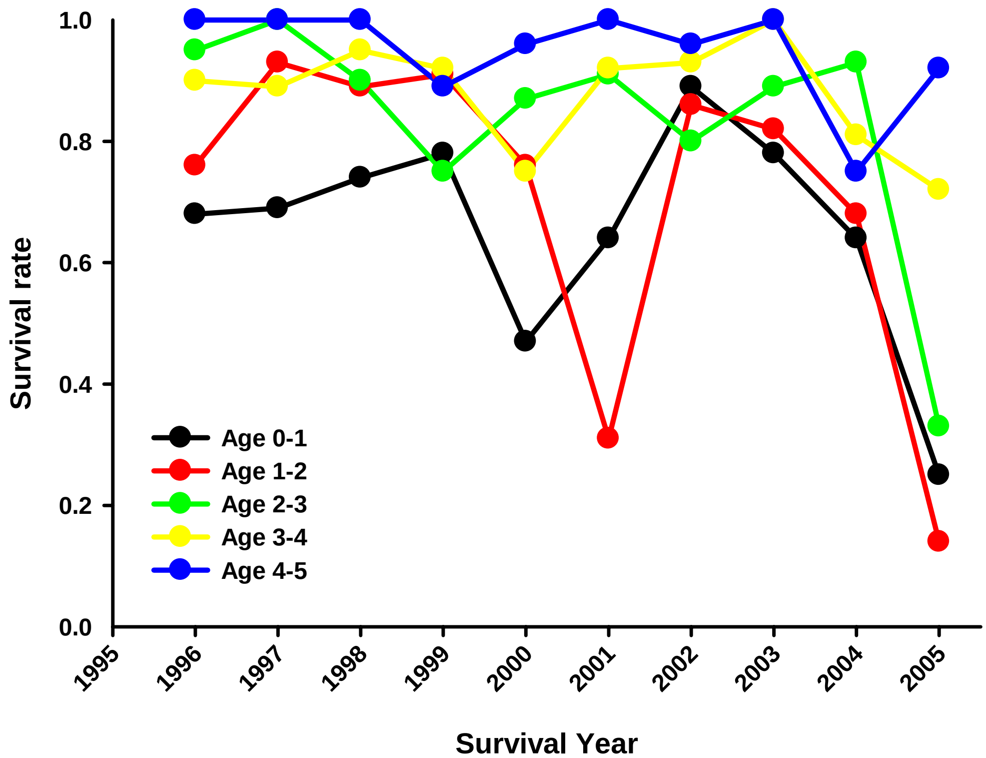
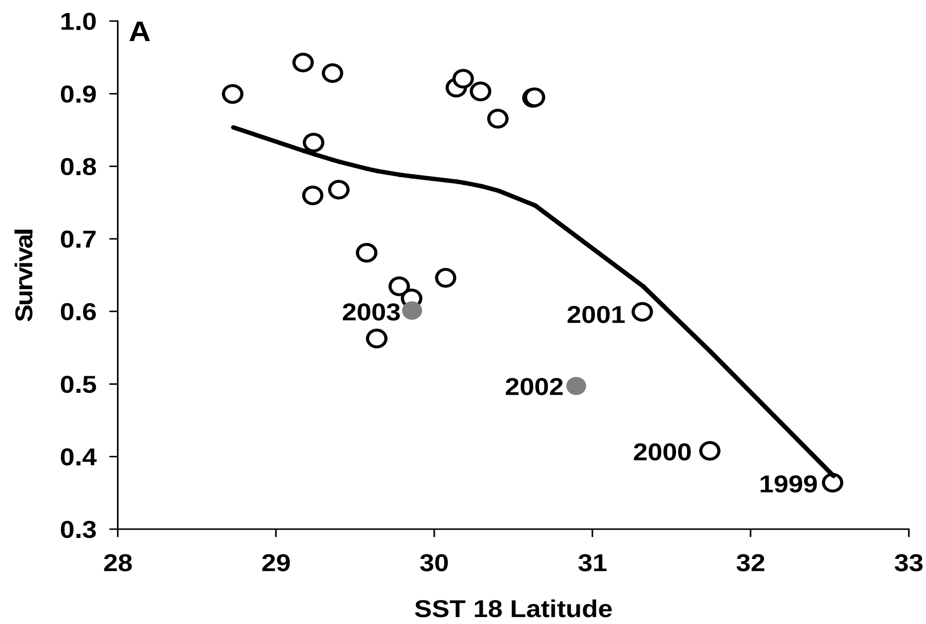


Figure 6.--Historical age-specific survival rates through age 5 yrs at Laysan Island, showing the extremely low rates through age 3 yrs from 2005 to 2006.



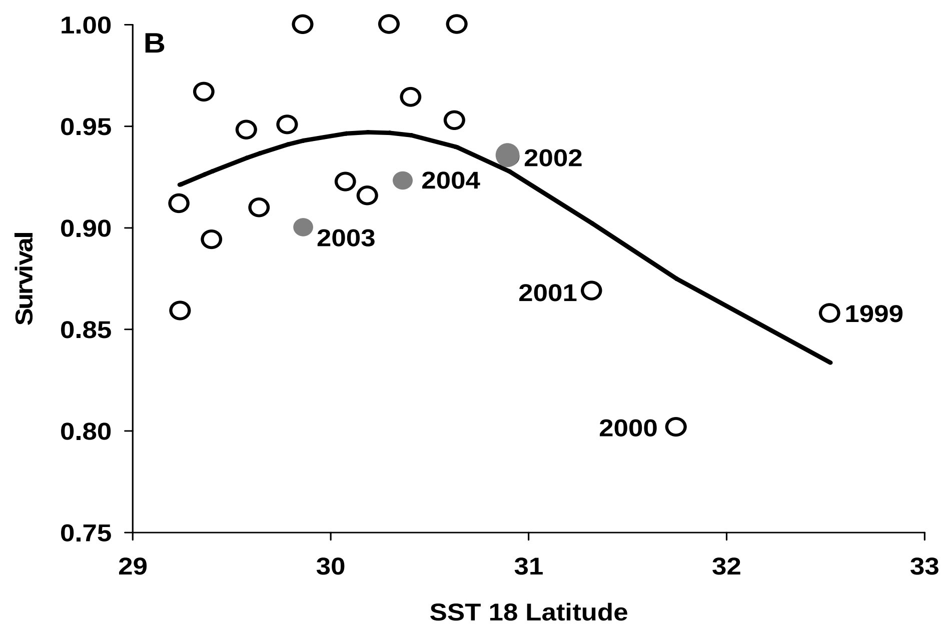


Figure 7.--Relationship between the southernmost wintertime latitude of the Transition Zone Chlorophyll Front (TZCF, as indicated by the 18 °C sea surface temperature isotherm) and survival of Hawaiian monk seals lagged by (A) 2 years for first and second year seals at LIS, PHR, MDY and KUR, and (B) 1 year for third and fourth year seals at PHR, MDY and KUR. Solid lines represent generalized additive model (GAM) fits. The consecutive years (1999−2001) when the front remained farthest north are identified. Solid gray points indicate the TZCF's position in 2002–2004 and recent preliminary (minimum) survival estimates lagged as noted above. (Baker et al., In press)

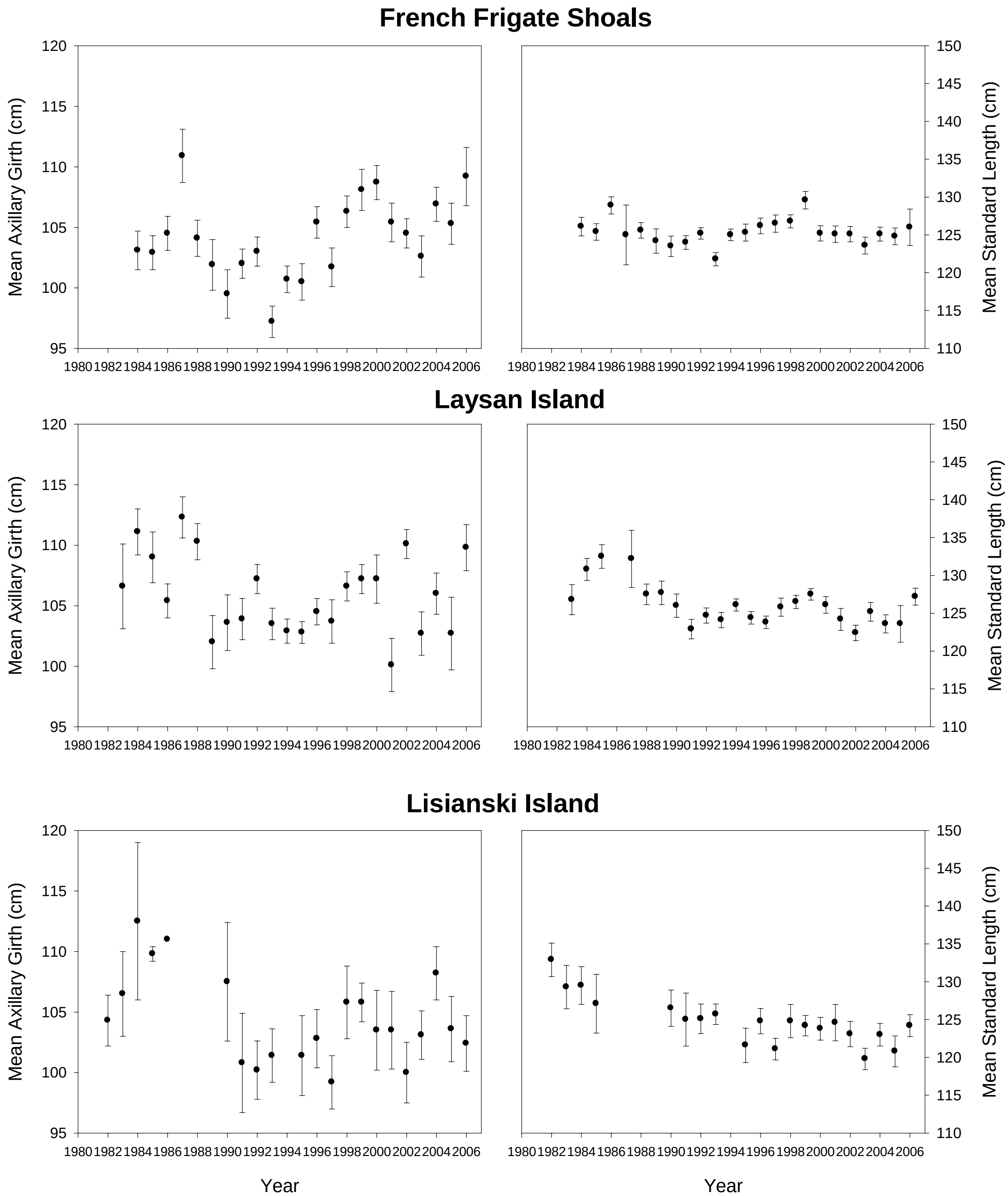


Figure 8a.--Mean girth and length (±1 s.e.) of Hawaiian monk seals within 2 weeks after weaning. Data for FFS, LAY and LIS are shown. Years with sample sizes less than 3 pups are omitted.

