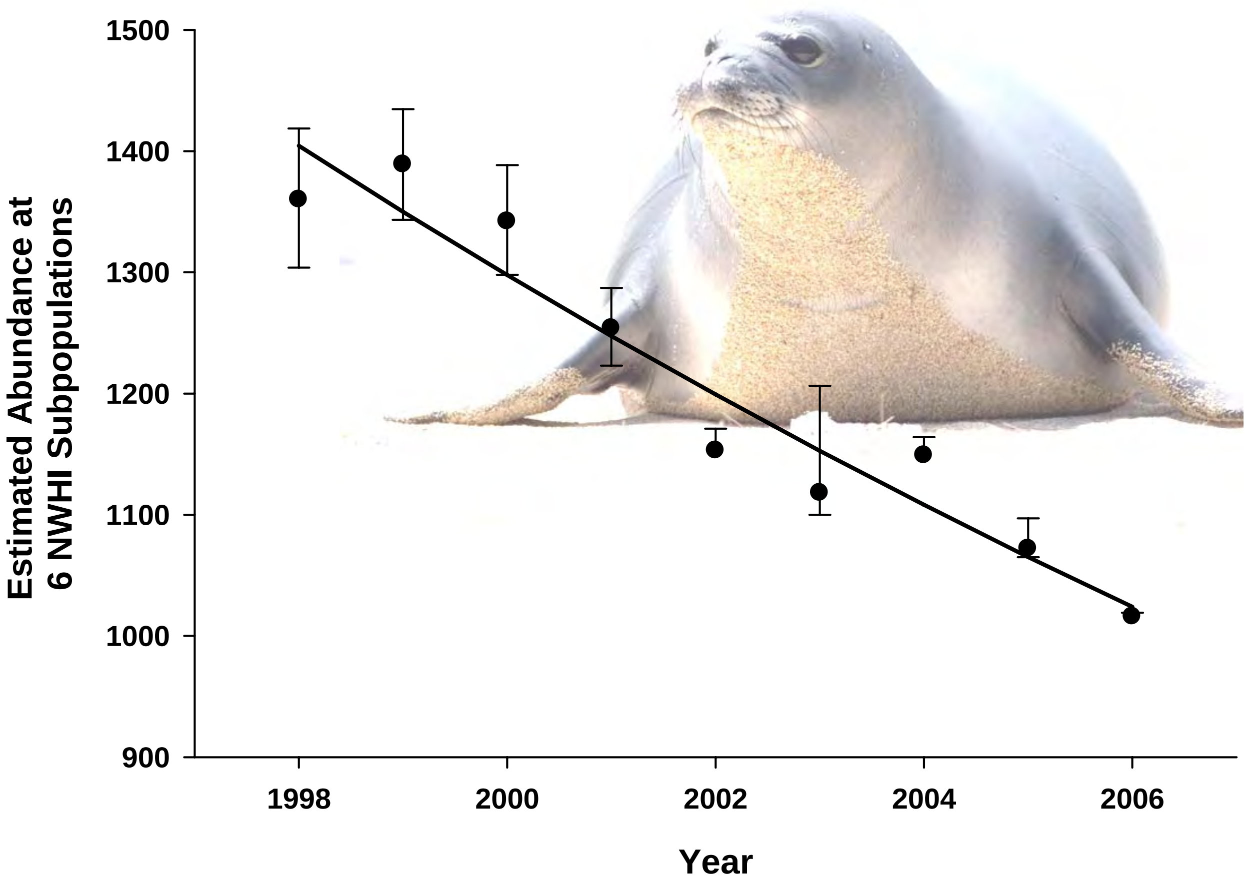
RECOVERY PLAN FOR THE HAWAIIAN MONK SEAL

(*Monachus schauinslandi*)

REVISION



National Marine Fisheries Service
National Oceanic and Atmospheric Administration

August 2007

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(*Monachus schauinslandi*)

REVISION

Original Version: March 1983

Prepared by

National Marine Fisheries Service
National Oceanic and Atmospheric Administration

Approved: *William T. Hogarth*

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Date August 22, 2007

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Cover photo by John Johnson (onebreathphoto.com) is of a female, juvenile Hawaiian monk seal that was protected, along with her mother, by volunteers during their six-week nursing period on the North Shore of Oahu. Sadly, this pup was found drowned in a gill net about three months after her weaning, highlighting one of the threats that Hawaiian monk seals face on the road to recovery. The graph on the cover (prepared by Jason Baker, NMFS PIFSC) depicts the estimated decline in abundance for the Hawaiian monk seals in the 6 Northwest Hawaiian Islands subpopulations, serving as a graphic reminder of the recovery challenge. This graph does not include abundance estimates for Necker, Nihoa or the main Hawaiian Islands. Error bars indicate + 2 standard errors and either – 2 standard errors or known minimum abundance. The fitted trend line reveals an estimated decline of 3.9% per year.

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EXECUTIVE SUMMARY

The Hawaiian monk seal (*Monachus schauinslandi*) is in crisis: the population is in a decline that has lasted 20 years and only around 1200 monk seals remain. Modeling predicts the species' population will fall below 1000 animals in the next five years. Like the extinct Caribbean monk seal and the critically endangered Mediterranean monk seal, the Hawaiian monk seal is headed to extinction if urgent action is not taken. Implementation of this plan, adequate resources, and improved coordination and cooperation provide hope that the species decline can be reversed.

For more than two decades, great effort has been made to manage, study, and recover the Hawaiian monk seal. However, actions to date have not been sufficient to result in a recovering population. The species status would undoubtedly have been worse but for these actions. Nonetheless, significant threats face this species:

- Very low survival of juveniles and sub-adults due to starvation (believed to be principally related to food limitation) has persisted for many years across much of the population
- Entanglement of seals in marine debris has and continues to result in significant levels of seal mortality
- Predation of juvenile seals by Galapagos sharks has significantly increased
- Human interactions in the Main Hawaiian Islands (MHI) including recreational fishery interactions, mother-pup disturbance on popular beaches, and exposure to disease
- Hawaiian monk seal haul-out and pupping beaches are being lost to erosion in the Northwest Hawaiian Islands (NWHI), and monk seal prey resources in the NWHI may have been reduced as a result of climate cycles and other factors
- Potential disease outbreaks could have a devastating effect due to small population size and limited geographic range

Due to low juvenile survival and an aging, breeding female population, there will not be sufficient replacement of breeding females, and