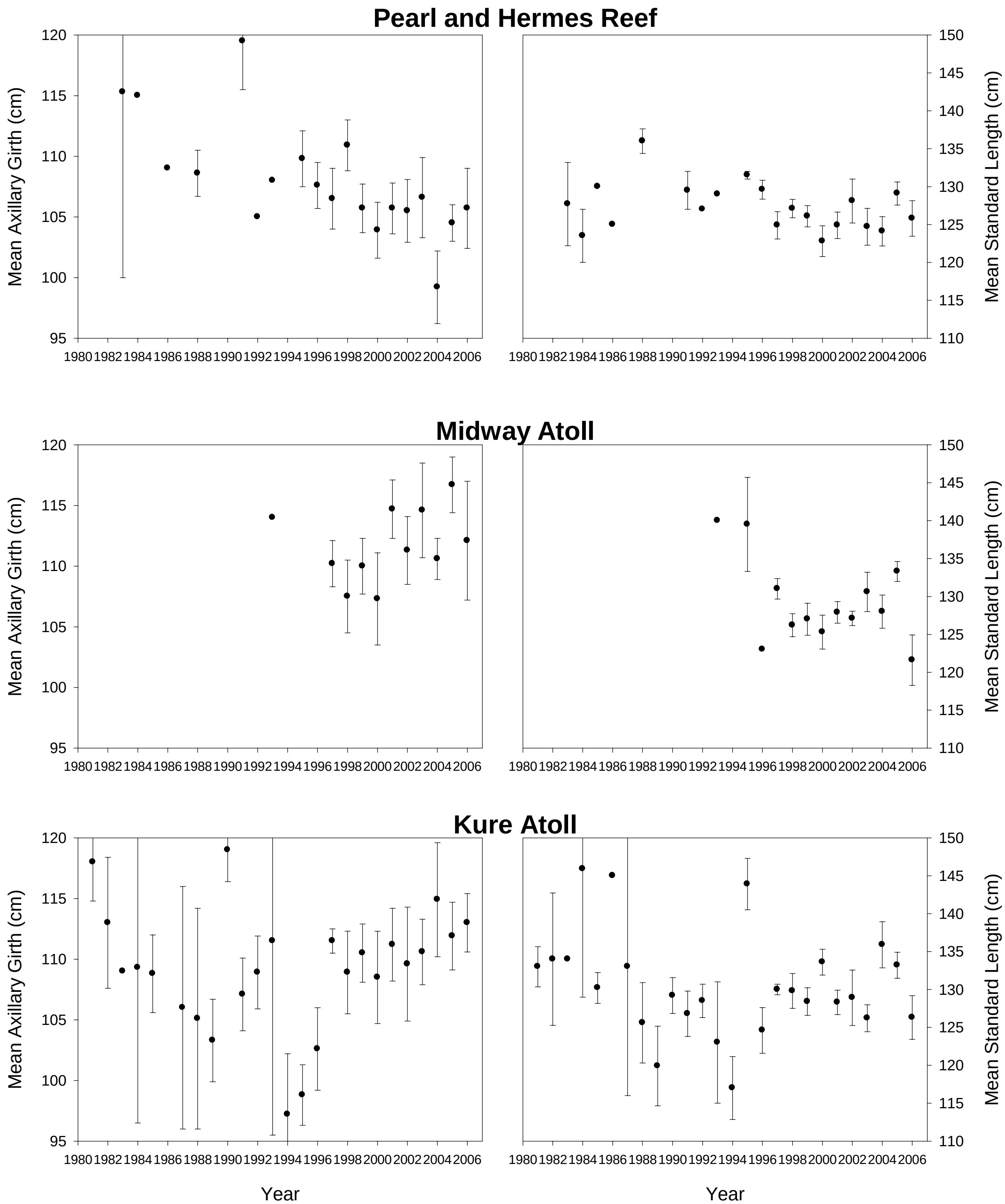


Figure 8b.--Mean girth and length (± 1 s.e.) of Hawaiian monk seals within 2 weeks after weaning. Data for PHR, MDY, and KUR are shown. Years with sample sizes less than 3 pups are omitted.

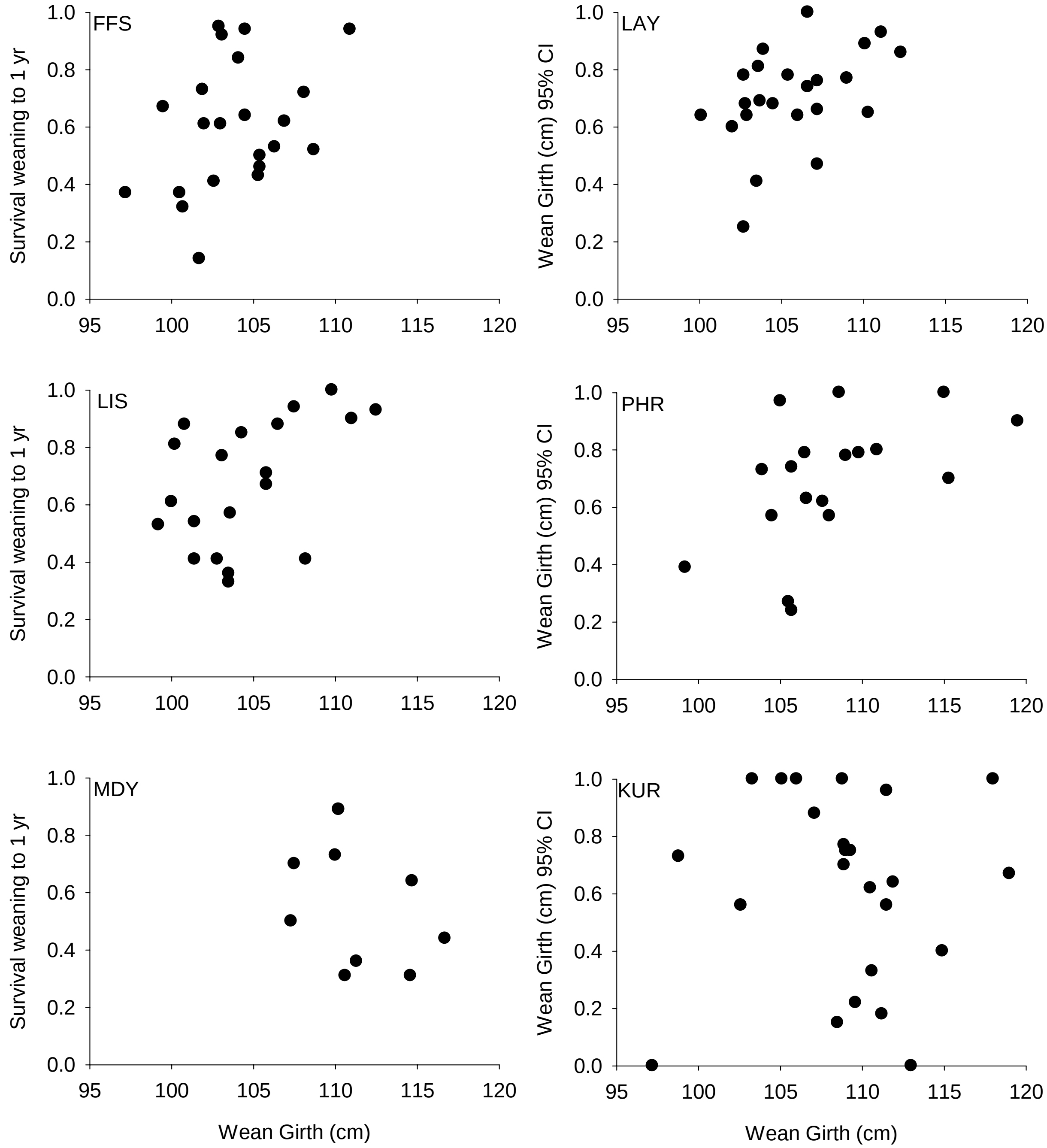


Figure 9.--Relationship between mean cohort weaning girth (cm) and survival from weaning to age 1 yr for six NWHI subpopulations. Girths were measured within 2 weeks of weaning.

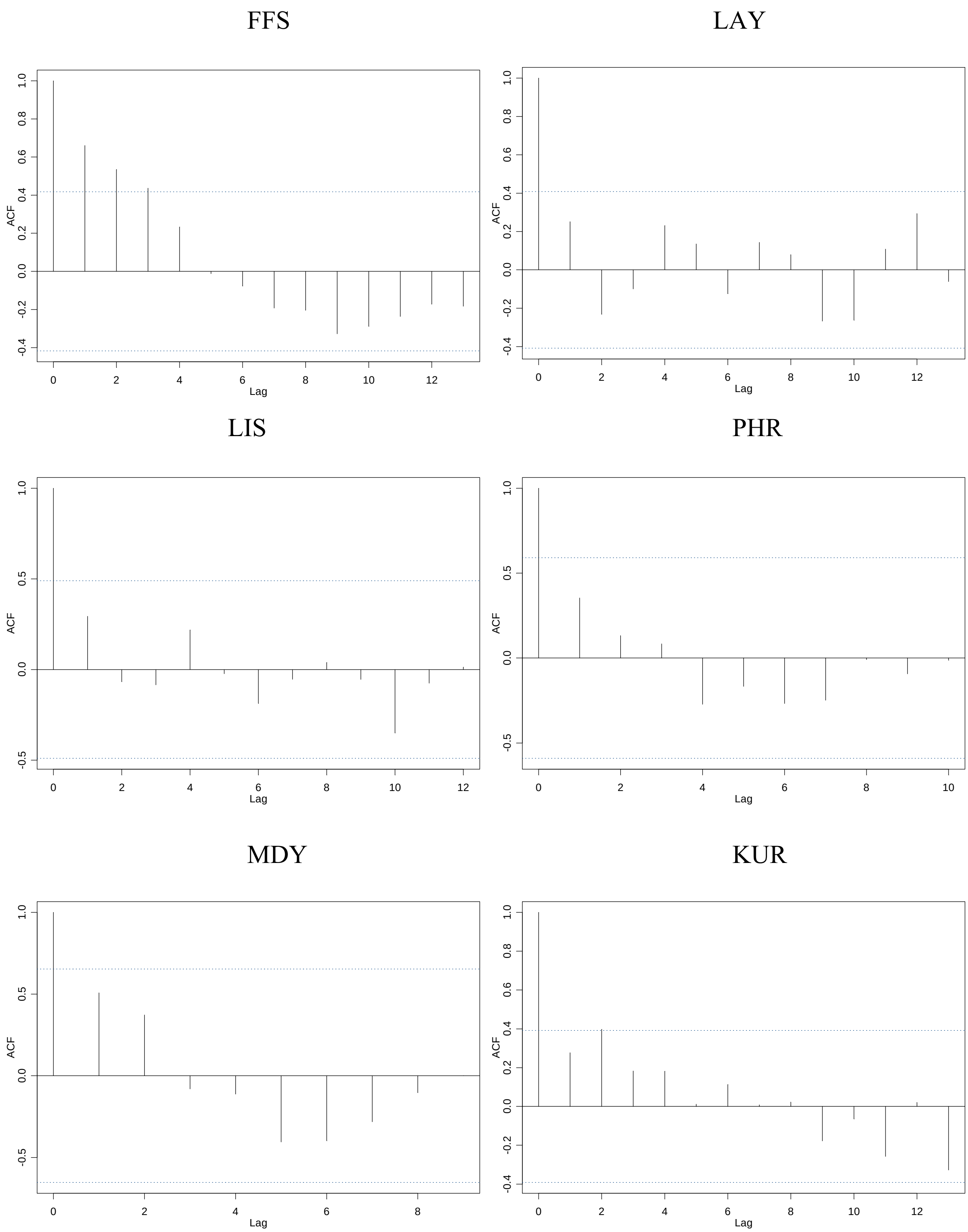


Figure 10.--Autocorrelation plots of survival from weaning to age 1 yr at six NWHI subpopulations. Values on *y*-axis are ρ (autocorrelation coefficients) after time lags indicated on *x*-axis. Where missing values occurred at LIS and PHR, the most recent years of consecutive survival estimates were analyzed.

HISTORY OF HAWAIIAN MONK SEAL CAPTIVE CARE EFFORTS

At KUR, in response to low recruitment of adult females into the monk seal population, a "head start" program was conducted by the NMFS Honolulu Laboratory (now PIFSC) during 1981–1991 to protect newly weaned females from shark injury and attacks by adult male seals. Thirty-two pups were collected within days of weaning and held in a large shoreline enclosure for 23 to 188 days. Food was offered only by introduction of live reef fish and invertebrate species into the water in the wire-screened enclosure. While held in the shoreline enclosures, the seals experienced a mean mass loss rate of 0.26 kg/day. No health problems were observed while the pups were in captivity. Average first-year survival of the penned native seals (85%) was the same as nonpenned seals.

In 1990, a direct translocation of five healthy, normal-size, weaned pups occurred from FFS to KUR. Within days of collection, the pups were placed in cages on a transport ship and taken to KUR where they were released in a "soft" manner by holding them for a few weeks in a fenced shoreline enclosure and offering them live local reef fish prey. A sixth translocation of a weaned pup from Oahu to KUR was conducted in 1991. Survival of these translocated seals was similar to KUR native-born seals for the first 2 years of life.

During 1984–1995, undersized weaned female pups and some ill juvenile seals at FFS were collected and transported to Oahu for captive feeding and other treatment. The goal of these efforts was to salvage the reproductive potential of juvenile females that were thought to have a relatively low chance of survival at FFS by fattening up and relocating them to the far western islands of KUR and MDY, where prey availability was thought to be greater. Collected seals were examined and screened for disease at capture and force fed until they were free fed. Most seals were given a soft release. Of 103 female seals collected, 16 seals (16%) died during rehabilitation, and nearly the same number were put into permanent captivity. In 1992, the effort was expanded to handle more pups (24) than had been treated in any previous year because more pups were known to be dying in the wild. In this case, post-release survival was well below average because the quality of treatment per individual was compromised. The pups collected in 1995 contracted an epidemic eye problem of unknown etiology, which caused blindness in all 11 pups and cessation of the rehabilitation effort. Resighting data suggest that the relocated seals have a greater propensity for movement away from the recipient atoll than native seals. In 2005 at KUR and MDY, the number of living seals that had undergone captive care or descended from those seals was at least 32 and more likely on the order of 45.

After an 8-year hiatus, captive care of Hawaiian monk seals was resumed in 2003 when a prematurely weaned female pup was cared for in a shoreline pen at MDY for 34 days. This pup was force and tube fed and never learned to free feed but gained 9 kg overall, representing a 21% increase in body weight. This seal was released on July 16, 2003, with a VHF tag. She was last sighted 112 days later on November 5, 2003.

In 2004, an effort termed "Second Chance," was attempted at FFS to provide nutritional support to undersized female seals 3–5 months post-weaning. Shoreline pens were maintained from November to February. However, no seals were collected because of time limits on the project and because no seal met the very poor body condition criteria that had been established for admission into captive care.

Two years later, in 2006, a similar project to provide nutritional supplementation to young female monk seals was scheduled for Autumn/Winter 2006–2007 at MDY. The birth of a rare set of twin female Hawaiian monk seals on MDY, both undersized at weaning and almost certain to die without intervention, prompted these efforts to begin 5 months earlier. The twin female seals were flown to Honolulu, Hawaii, and cared for at the PIFSC Kewalo Research Facility before being transported back to MDY at the start of the Midway Captive Care Project. Five other females were collected for inclusion in the captive care project on MDY: four weaners and one yearling. The twins and other seals collected on MDY were held in shoreline pens. All were fed a high-fat diet to encourage as much weight gain as possible prior to release. Six young-of-the-year seals gained weight commensurate with their duration in captivity, 89 to 297 days, with weight gains of 31 to 143% initial body weight, and were released in March 2007. The seventh seal, a female yearling, died from complications associated with stress 23 days after being admitted. To more thoroughly assess post-release behavior and survival, released females, along with three "control" seals that were not included in captive care, were instrumented with satellite-linked global positioning system (GPS) dive recorders, and VHF radio tags. At the time of the workshop, two of the captive-fed seals, the twins, and the three control seals, were still being tracked. The remaining captive care animals had disappeared and were believed dead.

Workshop Discussion: Key Lessons Learned from Previous Captive Care Efforts

The round table discussion by those familiar with and or directly involved in previous captive care efforts is summarized below:

- Animal selection is critical. Distinguishing between healthy but undersized versus ill animals determines the different requirements for treatment and associated risks. Intervention and treatment should address diagnosed problems with regard to emaciation, hydration, parasitism, nutritional state, and stress.

- Age and life stage are very important in determining likely challenges to be expected while holding animals. Captive care experience is greatest with recently weaned seals. Generally they transport well and adapt to captivity but can take quite a while to learn to free feed. Weaned seals with a few months experience of learning to forage required shorter periods of force feeding. Experience with juveniles suggests they have greater difficulty in captive management compared to pups. Emaciated juveniles with high parasitism appeared more stressed in captivity, responded slowly to treatments, and experienced higher mortality in captivity. A thorough study review of the 22 juveniles handled will aid in the development of adaptive protocols, which can be refined through small-scale future studies.

- Shoreline pens can be difficult to maintain and rapid erosion or accretion of sand compromise enclosures, allowing seals to escape. Environmental conditions (e.g., wind, rain, and ambient temperature) also make it difficult for care providers to attend to individual animal. Weather and sea conditions can disrupt feeding behavior at critical times. Remote locations limit diagnostic treatment and attendance of specialized medical expertise.

- Captive care at locations in the MHI, with release back to the NWHI, will require stringent disease screening and monitoring.

Workshop Discussion of the Monk Seal Captive Care Review Panel Report, Oahu, Hawaii, June 4, 1997

In response to the eye disease outbreak among seals brought into captivity for rehabilitation in 1995, a Hawaiian Monk Seal Captive Care Review Panel was established to review available information on the 10 monk seal pups then being held by the NMFS at the Kewalo Research Facility and the history of translocation of seals between island colonies. The committee made a number of recommendations, including:

- *The 10 seals currently held at the Kewalo Research Facility cannot be released into the wild. Efforts must continue to determine the infectious agent, if possible, and establish protocols for dealing with future outbreaks. Efforts should begin immediately to arrange for a non-NMFS facility that can care for the seals and provide opportunities for future critically needed research. If necessary, NMFS should undertake financial responsibility for maintaining these seals for a period of two years. If, at that time, the infectious agent has not been determined or there is no alternate facility willing to accept the animals for ongoing research, they should be humanely euthanized.*

- *At present, while focused research is being undertaken to identify other promising interventions, translocating, conditioning, and releasing of undersized pups from areas where the probability of survival is low to islands where it may be higher, appears to be the most useful intervention that can be implemented. Until it can be determined to be medically safe, no seals should be taken to Oahu for rehabilitation prior to reintroduction to the wild.*

The Marine Mammal Research Program (MMRP) PIFSC has since addressed these two recommendations. In 1998, the Honolulu Laboratory transferred 10 seals at Kewalo to Sea World of Texas where they are being held under a research and enhancement permitted program. Following eye disease problems in1995, an 11-year hiatus ensued in which guidelines did not allow seals to be brought from the NWHI to Oahu (the twin seals described above arrived on Oahu in 2006). During this interval, no reports of clinical signs similar to the eye problem which afflicted the seals in 1995 were observed among wild or captive seals.

The Review Panel further recommended the following four activities be conducted concurrently and supported by NMFS:

- *Continue annual high-resolution population assessment and monitoring of age and sex-specific annual survival of seals at all colonies.*
- *Conduct studies of foraging ecology, particularly of younger animals, food availability, and the role of local and ecosystem-wide environmental variations. Where and why pups die need to be determined.*

- *Efforts to define and characterize the medical conditions of Hawaiian monk seals in the wild that may lead to mortality and affect the success of translocation experiments should be enhanced and expanded.*

- *In addition, the captive seals should be used to conduct baseline studies of health, epidemiology, immobilization techniques, and reproductive biology.*

.

Annual research field camps have continued at all six main NWHI subpopulations, and the monk seal remains the subject of perhaps the most thorough long-term demographic study conducted for any marine mammal. In recent years, a number of related publications have appeared in the peer-reviewed literature, and a highly flexible, spatially implicit stochastic simulation model for the species has been developed (Baker and Thompson, 2007; Baker, 2004; Harting et al., 2007; Harting et al., 2004; Harting, 2002). Ambitious research programs on monk seal foraging behavior (Stewart et al., 2006, Parrish et al., 2000, 2002, 2005) epidemiology (Aguirre et al., 2007; Reif et al., 2006), and relationships between ecosystem variability and population parameters (Antonelis et al., 2003; Baker et al., in press) have also been carried out and published.

NWHI population assessment work includes field observations, sample collection (tissue, scat, spews, and other), as well as 8–12 necropsies a year. The necropsies have identified shark bites and negative energy balance as common afflictions. Endemic disease has been evaluated for a suite of potential pathogens at all six major subpopulations in the NWHI, and disease research is also underway in the MHI. To date, these studies have failed to reveal any pathogen or disease-related issues that would preclude translocation among breeding sites. The seals transferred to Sea World San Antonio have provided important information from research on fatty acid assimilation and a West Nile Virus vaccine trial.

In summary, while there is still much to learn about the causes of death, foraging behavior and ecological drivers of monk seal populations, the scientific basis on which to support renewed captive care initiatives has advanced a great deal during the past decade.

MAJOR ADVANTAGES OF VARIOUS ENHANCEMENT APPROACHES

During the workshop three general strategies for increasing survival of young females were discussed, and their strengths and weaknesses were assessed. The three primary activities are described below.

Long-term Captive Care in the Northwestern Hawaiian Islands

This strategy is similar to the efforts conducted at MDY during 2006–2007. It involves taking seals into captivity and keeping them in the NWHI, but not specifically at their natal atoll.

Captive care in this scenario would likely occur in shoreline pens; however, certain sites (FFS and MDY) have supporting infrastructure. On-site captive care offers the benefit of keeping NWHI monk seals in their 'native' environment, lessening disease concerns and reducing some of the logistical difficulties associated with other strategies. However, on-site care makes staffing and training difficult and shoreline pens are susceptible to storm surge and other threats.

Long-term Captive Care at a Central Facility in the Main Hawaiian Islands

A centralized captive care facility in the MHI would allow captive care and treatment of monk seals in a controlled setting with high quality medical equipment at relatively low cost. The facility would provide a relatively stable environment (e.g., water quality, controlled temperature, protection from environmental hazards) and would allow for easier coordination of medical treatment, supplies, staffing, and training. It would also be beneficial for public outreach. The facility would also be disease-secure to preclude, as much as possible, the introduction of diseases to seals. Transportation of seals to and from this facility, however, represents a significant logistical and financial hurdle.

Direct Translocation without Long-term Captive Care

Direct translocation involves the movement of seals from one location to another, with the potential of some minimal level of treatment between stages. The critical assumption in direct translocations is that animals are being moved to areas that give them a higher probability of survival relative to their site of origin.

Several scenarios were presented for potential translocations:

Within the NWHI: Higher survival rates for young seals could be achieved by moving them to areas with greater prey resources or lower levels of shark predation and other threats. Low foraging success of young seals appears to be a problem throughout the NWHI and raises concern about the appropriateness of moving animals within the NWHI. The islands of Necker and Nihoa may be appropriate release sites to consider for translocations within the NWHI.

Between the NWHI and MHI: The movement of seals from the NWHI to the MHI either permanently or temporarily (e.g., for the first few years of life before being returned to the NWHI) may be a desirable option for direct translocation. Girth and length at weaning of MHI seals is much higher than seals in the NWHI and generally, visual assessment suggests all age classes appear in better condition in the MHI compared to the NWHI. While survival rates in the MHI are uncertain based on insufficient monitoring effort, the condition of animals and apparent population growth suggest the habitat is highly favorable. However, there are several issues of concern that must be taken into account when moving seals from the NWHI to MHI. The first is the threat of potentially spreading pathogens between the MHI and NWHI populations if animals are moved with the expectation that after one or more years of free feeding they will be returned to the NWHI. There are also political, social, and legal considerations in supplementing the growing population of seals in the MHI with NWHI animals. It is critical that if direct translocation to the MHI is pursued, steps must be taken now to facilitate this option.

Between the NWHI and Johnston Atoll: Johnston Atoll has been a translocation destination site for monk seals on multiple occasions in the past. No seals are currently known to be at the atoll, raising questions on the suitability of the location for creating either a new subpopulation or temporary feeding area for juvenile animals. However, monk seals do naturally occur at Johnston Atoll sporadically. More research on the atoll's suitability may be needed.

KEY CONSIDERATIONS IN THE DESIGN AND EVALUATION OF CAPTIVE CARE PROJECTS

The Concept of Age-Specific Reproductive Value (v_x)

The benefit derived from a particular captive care intervention is primarily a function of:

- Number of animals treated
- Magnitude of the benefit conferred on a per-capita basis
- Age or life history stage of the treated animals and their intrinsic value to the population

The relevance of the first two items in determining the outcome of an intervention is clear, while the significance of the last item may be less apparent. By default, much of the attention for monk seal captive care and other interventions are focused on pups. This arises primarily because pups have inherently low survival in the wild and, therefore, captive care is hypothetically capable of awarding a substantial survival boost to pups. Pups are also relatively abundant and easy to capture and handle as compared to other age classes. Finally, protocols for pup captive care have been explored and refined during the previous efforts described above. Whether or not pups are the optimal age class for intervention remains an unresolved question.

Certain demographic descriptors can provide useful information for assessing the relative benefits of selecting different age classes for intervention. One such descriptor is age-specific reproductive value (v_x). This parameter conveniently summarizes a seal's likely contribution to the population throughout the remainder of its expected lifespan. It incorporates information on both the likelihood of survival to each reproductive age as well as the expected reproductive output of an individual of age x and all future ages. The reproductive value v_x is scaled in units of newborn equivalents and is, therefore, most useful for comparing the relative value of seals of different ages within a given subpopulation (Table 1; Fig. 11).

Table 1.--Reproductive value for ages 0–10 at the six primary breeding sites in the NWHI, based on survival rates from the last 3 years.

Age	**FFS**	**LAY**	**LIS**	**PHR**	**MDY**	**KUR**
0 (pups)	1.00	1.00	1.00	1.00	1.00	1.00
1	2.63	1.79	1.85	1.89	2.26	1.53
2	3.89	2.55	2.52	2.15	2.84	1.87
3	4.55	3.18	2.97	2.30	3.08	2.11
4	4.83	3.64	3.25	2.45	3.22	2.31
5	4.93	3.98	3.45	2.61	3.33	2.50
6	4.95	4.20	3.59	2.76	3.42	2.69
7	4.92	4.31	3.70	2.87	3.47	2.83
8	4.84	4.25	3.76	2.88	3.42	2.87
9	4.72	4.04	3.74	2.78	3.25	2.79
10	4.54	3.75	3.62	2.62	3.03	2.65

The value of v_x increases from 1.0 at birth (by definition) until the age of full reproductive maturity (age 7–10 in the monk seal). Thereafter, v_x decreases annually as the total number of pups a seal is likely to bear in the future decreases. The maximum value of v_x and the rate of change from birth to maturity are inversely related to a female's survival prospects from birth through becoming a subadult. For example, at FFS where pup and juvenile survival is lowest, a 5-7-year-old female is equivalent to nearly 5 FFS pups, while at the western end of the archipelago, a mature seal is worth only about 3 pup equivalents.

Because the most likely candidates for captive care are pups and yearlings, the most interesting application of v_x for captive care intervention lies in the relative value of yearlings as compared to newborn seals. The value of a yearling ranges from 1.5 newborns at KUR to 2.6 newborns at FFS. A simple interpretation of this is that preserving a yearling at FFS is demographically equivalent to preserving more than 2½ pups. That observation alone might lead us to the erroneous conclusion that all captive care intervention should be focused on yearlings. However, v_x does not incorporate information on the other two factors that determine the benefit of an intervention: the number of seals that are handled and the quantity of benefit that can be conferred on each seal. That is, given the low pup survival at most sites, there may be insufficient numbers of yearlings available to provide a large net benefit to the population. Also, because yearlings now have 60–85% annual survival, the maximum amount of benefit that can be conferred on them is less than the maximum benefit that can be conferred on pups, of which only 40–50% now survive in the wild. Optimizing a captive care program requires that each of these factors (number of seals, per-capita benefit, and intrinsic value) be strategically balanced.

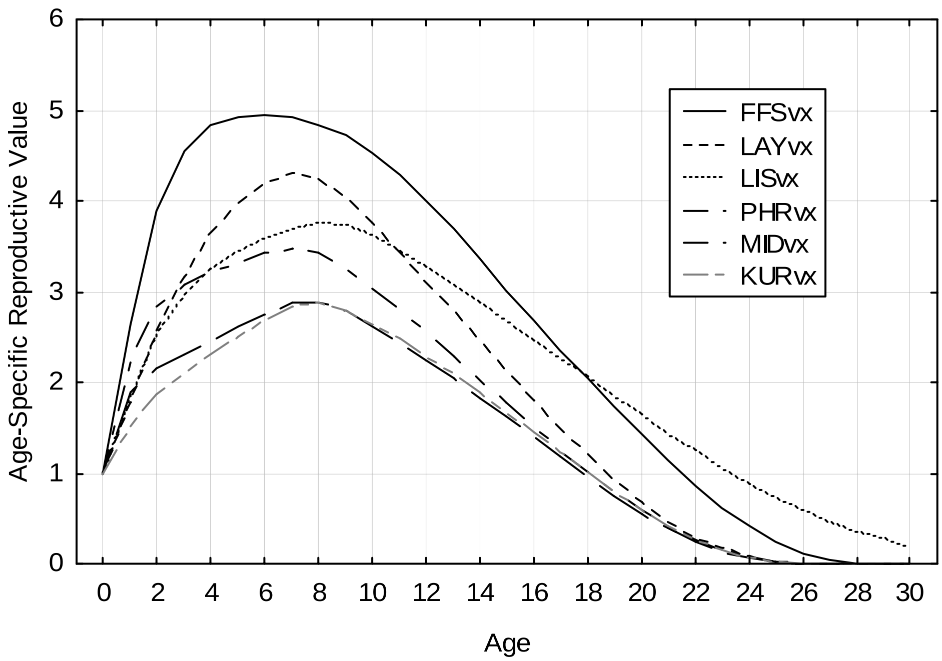


Figure 11.--Age-specific reproductive value (v_x) for female monk seals at the six primary breeding populations in the NWHI.

Program Assessment and Post-release Monitoring

Aspects of Project Assessment

Because the optimal approach for achieving higher juvenile monk seal survival is not known, interventions must be designed and carried out in an experimental fashion and properly assessed and altered if necessary. This section discusses project assessment on several levels. To begin, it is useful to think of three distinct aspects of assessing monk seal captive care interventions:

- Feasibility—Capable of being done, effected, or accomplished.
- Efficacy—Capacity for producing a desired result or effect.
- Efficiency—The ratio of the output to the input of any system.

An example of assessing the feasibility of a captive care project is determining whether we can raise prematurely weaned pups to a healthy weaned condition. Next, assessing efficacy would, for example, determine whether prematurely weaned pups that have experienced captive care survive better than those left untreated. Here, the focus is on the desired result or effect, i.e., increased survival. Finally, assessing efficiency might involve determining whether, given constraints of funding, infrastructure, logistics, and personnel, we achieve more by treating premature weaners, older weaners, or juveniles. As with efficacy, the focus of efficiency remains on the outcome (survival), but instead of evaluating whether a single approach works better than doing nothing, here we compare multiple approaches.

Experimental Design

To assess efficacy (and efficiency) of captive care, the project must be designed and conducted in a rigorous experimental fashion. This will allow us to answer the fundamental question: Did treated animals have a chance of better survival than they would have otherwise (i.e., if they had not been subject to captive care)? Control animals need to be identified from the time that any captive care effort begins and is monitored thereafter. Monitoring to assess survival of treatments and controls will be achieved through the standard resighting surveys conducted by the Hawaiian monk seal population assessment program each year. More in-depth monitoring of movements and at-sea behavior will be achieved through telemetry (see below).

The rigor applied to experimental design will necessarily be constrained by issues associated with logistics and the available sample sizes for analysis. For example, the best designed experiment would involve treatment and control seals being identical in all aspects except that one group is subject to captive care and the other is not. Further, ideally individuals would be randomly assigned to these two experimental groups and treatment of each seal in captive care would be identical. In practice, this will not prove possible or even desirable in all cases. For example, the goal of captive care is to improve survival, particularly of female seals. Owing to the small number of females available, during the 2006–2007 captive care project, all surviving female pups born at MDY were brought into captive care, whereas males (and one female born at KUR) were assigned as controls. While less than ideal, this was agreed acceptable because other research has indicated no sex differences in survival of monk seals (except at FFS). Similarly, it would have been ideal if each captive care animal was taken in at the same age and in the same condition, but both logistical and biological realities precluded this. Thus, we must recognize that it will never be possible to adhere to an idealized experimental design. However, we must in all cases endeavor to apply as rigorous an experimental design as practicable. For example, even when variables such as age and condition at admittance and duration and details of captive care treatment vary among individuals, this nonhomogenous group can still be compared to a control group. In this way, we can still assess the efficacy of a project. However, lumping individuals with differing treatments weakens our ability to resolve why a particular approach did or did not succeed.

Post-release Monitoring

The post-release monitoring of control and captive-fed seals is critical for determining the effectiveness of the captive care program. Monitoring can be considered at two time scales, short- and long-term, and these are both discussed more thoroughly in the following section. Here we focus on the techniques of monitoring seals immediately after release into the wild. Short-term monitoring will involve the use of telemetric instrumentation and will aid in determining at-sea movements, foraging behavior, and potentially, mortality. Comparisons of foraging behaviors (dive effort, trip duration, distance traveled, etc.) will be used primarily to assess whether captive-fed seals are behaving ‘normally’ relative to control seals and other seals studied previously.

Two basic types of instrumentation will be used in this project: VHF transmitters and dive/location recorders. The VHF transmitters will provide the ability to identify individual animals’ presence/absence on an island and allow researchers to locate each seal when desired (for photo-documenting condition or recapture, etc.). The foraging behavior of captive care and control seals will be recorded using some variant of location/dive recorder technology. The Midway captive care program used Wildlife Computer MK-10 (Mark 10) GPS dive recorders which provide high resolution GPS location data and dive behavior. At a minimum, the telemetry instrument should provide reasonably accurate locations and dive summary information remotely (i.e., through the Argos satellite system). For planning purposes, it should be estimated that the cost of instruments, consumables, and satellite time would be around $7000 per seal.

Visual assessment of the condition of the seals should also be conducted after release. This is important to (1) determine whether further intervention for feeding or treatment for illness is appropriate, (2) evaluate varying body condition post release, as well as (3) provide information regarding likely causes of mortality. Standard qualitative condition codes have long been used for field surveys of monk seals: *F* = fat, *M* = medium, *T* = thin, *E* = emaciated (ribs visible, neck obvious). The subjective nature of these codes makes it useful to routinely collect photographs to document changes in body condition.

Metrics for Assessing Captive Care Efforts

Foregoing sections have discussed experimental design and post-release monitoring of captive care animals (and controls). These considerations are paramount for gathering reliable data to assess project success and, importantly, to help interpret why a given seal might have succeeded or failed. In this section, we consider the analysis phase of project assessment, specifically with regard to metrics that can be used to evaluate success.

It is important to identify the desired responses (short- and long-term, individual and population level) to be achieved through captive care intervention, along with the best metric(s) for quantifying that response. Because no single metric encapsulates all aspects of the desired responses, a tiered approach with multiple metrics is appropriate. Table 2 is a proposed list of responses and potential metrics. Details are described in the text that follows.

Table 2.--Summary of measurable responses and associated metrics for assessing captive care programs.

Response	Time scale	Biological scale	Metric(s)
Normal movement and foraging behavior	Short-term (months)	Individual or group (treatment vs. control)	Time-at-sea, dive depth, dive duration, time-at-depth
Foraging success	Short- to mid-term (≤ 1 yr)	Individual or group (treatment vs. control)	Body mass, girth, length, visual assessment of body condition
Survival	Short- to long-term	Individual, group (treatment vs. control), and population	Capture-recapture survival rate estimates
Population growth	Mid- to long-term	Population	"Realized" and intrinsic population growth rate (λ)
Reproductive potential	Mid- to long-term	Population	Population reproductive value (v_{pop})

The goal of captive care will be to facilitate reversing population declines and foster healthy monk seal populations. Those long-term goals depend on many factors in addition to captive care efforts. However, we require distinct metrics to assess interventions on various temporal scales and levels of biological organization. First, an entire suite of metrics associated with animal health will be required for animals in captivity and considered for release. These metrics are not in this document. Here we are concerned with results following the release of treated animals. As mentioned in the section on post-release monitoring, we will want to know whether both treated and control animals are behaving normally, (foraging, diving patterns) and whether their body condition is changing. While measures of these responses do not address the ultimate goal of captive care, they will provide great insight into what may have gone right or wrong. For instance, if animals fail to dive normally, become emaciated or remain healthy but sustain shark wounds, these observations may suggest very different types of modification to the applied protocols.

On a longer time scale we want to know whether captive care animals survive better or worse than controls. Again, this does not address whether the intervention will succeed in halting the population decline, but it does begin to address the efficacy of the approach.

The ultimate metrics are population abundance and growth rate. These metrics were used in an earlier analysis to help define the necessary scale for the captive care project (Harting and Baker, unpublished). That simulation analysis indicated that only a very large scale project in which all female pups were handled and awarded high survival, as both pups and yearlings would be sufficient to obtain a system-wide increase in seal abundance. Further, that finding required that, along with captive care, natural survival rates must improve to approximate those rates observed historically in the NWHI.

Here, we distinguish realized population growth rates from intrinsic population growth rates. The former reflects the projected change in abundance given the current age structure and vital rates, whereas the latter is the theoretical growth rate determined solely by the vital rates in the Leslie matrix (fecundity and survival). Detecting a statistically significant increase in either population abundance or either type of growth rate would likely require 10 or more years of intervention. In the interim, other metrics are needed to gauge the progress and benefits derived from captive care.

A primary objective of captive care is to maintain or increase the reproductive capability of the population. In this context, a variant on the concept of age-specific reproductive value, called "population reproductive value" (v_{pop}) provides an informative descriptor for evaluating the near-term returns associated with captive care. This parameter is the sum of the age-specific reproductive values for all of the females currently in the population. Greater numbers of females within the high v_x age classes (Table 1) translates into a higher v_{pop}. It is, then, essentially a measure of population vitality. Comparing v_{pop} with and without an intervention (or before and after it is applied), can inform us about the magnitude of the realized benefit in terms of stored reproductive potential in a population.

Risks and an Adaptive Approach

Workshop participants recognized that there are a variety of risks associated with all of the captive care scenarios being contemplated. Based on previous experience, some monk seals brought into captivity may become ill and die, disease may spread among the captive animals, or even if all the seals do well in captivity, they may yet suffer high mortality post-release. In addition to risks associated with the individual seals brought into captive care, there are potential hazards for the monk seal population at large. For example, there is some potential for captive care seals to acquire diseases in the MHI and spread them to the population in the NWHI on release. Also, we must consider the repercussions of removing females from one location and releasing them elsewhere. This could eventually lead to a male-biased sex ratio at the source location, a circumstance which, in the past, has been associated with increased male aggression at sites such as LAY and LIS. The potential also exists that releasing a significant number of seals may result in increased competition at the receiving site.

Many of these risks can be minimized and managed by careful planning, project and facility design, and adherence to proper protocols. However, it is unlikely that all such risks can be eliminated, especially those that are largely outside our control (e.g., post-release survival). It is therefore advisable that as many of these negative scenarios as possible are considered prior to inception of the project and that contingency plans for each project are well formed.

The initial stages of any captive care program will, in large part, entail experimentation to determine the best approaches and tools for increasing juvenile survival. That means that some suboptimal approaches will necessarily be tried, such that failures and setbacks are inevitable. An adaptive approach to the development of the captive care program is crucial in this regard. While experiments will be designed to statistically assess various treatments, we must be prepared to alter course based on short-term results, even if that occurs prior to achieving a statistically significant result at times. For example, if a certain approach results in a high percentage of animals dying, that trial may be suspended or altered. Conversely, if a method is yielding very positive results, sample sizes may be adjusted upward to obtain a definitive conclusion sooner.

Transportation and Logistics

The NWHI is an extremely remote archipelago, which means that cost and logistical constraints associated with conducting captive care operations will be considerable. Table 3 outlines information on distance from Oahu, vessel transit time (assuming roughly 10-kn speed), and on-site infrastructure.

Table 3.--Logistic and infrastructure characteristics of six NWHI monk seal subpopulation sites.

Location	Distance to Oahu (km)	Vessel transit from Oahu (days)	Air transport	Infrastructure
French Frigate Shoals	830	2	Small charter aircraft possible. 4 passengers, limited cargo.	Permanent Fish and Wildlife Service (FWS) station. On Tern I., ex-USCG barracks with solar power, augmented by diesel, reverse osmosis water maker, freezers, several bedrooms, communal kitchen, some storage sheds, dock w/powered davit. Power/water generation limits number of people and operations.
Laysan I.	1300	4	No	Permanent FWS tent camp. No other infrastructure.
Lisianski I.	1760	5	No	No permanent infrastructure.
Pearl and Hermes Reef	1900	6	No	No permanent infrastructure.
Midway Atoll	2100	6.5	Runways can handle aircraft to large passenger jets.	Permanent FWS station. Like small town. Power plant, water, jet fuel, telephone, internet, heavy equipment, houses, harbor, docks.
Kure Atoll	2300	7	No	Ex-USCG bldg w/ 3 rooms + kitchen. Seasonal State of HI field presence. Storage shed. Limited catchment water, no permanent power supply.

A detailed captive care project plan has not yet been formulated. However, simulations (Harting and Baker, unpublished) demonstrate that a sustained, large-scale effort will be required to improve population trends. For the sake of demonstration, then, let us assume a large-scale captive care effort will be mounted, the care of animals will be based on Oahu, and animals will be returned to the NWHI. Under this scenario, three key portions of the overall effort will involve NWHI logistics:

- Assessment and capture of subject animals
- Transport of animals from NWHI to MHI and return, including temporary holding at collection site
- Release and post-release monitoring

Below we characterize some of the requirements at each of these steps.

Assessment and Capture of Subject Animals

Annual monk seal assessment field camps occur roughly during June–August at each subpopulation during the peak of pupping season. The information available from the field camps (age and sex structure of populations) will be invaluable for near-term planning for captive care. However, most captive care scenarios tend to focus on the autumn/winter period, such that survey and capture of animals would likely require staging either extended camps or another entirely separate seasonal effort. In any case, just as with standard field camps, large amounts of equipment and supplies will be required, along with a complement of three personnel in single island (LAY and LIS) camps, and four personnel in multi-islet atoll camps (FFS, PHR, MDY, KUR) where boating is done. These numbers are based on the premise that safely capturing and moving animals within a site will require three people. At boating camps, a fourth person is required to serve as a safety measure to man a backup skiff. The time required to visually identify and assess all pups and juveniles varies among subpopulations, but probably ranges from a minimum of 2 weeks up to more than a month.

Any given subpopulation may have only a few candidates of up to more than a dozen seals for captive care in a given year. Each of these individuals will have distinct haulout patterns and, at some sites, will be spread over numerous small islets. Clearly, all desired candidates cannot be captured simultaneously for transport to a captive care facility. Therefore, either all animals will have to be captured one by one and held in advance of the arrival of a transport vessel (or aircraft), or the means of transport will have to arrive and stand by while animals are caught and brought aboard. The vessel or plane could also take a few seals at a time and return to pick up more seals periodically. In any scenario, there will be some delay while animals are accumulated. If the temporary holding is to be on land at the field camp, another whole set of requirements emerges. Holding pens will need to be erected and maintained and animals will need to be looked after and possibly fed, which would require animal care staff in addition to the previously mentioned field crews. If extended feeding is necessary, frozen fish may need to be delivered and maintained on-site, requiring a reliable refrigeration system.

Transport of Animals from NWHI to MHI and Return, Including Temporary Holding

One of the costliest elements of a large-scale captive care program will be transportation. As noted in Table 3, it is only possible to fly to two of the six subpopulations. At those sites, costly charters would likely be required to transport people and seals. Moreover, air support, particularly at FFS is constrained. The planes that fly to Tern Island are quite small, contractors are not always available, the frequency of flights are limited by impacts to nesting birds, and demands for flights from other projects limit space. Midway is a far more reliable flight destination. Small and large charter or other U.S. Coast Guard (USCG) planes can usually arrive and depart from MDY. Fueling is currently possible as well. However, flight operations at MDY rely on FWS staff and contractor support, which entails considerable cost.

Transport to and from the remaining sites will have to be accomplished by oceangoing vessels. Vessel requirements will include ample appropriate space to secure caged animals; ability to carry, launch, and retrieve small boats; sufficient berthing for crew, field staff, and animal caregivers; and a host of other necessities for vessels operating in the Papahānaumokuākea (NWHI) Marine National Monument. From previous experience, such vessels will likely cost somewhere in the range of $5K–$10K per day to charter. NOAA vessels would also meet these requirements, but competition among existing NOAA projects for sea-days on NOAA vessels is already intense. As mentioned above, when animals are picked up in the NWHI, there may be considerable time when a vessel must stand by while animals are gathered.

The scenario with the minimum time requirement to obtain seals from the NWHI would involve a round trip from Honolulu to FFS, with 4 days on site to collect animals. This would entail a minimum 8-day cruise, which, if chartered and using the range of costs above, would require an expenditure of $40K–$80K for vessel transport alone. To conduct a large-scale project, multiple sites more distant than FFS with longer standby periods and perhaps multiple trips would be required. It is easy to see that vessel costs can rapidly become exceedingly high.

Release and Post-release Monitoring

Releasing animals in the NWHI will require transport as outlined above. If animals are to be held at the release site for some clearance period, then, as above, temporary holding facilities will need to be erected and animal care staff provided. As described above, post-release monitoring is a critical aspect of project assessment. Some of this can be accomplished with telemetry, which does not require prolonged staff time in the field. However, if the condition of animals is to be assessed following release, then field camp technicians (2–3 per release site) will need to be deployed. Depending on the timing of releases, regular monk seal field assessment teams may be on site and can accomplish this work at no additional cost.

Ocean Conditions

It is worth noting that most field operations in the remote NWHI traditionally occur in the spring and summer when storms are infrequent and sea states tend to be benign. Even so, these field camps experience periods when wind conditions prohibit small boat operations.

During autumn, winter, and spring the NWHI experience frequent North Pacific storms, which bring high winds and extremely heavy surf, which, when coupled with tidal surge, can severely limit field camp operations. Maintaining shoreline pens during these times may be entirely impractical. Also, some islands (particularly at PHR) may be completely inundated during winter storms, making over-winter camping a dubious and dangerous proposition. Additionally, transporting people, gear, and animals to and from large vessels to shore aboard small boats is a challenging task under the best of conditions. Outside the summer season, channels into atoll lagoons and islands can remain closed out by large swells for days at a time.

Conclusions

There are many challenges to implementing a NWHI monk seal captive care project. Logistical constraints include limited infrastructure on the islands, limited transport, and challenging ocean conditions at some times of the year. Overcoming these constraints and providing the transportation and labor to properly conduct the kind of large-scale effort considered necessary to effectively achieve captive care's stated goals will be exceedingly costly.

Permitting Hawaiian Monk Seal Research and Enhancement Activities

Currently, the NMFS PIFSC holds an MMPA/ESA research and enhancement permit (Permit No. 848-1695, expiration June 2008), which authorizes takes of Hawaiian monk seals in the Hawaiian Archipelago and Johnston Atoll for the purposes of population monitoring, disease and health assessment, foraging studies, and recovery actions to enhance the survival of the population. Enhancement activities authorized include relocation and translocation of pups and juveniles, the "Second Chance" captive care project, disentanglement, and adult male removals. Seals that are injured or debilitated by illness are not authorized for captive care under this permit. The permit does not authorize captive care or inter-atoll/island relocations in the main Hawaiian Islands.

A total of five accidental mortalities over the 5-year duration of the permit are authorized, not to exceed two mortalities in a single calendar year. A total of three mortalities remain for the duration of the permit. A minor amendment could be issued to remove the two-mortality-per-year cap. A major amendment would be necessary to include the main Hawaiian Islands or allow additional incidental deaths for the Second Chance captive care project for the duration of the permit. Processing a major amendment follows the same steps involved in issuing a new permit and requires submission of a complete application; a 30-day public comment period and review by the Marine Mammal Commission, Pacific Islands Regional

Office (PIRO), and solicited experts; reinitiation of Section 7 consultation under the ESA; additional National Environmental Policy Act (NEPA) analyses; and coordination and consultation with FWS and other agencies (e.g., the NOAA National Ocean Service—Papahānaumokuākea Marine National Monument).

The NMFS Office of Protected Resources (OPR) has recommended that the PIFSC apply for two new permits to separate the population monitoring and ongoing research activities from the captive care enhancement and research activities. Issuance of MMPA/ESA permits can take up to 1 year for the entire process as described above.

A captive care permit application must reflect considerable planning and foresight to allow for future flexibility in the project to avoid the need for a major amendment to accommodate such changes as the number, age and sex of subject animals, and locations of operations or protocols. All realistic and potential scenarios that could occur should be described in as much detail as possible. Information necessary for an application will include:

- Background review of past captive care operations
- Objectives and justification for captive care and how it will promote recovery (including justification for age/sex and number of animals)
- Research hypotheses and study designs, as applicable
- Measures of enhancement success and failure
- Decision matrices for determining capture locations, animal collection, captive care locations, and release sites
- Descriptions of transport methods and holding facilities
- Captive care protocols by location (e.g., quarantine, feeding, health and body condition assessment by husbandry staff)
- Qualifications of veterinary and husbandry staff
- Veterinary care, medical treatments, and sample collection, analysis, and banking
- Contingency plans (e.g., weather, disease outbreak in captivity, euthanasia, placement of nonreleasable animals)
- Release protocols (time of year, release condition, disease screening, genetics, soft or hard release, post-release monitoring, etc.)
- The number of potential mortalities in captivity
- Measures to minimize treatment variables

- Financial and logistical resources, including consideration of constraints that may drive treatments, duration of captivity, etc., and ultimately outcomes

- The known and potential effects of these activities on the target species, nontarget species, and physical environment

In addition to the requirements above, consideration of the following measures and their incorporation into the permit application is advised:

- Develop seal care capability incrementally, scaling up as critical resources (experienced staff, facilities, logistical support, and funding) may become available

- Set captive care evaluation criteria, then start operations at a low level, increasing the number of seals handled based on how well criteria are met

- Develop expertise on easier-to-manage seals and scale up to older seals cautiously

- Request permission for sufficient deaths to facilitate handling higher risk (older, possibly ill) seals. Check historical losses and request flexibility, allowing for possible recapture and retreatment if required

- Develop contingency plan for disease outbreaks. Identify potential risks and adequate mitigation and containment responses

- Include redundancy in the facility design to maintain safe and effective operations at all times in the event of power outages and other unforeseen problems

- Develop clear memorandums of understanding (MOUs) with all collaborators delineating relationships and responsibilities among federal agencies, other governmental institutions and nongovernmental organizations (NGOs)

RESOURCES NEEDED FOR CAPTIVE CARE

To operate an effective Hawaiian Monk Seal Captive Care Program it will be necessary to have in place adequate resources of several types at the appropriate locations. Those resources are briefly described below.

Northwestern Hawaiian Islands

Seals may be collected for captive care from any of the six main NWHI subpopulations. An array of resources will be needed at source sites. Potential candidates for captive care will be found, observed, selected, captured, treated, and held for relatively short periods until they can be transported to a captive care facility (refer to preceding section on Transportation and Logistics). Also, seals that have completed captive care will be released at the atolls. The release site may require holding for acclimation and treatment and post-release monitoring. The resources required vary but will include at least:

- Two staff trained and experienced with the capture, handling, and care of seals
- Kennels, pens, and other structures that can adequately hold the number of seals expected to be collected or released
- Basic husbandry and veterinary supplies
- Communication system to allow dependable contact with other atolls and the main Hawaiian Islands
- Housing, kitchen, etc., for staff
- Small boats at multi-islet atolls

Midway "Hub" Captive Care Satellite Facility

Midway has the most extensive support infrastructure and facilities (buildings, fuel storage, water supply, etc.) in the NWHI. Currently, there are only two places in the NWHI where non-amphibious aircraft can land: MDY and FFS. MDY has the most appropriate facilities and it is possible that regular flights to FFS may cease in the near future. MDY currently serves as a hub for a variety of agencies' activities in the NWHI. The Papahānaumokuākea Marine National Monument plans to use MDY as a primary access point and is currently in the process of planning for future needs. MDY is therefore the logical place where seals headed to a central captive care facility, via air or vessel, would be held and cared for while awaiting transport. Seals that have completed captive care may also be held and treated at MDY prior to their release. Further, it is possible that some seals needing minor intervention might be treated adequately at an MDY facility, eliminating the need for them to be transported to the main Hawaiian Islands. The resources that should be provided at the MDY hub include:

- Space (pools or shoreline pens), equipment (water supply, sanitation system, freezers for food storage), and supplies (seal food, veterinary supplies) to accommodate 10–15 seals in care
- Qualified staff to care for 10–15 seals and food and housing for staff
- Space for seals on airplane flights to Oahu, at least weekly

Centralized Facility in the Main Hawaiian Islands

The central facility that would receive, hold, and care for seals would be located in MHI. Resources required at a central MHI facility include:

- Space and water systems adequate to support 50–100, though the facility would likely be more modest initially and eventually scale up
- Equipment and supplies to care for the number of seals likely to be in the facility at any one time
- Laboratory, surgical, and other medical facilities and equipment, including provisions for isolation of animals
- Facilities for seal food storage and preparation
- Qualified staff sufficient to care for the number of seals likely to be in the facility at any one time, and housing for staff needs consideration
- Office space, computer systems, and provisions for conferencing and training

ESTABLISHMENT OF A CONSORTIUM

Participants at the workshop discussed how the captive care system, especially the central captive care facility in MHI, would be operated. It was recognized that the responsibility for recovery of monk seals belongs with NMFS, which does not have substantial expertise with operating the type of central captive care facility or care for juvenile seals being envisioned. That expertise resides with private organizations such as The Marine Mammal Center (TMMC) and Hubbs/SeaWorld, who we have worked with before, as well as others. Therefore, a proposed model for this effort is a consortium of collaborators, with NMFS having primary responsibility for developing projects, selecting seals, providing logistical support for transporting seals to and from the central facility, and conducting post-release monitoring. Partners with the right expertise would take responsibility for operations of the captive facility and the care of seals from collection to release. Collaborators in the overall effort would include the State of Hawaii, the U.S. Fish and Wildlife Service, the Papahānaumokuākea Marine National Monument, the U.S. Coast Guard, and others yet to be identified.

The development and operation of a successful captive care program will require definition of the roles and responsibilities for the various parties involved. Brief discussion of this issue at the workshop is summarized below.

Current roles and expertise will be important considerations in devising the captive care program:

- NMFS is divided into management (PIRO) and science/enhancement (PIFSC) functions. Responsibility for management of the Hawaiian monk recovery program seal falls to PIRO, while responsibility for research to monitor and assess recovery and carry out some enhancement actions (e.g., disentangling seals, removing debris from beaches, removing aggressive male seals, etc.) falls to PIFSC. The captive care program will incorporate both management and science objectives—management to support future recovery, and research to determine the most effective methods to accomplish this goal and to assess the project. Relevant permits are divided accordingly.

- PIFSC currently has developed capacity in the NWHI with field teams that run annual monk seal camps.

- NMFS oversees and permits the care of marine animals but does not often engage in their care. The best expertise and capacity for captive care of monk seals likely lies with an established animal care organization. The Marine Mammal Center and Hubbs/SeaWorld are examples of established organizations with many years of experience in caring for marine mammals.

- The U.S. Fish and Wildlife Service supports NMFS field efforts in the NWHI with staff assistance and expertise, and through the use and support of FWS facilities and transportation.

- The Papahānaumokuākea Marine National Monument (PNMN) is planning for and developing an advanced logistical and transportation system to support PMNM conservation actions.

- The United States Coast Guard has supported requests for transportation assistance with both aircraft and vessels.

- The Hawaiian Monk Seal Recovery Team (HMSRT)is an advisory body to NMFS that makes recommendations to NMFS on recovery implementation.

- The State of Hawaii supports monk seal conservation and recovery and is a key partner for recovery implementation.

Given these current roles, the captive care program should be designed with the following organizational structure:

<u>Recovery Coordination and Management: PIRO</u>

- Develop a framework for animal care operations and manage relationships with animal care organizations necessary for those organizations to assume a central role in the care of the monk seals in the captive care program.

- In coordination with PIFSC, integrate monitoring, analysis and evaluation of captive care actions and population demography into the development of the captive care program strategy for population enhancement.

- In coordination with PIFSC, HMSRT, and involved animal care organizations, develop and implement captive care enhancement projects consistent with program design and operations.

- Support PIFSC and other partner logistical and research activities in the NWHI.

- Engage in public education and outreach regarding the captive care program.

<u>Scientific Research: PIFSC</u>

- Lead research and development of captive care tools and methods. Coordinate with PIRO for incorporation into the captive care program to enhance recovery.

- Lead research and logistical activities throughout the NWHI with the support of PIRO and other partners.

- Design, monitor, assess, and evaluate captive care actions.

- In coordination with PIRO, HMSRT and involved animal care organizations, develop and implement captive care enhancement projects consistent with changes in the population.

<u>Animal Care: Consortium of animal care organizations</u>

- Assume the leading role in the day-to-day operation of animal care.

- Provide guidance and expertise to NMFS on recovery actions, facility design and operation, and animal care best-practices for incorporation into the captive care program.

- Develop, nurture and implement relationships with all stakeholders necessary to develop a cadre of skilled personnel with supporting infrastructure for care of the animals.

- In coordination with NMFS, HMSRT and other animal care organizations, develop and implement captive care enhancement projects consistent with changes in the population.

- Apply science-based husbandry and veterinary care for seals in the captive care program in consultation with PIFSC.

Logistical and Transportation Support

The U.S. Fish and Wildlife Service, Papahānaumokuākea Marine National Monument, U.S. Coast Guard, and State of Hawaii are to provide logistical, transportation, and other assistance as possible to support the captive care program.

FUNDING AND COST ESTIMATES

The specifics of funding sources and amounts needed were not discussed in detail at the workshop. As stated earlier, there was broad support for a central captive care facility to be developed in the main Hawaiian Islands. It was recognized that costs associated with such a facility would vary a great deal dependent on the specific site and many other factors. Acquisition of a captive care facility site, whether in association with other federal activities such as NOAA's Ford Island facility development, the U.S. Fish and Wildlife Service's expansion of a National Wildlife Refuge in Kahuku, Oahu, lease arrangement with Oceanic Institute, or the purchase of land represent vastly different costs. The need to renovate or erect new infrastructure for holding and life support systems, as well as associated operating costs, vary greatly depending on the site procured. The organization and implementation of captive care programs with NGOs and the inclusion of volunteers add additional cost variables. PIFSC is actively engaged in evaluating the costs and feasibility of various potential sites on Oahu. It is expected that by Fall 2007, greater definition of site characteristics will facilitate more useful cost estimates.

A MDY "hub" facility for treating, holding, and aggregating seals for transport to and from the MHI was discussed. The requirements of maintaining such a facility have been passed to the National Oceanic Service review of resource needs in the newly established national monument. The costs of construction as a stand alone effort are considerably more than that of an addition to other federal infrastructure development.

Project specific costs in transportation, holding, observation, duration, and effort are location dependent and correlate with the scale of the effort (refer to preceding section on Transportation and Logistics). The inclusion of a NWHI captive care excursion with other work and shared transportation greatly affect the costs allocated to each project. The pre- and post-release monitoring portion of a project, whether it includes visual observation or satellite-linked instrumentation, entails significant variability in cost.

Further, it was acknowledged that program development and operation would require additional expense to flesh out a 10-year plan and the pursuant detailed planning, permitting (including an Environmental Impact Statement [EIS]) and implementation of various strategies discussed at the workshop.

It was noted that NMFS has limited funds available in FY 2007 to improve the existing seal care facility at Kewalo Research Facility and also to operate a captive care program for perhaps up to eight seals. Efforts are underway to evaluate potential sites for the larger central facility in the MHI, and costs for facility construction will vary greatly depending on the site chosen. Substantial funding for the facility has not been included in existing federal budgets although there is the possibility for Congressional support. Funds for facility construction are unlikely to come from existing captive care organizations, but those organizations can be expected to contribute substantially to operation and staffing of the facility. It was recognized that better cost estimates are needed and this will be considered during upcoming meetings of the collaborators.

2007–2008 CAPTIVE CARE PROGRAM PLANS

Enhancement Actions under Development for Fall 2007 through Spring 2008[1]

Two primary activities for fall 2007 through summer 2008 have been proposed. The first is to provide nutritional support for up to eight juvenile female seals collected in the NWHI at Kewalo Research Facility, Honolulu, Hawaii. The second is to perform an antihelminthic (worming) trial on juvenile seals in the NWHI (see Appendix B).

Nutritional Support at Kewalo Research Facility

The proposed priority for a captive care project in 2007–2008 is to focus on no more than eight female seals, up to four 1- and 2-year-olds and four "experienced" weaners (i.e., post-weaning experience in the wild). The higher reproductive value of older juvenile female seals warrants the development of captive care and husbandry practices for these age classes. Higher survival rates after age 2 suggests enhancement efforts might best focus on 1- and 2-year-olds. Past captive care efforts experienced poor results working with seals of this age, many of which were ill or in very poor condition at collection. A balance between handling animals with likely higher success potential (weaners) and those representing greater risk (1- and 2-year-olds) is proposed.

Seals would be collected and transported to Kewalo Research Facility (KRF), Honolulu, from an appropriate NWHI site to be determined. After improving the seals' body condition, they would be released back in the NWHI subject to health and location considerations. Post-release monitoring would be coordinated with regular population assessment field research camps. In the event that KRF is not available as a holding and care facility by Fall 2007, an alternative site in the MHI should be sought and a Midway captive care project reconsidered. The time required to obtain necessary permits may preclude work beginning in 2007.

Antihelminthic Trial

Removal of intestinal parasites has long been discussed as a potential method for increasing juvenile survival. It is understood that free-feeding seals, once treated, readily become reinfected with internal parasites from the prey they consume. Experience suggests

---

[1] The plans for experimental captive care and antihelminthic trials described in this section for Fall 2007 through Spring 2008 were subsequently deferred to allow additional time for project planning, site development and permit acquisition, as well as project funding.

complete removal of intestinal parasites inhibits a developing seal's immune system from building internal defenses and, in some cases, increases the risk of the seal acquiring overwhelming infections. An antihelminthic trial is recommended to evaluate the potential survival benefits of reducing the parasitic load in juvenile seals. There is sufficient confidence in the safety and efficacy of current antihelminthic drugs to advocate starting with juvenile females.

Next Steps for Captive Care Program Development in 2007

PIFSC will continue efforts to ready the Kewalo Research Facility to accept up to eight juvenile seals in Fall 2007. Steps toward construction of an expanded discharge water treatment system are underway as is obtaining the necessary State of Hawaii Department of Health permits.

Scoping for an Alternative Captive Care Facility in the MHI

PIFSC will continue scoping for other potential sites to be used in 2007–2008 and in the future while taking into account the following list of facility features generated during the workshop:

- Diagnostic and treatment abilities
- Labor and potential volunteers
- Water source and discharge
- Link to logistics to and from NWHI
- Capacity for 50–100 seals
- Costs, capitalization, existing infrastructure, and operation
- Potential for public education and outreach

SYNTHESIS/RECOMMENDATIONS

The abundance of Hawaiian monk seals in NWHI is declining about 4% per year and the population decline will continue indefinitely unless juvenile survival improves. Hence, immediate and aggressive intervention is needed to enhance recovery of the species. "Captive care," defined to include a variety of activities, has been identified as a potential means for increasing juvenile female survival.

The goal of captive care will be to substantially increase the survival of treated animals over natural survival rates. The biggest impact may be achieved at locations where natural survival is lowest, such that the ability to predict where and when survival is likely to be low would be valuable. Some physical and biological correlates with juvenile monk seal survival have been identified, but the desired predictability of those rates has not been achieved.

Prospective strategies for increasing juvenile survival were discussed at the workshop, including captive care in the NWHI, care of NWHI animals brought to a centralized facility in the MHI and subsequent release back in the NWHI, a variety of direct translocation scenarios (within the NWHI, or from the NWHI to the MHI or Johnston Atoll), and in situ antihelminthic treatment. Each approach entails its own advantages and challenges, the latter ranging from logistical, or cost-related, to sociopolitical. However, these general categories seem to encompass the range of strategies currently conceived for captive care.

The most effective means of improving juvenile survival is uncertain. It was agreed, however, that the focus should be on improving juvenile female survival, with captive care or treatment of juvenile males undertaken primarily where doing so offers a significant opportunity to improve understanding of treatment methodologies. One key consideration is the best age at which to bring animals into captive care. This will entail a balance between the number of animals available for treatment, the potential survival benefit that can be conferred, and age-specific reproductive value (v_x). Moreover, uncertainty remains regarding factors such as animal condition at admission, duration of captivity, and timing, method and location of release. These uncertainties can only be resolved through a carefully designed experimental approach with diligent project assessment. Experimentation inherently entails risks to the individual seals involved and the broader wild population. Hazards can be minimized but not eliminated, such that contingency planning and an adaptive approach are crucial. We must be prepared to respond to failures and change course appropriately.

A key consideration in the development of future captive care activities is that transportation and logistics will be very costly and difficult to arrange. A new Marine Mammal Protection Act/Endangered Species Act research and enhancement permit will also be required, as will other permits. Personnel and supporting infrastructure will be needed. A key missing component is a captive facility in the MHI capable of supporting animals requiring care. The funding required to launch and sustain a captive care program cannot be accurately estimated at this time, as costs will vary enormously depending on such factors as how plans for the MHI captive care facility develop, location of candidate animals in the NWHI, duration of captivity, and scale of the program. Institutional structures, expertise, and capacity are critically important for initiating an efficient and sustained captive care program. NMFS requires partners with expertise in captive marine mammal care, captive facility design and management, and a number of other areas. It is proposed that a consortium of partners be established among NMFS, nongovernmental organizations, and other contributing agencies and institutions to design and execute a Hawaiian monk seal captive care program.

LITERATURE CITED

Aguirre, A. A., T. J. Keefe, J. S. Reif, L. Kashinsky, P. K. Yochem, J. T. Saliki, J. L. Stott, T. Goldstein, J. P. Dubey, R. Braun, and G. Antonelis.
2007. Infectious disease monitoring of the endangered Hawaiian monk seal. J. Wildl. Dis. 43:229-241.

Antonelis, G. A., J. D. Baker, and J. J. Polovina.
2003. Improved body condition of weaned Hawaiian monk seal pups associated with El Nino events: Potential benefits to an endangered species. Mar. Mamm. Sci. 19:590-598.

Baker, J. D.
2004. Evaluation of closed capture-recapture methods to estimate abundance of Hawaiian monk seals, *Monachus schauinslandi*. Ecol. Appl. 14:987-998.

Baker, J. D., J. J. Polovina, and E. A. Howell.
In press. Effect of variable oceanic productivity on the survival of an upper trophic predator, the Hawaiian monk seal, *Monachus schauinslandi*. Mar. Ecol. Prog. Ser.

Baker, J. D., and P. M. Thompson.
2007. Temporal and spatial variation in age-specific survival rates of a long-lived mammal, the Hawaiian monk seal. Proc. Roy. Soc. B 274: 407-415.

Craig M. P. and T. J. Ragen.
1999. Body size, survival, and decline of juvenile Hawaiian monk seals, *Monachus schauinslandi*. Mar. Mamm. Sci. 15: 786-809.

Harting, A. L.
2002. Stochastic simulation model for the Hawaiian monk seal. Ph.D. thesis, Montana State University, Bozeman, MT. 328 pp.

Harting, A. L., J. D. Baker, and B.L. Becker.
2004. Nonmetrical digital photo identification system for the Hawaiian monk seal. Mar. Mamm. Sci. 20:886-895.

Harting, A. L., J. D. Baker, and T. C. Johanos.
2007. Reproductive patterns of the Hawaiian monk seal. Mar. Mamm. Sci. 23:553-573.

Parrish F. A., M. P. Craig, T. J. Ragen, G. J. Marshall, and B. M. Buhleier.
2000. Identifying diurnal foraging habitat of endangered Hawaiian monk seal using a seal-mounted video camera. Mar. Mamm. Sci. 16:392-412.

Parrish F.A., K. Abernathy, G. J. Marshall, and B. M. Buhleier.
2002. Hawaiian monk seals (*Monachus schauinslandi*) foraging in deep-water coral beds. Mar. Mamm. Sci. 18:244–258.

Parrish F. A., G. J. Marshall, C. L. Littnan, M. Heithaus, S. Canja, B. Becker, R. Braun, and G. A. Antonelis.
2005. Foraging of juvenile monk seals at French Frigate Shoals, Hawaii. Mar. Mamm. Sci. 21:93–107.

Reif, J. S., M. M. Kliks, A. A. Aguirre, D. L. Borjesson, L. Kashinsky, R. C. Braun, and G. A. Antonelis.
2006. Gastrointestinal helminths in the Hawaiian monk seal (*Monachus schauinslandi*): associations with body size, hematology, and serum chemistry. Aquat. Mamm. 32:157-167.

Stewart B. A., G. A. Antonelis, J. D. Baker, and P.Y.Yochem.
2006 Foraging biogeography of the Hawaiian monk seal in the Northwestern Hawaiian Islands. Atoll Res. Bull. 543:131-145.

APPENDICES

APPENDIX A: DECISION TREE FOR TRANSLOCATING, HEALTH INTERVENTION OR BRINGING SEALS INTO CAPTIVE CARE

While the most appropriate age at which to intervene and the best protocols for captive care are not yet determined, workshop participants recognized the value of delineating key considerations for deciding whether intervention might be warranted at various ages. The following was formulated to help organize decision making.

Note: Unless noted otherwise, decision criteria apply to females only.

Decisions to be made when a pup is born

Mother present, healthy, and appears able to successfully rear pup:

- Yes: Leave with mother.
- No: Take into captive care.

Mother's maternal quality (based on history of successfully weaning pups):

- Good: Leave with mother.
- Poor: Take into captive care or translocate mother and pup if such action would address the reason for poor maternal history.

Risk of death prior to weaning (e.g., due to shark attack or human interaction):

- Low: Leave with mother at birth site.
- High: Translocate mother and pup, or take mother and pup or pup alone into captive care.

Twin pups born: Determine sex, favor female over male to stay with mother.

Decisions to be made during nursing period or for prematurely weaned pups

Probability of survival until weaning:

- Low due to likelihood of shark attack: Translocate mother and pup or pup alone and provide care and medical intervention.
- Low due to poor performance by mother: Take into captive care.
- High: Leave with mother at birth site.

Duration of suckling period:

- Normal term: Leave at birth site.
- Premature weaning: Take into captive care.

Pup appears sick: Consider test for disease medical intervention on site or take into captive care.

Pup is injured:

- If likely to be releasable after treatment: Treat on-site or take into captive care.
- If not likely to be releasable after treatment: Leave at site without treatment.

Decisions to be made for normally weaned pups
Pup condition at weaning:

Poor: Take into captive care.
Normal: Leave at weaning site.

Pup appears sick: Test for disease and provide medical intervention on site or take into captive care.

Pup is injured:

If likely to be releasable after treatment: Treat on-site or take into captive care.
If not likely to be releasable after treatment: Leave at site without treatment.

Decisions to be made for weaned pups during the first summer
Probability of survival:

Low: Mitigate factors likely to cause mortality (e.g., translocate to site with higher probability of survival, protect from sharks on-site, take into captive care).
High: Leave at site without treatment.

Body condition:

Thin: Administer antihelminthics or take into captive care.
Not thin: Leave at site without treatment.

Pup appears sick: Test for disease and provide medical intervention on-site or take into captive care.

Pup is injured:

If likely to be releasable after treatment: Treat on-site or take into captive care.
If not likely to be releasable after treatment: Leave at site without treatment.

Decisions to be made for weaned pups during the first winter
Probability of survival:

Low: Mitigate factors likely to cause mortality (e.g., translocate to site with higher probability of survival, protect from sharks on site, take into captive care).
High: Leave at site without treatment.

Body condition:

Thin: Administer antihelminthics on site or take into captive care.
Not thin: Leave at site without treatment.

Pup appears sick: Test for disease and provide medical intervention on-site or take into captive care.

Pup is injured:

If likely to be releasable after treatment: Treat on-site or take into captive care.
If not likely to be releasable after treatment: Leave at site without treatment.

Decisions to be made for juvenile seals, 1-2 years old

Body condition:

Thin: Administer antihelminthics on site or take into captive care.

Not thin: Leave at site without treatment.

Animal appears sick: Test for disease and provide medical intervention on-site or take into captive care.

Animal injured:

If likely to be releasable after treatment: Treat on-site or take into captive care.

If not likely to be releasable after treatment: Leave at site without treatment.

Decisions to be made for older animals (> 2 years of age):

Body condition:

Thin: Administer antihelminthics on site.

Not thin: Leave at site without treatment.

Animal appears sick: Test for disease and provide medical intervention on-site or take into captive care.

Animal injured:

If likely to be releasable after treatment: Treat on-site or take into captive care.

If not likely to be releasable after treatment: Leave at site without treatment.

APPENDIX B: TESTING THE EFFICACY OF TREATING MONK SEALS FOR PARASITES TO IMPROVE JUVENILE SURVIVAL*

* The following is one potential research project to enhance juvenile monk seal survival. The general concept of this study was discussed in the workshop and methodology further developed by F. Gulland and J. Baker. The actual research plan may be modified.

Introduction

Hawaiian monk seal abundance is declining as a result of low juvenile survival, which appears to be associated with food limitation and poor body condition. Monk seals are known to host a variety of gastrointestinal parasites (Dailey et al.,1988, 2004). Reif et al. (2006) reported that young seals infected with *Diphyllobothrium spp.* (tapeworms) tended to be in poorer body condition than those uninfected and he proposed that "intervention strategies to reduce the gastrointestinal helminth burdens in immature animals should be considered as a conservation measure." To date, no studies have been conducted to evaluate the efficacy of anti-helminth treatment as a method to improve juvenile survival.

Parasites are likely not a primary cause of mortality in monk seals; however, they may further compromise animals already in ill health because of food limitation, thereby increasing their likelihood of dying (Gulland, 1992). Gulland et al. (1993) showed that anti-helminthic treatment increased the probability of survival in Soay sheep during a period of high overall mortality. Because monk seals are likely exposed to parasites frequently through their prey, anti-helminthic treatment will only relieve parasite burden for a limited time. This study, then, is designed to test the hypothesis that temporarily relieving compromised young monk seals of their parasite burden will improve their chances of survival in a food-limited environment.

Experimental Design and Protocols

This study will focus on juvenile seals up to 2 years of age (possibly up to age 3), which is the age range exhibiting lowest survival. Further, only animals that have been weaned for at least 2 years will be considered to ensure that they have had ample exposure to parasites through feeding. As sex has been recognized to influence worm burden and its effects on the host in other mammals, the study will attempt to sex-match treated and control animals. This will, however, be influenced by logistics.

To test the hypothesis above, we will focus on animals that are most likely to be compromised by nutritional stress and parasites but which are not moribund and unlikely to survive under any circumstances. Animals judged to be in medium to thin body condition will be selected. Very healthy, robust as well as emaciated moribund animals will be excluded.

Standard population surveys will be conducted to identify potential study subjects. Those that meet the criteria will either be randomly assigned to a treatment or control group, or assignment will be alternated systematically as they are encountered.

All study subjects will be captured by hand and net, sedated, and sampled for subsequent determination of parasite burden (fecal loop), measured (axillary girth and dorsal standard length), tagged if necessary, and either injected (subcutaneously) with an approximate dosage of praziquantel (Droncit, Bayer) at 5 mg/kg for one treatment, or with an equal volume of saline (controls), and released.

Subsequent survival will be determined through visual reidentification during regular monk seal population assessment field research, which typically occurs during June through August. If possible, survivors will be recaptured as above, measured, and resampled for parasite burden. If recapture is not possible, then visual assessment of condition will be recorded and scat samples will be collected and preserved for detection of parasites. The duration of the survival period will depend on the timing of the initial field phase of the study relative to the assessment field season.

The primary statistical analysis will consist of modeling survival (either with capture-recapture or logistic regression) of treatment and control animals to determine whether there is evidence that anti-helminthic treatment improves survival. Initial parasite load will be modeled as a covariate. Additional analysis will include comparison of body condition change of treated versus control animals as well as comparison of parasite loads at the first and second sampling for both groups. Parasite load will be estimated from fecal egg count, recognized as a measure of parasite fecundity combined with worm burden and host immunity, in live animals, and by absolute worm count in dead animals. Sample sizes will likely be limited by the number of available juveniles that meet the selection criteria for inclusion in the study. Unless the treatment effect is very large, the study may need to be carried out in either more than 1 year or at more than one site in order to draw definitive statistical conclusions. The study may be facilitated by conducting it in conjunction with other research involving capture and handling of juvenile monk seals (e.g., foraging and health screen studies).

REFERENCES

Dailey, M. D., R.V. Santangelo, and W.G. Gilmartin.
1988. A coprological survey of helminth parasites of the Hawaiian monk seal from the Northwestern Hawaiian Islands. Mar. Mamm. Sci. 4:125-131.

Dailey, M. D., M. M. Kliks, and R. S. Demaree.
2004. *Heterophyopsis hawaiiensis n. spp.* (Trematoda:Heterophyidae) from the Hawaiian monk seal, *Monachus schauinslandi matschie*, 1905 (Carnivora: Phocidae). Comparative Parasitology 71:9-12.

Gulland, F. M.
1992. The role of nematode parasites in Soay sheep (*Ovis aries L.*) mortality during a population crash. Parasitology 105:493-503.

Gulland, F. M. D., S. D. Albon, J. M. Pemberton, P. R. Moorcroft, and T. H. Clutton-Brock.
1993. Parasite-Associated Polymorphism in a Cyclic Ungulate Population. Proc. Roy. Soc. B 254:7-13.

Reif, J. S., M. M. Kliks, A. A. Aguirre, D. L. Borjesson, L. Kashinsky, R. C. Braun, and G. A. Antonelis.
2006. Gastrointestinal helminths in the Hawaiian monk seal (*Monachus schauinslandi*): associations with body size, hematology, and serum chemistry. Aquat. Mamm. 32:157-167.

APPENDIX C: LIST OF WEBSITE LINKS FOR BACKGROUND INFORMATION

Hawaiian Monk Seal Recovery Plan:
http://www.nmfs.noaa.gov/pr/recovery/plans.htm#mammals

2006–2007 Hawaiian Monk Seal Captive Care Project
http://www.pifsc.noaa.gov/psd/captivecareproject.php

NMFS permit application instructions and additional information
http://www.nmfs.noaa.gov/pr/permits/

APPENDIX D: HAWAIIAN MONK SEAL CAPTIVE CARE WORKSHOP AGENDA

Day 1 - June 11, 2007

8:00 Convene meeting
Welcome, opening remarks, and introduction of chair (Antonelis)
Meeting ground rules (Braun, Gulland)

8:15 Statement of meeting purpose (Yates, Antonelis)
Long-term purpose – development of captive care capability (Yates)
Initial experimentation to see what works
In time management implementation of the tried/proven methods
Experimental vs. empirical approach to captive care (Antonelis)
Acknowledgement and acceptance of risks (Yates)

8:45 Definition of the problem(s) – a review of juvenile survival patterns (Baker)
Variability in NWHI juvenile seal survival (Baker)
Demography relevant to captive care interventions (Harting)

9:30 Previous captive care efforts
Head-start, rehabilitation, direct translocation (Gilmartin)
06/07 captive care project (Braun)
1997 workshop recommendations (Braun)

10:30 Break

10:45 Key considerations based on previous captive care efforts. (Open discussion)
Animal selection- weaners vs. older; good condition poor; healthy vs. sick
Health evaluation and diagnostic/treatment capabilities-then and now
Initial support; fluids, force feeding/fish school, dietary "caps" at approximately 6% body weight
Handling and stress from morphometrics and sampling
Quarantine/isolation
Shore pen dynamics
Lack of control of environment during critical periods
Learning to free feed
Critically ill
Social issues
Large resources
Personnel- Importance of skills and experience
Competence vs. availability-MHI vs. remote locations

12:00 Lunch

1:15 Major strategies for captive care (General discussion)
On-site supplementation/care and release
Shore pens
Pools on shore
Post-release support/free feeding
Direct translocation
Translocate to "wild nursery" in MHI/return to NWHI
Main Hawaiian Islands Centralized Facility
Nutritional support
Treatment of sick and injured
Rehabilitation
Temporary holding/translocation
Open discussion and "out of the box thinking"

1:45 Matrix building – key considerations for each strategy. Review key considerations for each strategy-Begin with the three categories of previous experience. (Open discussion)

2:00 Three breakout groups (more if appropriate)
On-site supplementation/care and release- (Braun)
Direct translocation- (Littnan)
Centralized Captive Care Facility- (Gulland)

*** Matrix would have in columns the headings of each of the major strategies (in situ, translocation etc.), as well as specific modifications. Rows would consist of the considerations from the earlier discussions (veterinary care, isolation quarantine, etc.)

3:30 Break

3:45 Plenary presentations for each strategy with discussion (appointed leader from each breakout group)

5:00 Adjourn for the day

Day 2 - June 12, 2007

8:00 Further discussion of previous days plenary session results (Braun, Gulland)

9:00 Selection and release criteria as related to previous days strategies (Open discussion)
Island/subpopulation
Gender
Size
Age
Condition

Foraging condition
Predicting survival by location
Ecological conditions
Repeat individuals selected for treatment
Scale and risk related to the number of animals in a particular project

10:00 Husbandry and Veterinary Care (Braun, Gulland)
Treatment for parasitism
Treatment of sick and injured seals
Incoming and outgoing assessments
Contingency plans
Determination of releasability
Transfer to other facilities
Euthanasia

11:00 Post-release monitoring/Project Assessment
Post-release monitoring (Charles)
Information potential
Cost of potential information
Beach observations
Project Assessment (Jason)
Goals and objectives defined
Hypothesis driven
Experiment design

12:00 Lunch

1:15 Administrative considerations
Funding (Open Discussion)
Costs of various strategies
Cost comparisons; absolute/relative
Influence of scale
Sources of funding
Effects of varying annual budget
Infrastructure/atoll variables
Atoll-permits, access, limits to activities, scale limitations; other species concerns
NMFS Permits (Sloan)
Reporting/data collection
Collaboration
Roles/responsibilities
PIFSC/PIRO (science/management)
Other Government Agencies–USFWS, NOS, USCG, NWS
NGOs
Others

2:45 Summary discussion–other thoughts

3:15 Options for Fall 2007

4:00 Review of report outline and assignments
Introduction (Antonelis/Moura)
The problem of poor juvenile survival (Harting)
Past efforts (Gilmartin, Lowry)
Captive care alternatives and major considerations (Gulland)
Selection and release criteria (Bowen, Baker)
Husbandry and Veterinary Care (McBain)
Post-release monitoring and Project Assessment (Littnan)
Administrative considerations (Yates)
2007 Project (Braun)

5:00 Adjourn for the day

Day 3 - June 13, 2007

8:00 Begin writing

12:00 Lunch

1:00 Resume writing

5:00 Hand in written materials to Braun and Gulland

5:15 Adjourn meeting

APPENDIX E: LIST OF WORKSHOP ATTENDEES
(In alphabetical order)

Bud Antonelis
NOAA Fisheries, Pacific Islands Fisheries Science Center, Marine Mammal Research Program
2570 Dole Street
Honolulu, HI 96822 USA
Bud.Antonelis@noaa.gov

Jason Baker
NOAA Fisheries, Pacific Islands Fisheries Science Center, Marine Mammal Research Program
2570 Dole Street
Honolulu, HI 96822 USA
Jason.Baker@noaa.gov

Don Bowen
Dalhousie University
Bedford Institute of Oceanography
1 Challenger Drive
Dartmouth, NS B2Y 4A2 Canada
BowenD@mar.dfo-mpo.gc.ca

Robert Braun
Contract veterinarian, NOAA Fisheries
44-299 Kaneohe Bay Drive
Kaneohe, HI 96744 USA
rbraun@lava.net

Marlee Breese
University of Hawaii, Manoa
Hawaii Institute of Marine Biology
P.O. Box 1346
Kaneohe, HI 96744 USA
marlee@hawaii.edu

Tom Eagle
Marine Mammal Conservation Division
Office of Protected Resources, NMFS/PR2
1315 East-West Highway
Silver Spring, MD 20910 USA
Tom.Eagle@noaa.gov

Bill Gilmartin
Hawaii Wildlife Fund
P.O. Box 540
Volcano, HI 96785 USA
bill-gilmartin@hawaii.rr.com

Frances Gulland
The Marine Mammal Center
1065 Fort Cronkhite
Sausalito, CA 94965 USA
gulland@tmmc.org

Albert Harting
Harting Biological Consulting
8898 Sandy Creek Lane
Bozeman, MT 59715 USA

Randall Kosaki
Papahānaumokuākea Marine National Monument
6600 Kalaniana'ole Hwy, #300
Honolulu, HI 96825 USA
Randall.Kosaki@noaa.gov

David Laist
Marine Mammal Commission
4340 East-West Highway
Bethesda, Maryland 20814 USA
dlaist@mmc.gov

Charles Littnan
NOAA Fisheries, Pacific Islands Fisheries Science Center, Marine Mammal Research Program
2570 Dole Street
Honolulu, HI 96822 USA
Charles.Littnan@noaa.gov

Lloyd Lowry
Marine Mammal Commission
4340 East-West Highway
Bethesda, Maryland 20814 USA
llowry@eagle.ptialaska.net

Jim McBain
SeaWorld of California
500 SeaWorld Drive
San Diego, CA 92109 USA
james.mcbain@anheuser-busch.com

Tenaya Norris
The Marine Mammal Center
1065 Fort Cronkhite
Sausalito, CA 94965 USA
Norris@tmmc.org

David Schofield
Protected Resources Division
NOAA Pacific Islands Regional Office
1601 Kapiolani Blvd., Suite 1110
Honolulu, HI 96814 USA
David.Schofield@noaa.gov

Amy Sloan
Office of Protected Resources
National Marine Fisheries Service
1315 East-West Highway
SSMC3, F/PR1, Room 13730
Silver Spring, MD 20910 USA
Amy.Sloan@noaa.gov

Chris Yates
Protected Resources Division
NOAA Pacific Islands Regional Office
1601 Kapiolani Blvd., Suite 1110
Honolulu, HI 96814 USA
Chris.Yates@noaa.gov

Michelle Yuen
Protected Resources Division
NOAA Pacific Islands Regional Office
1601 Kapiolani Blvd., Suite 1110
Honolulu, HI 96814 USA
Michelle.Yuen@noaa.gov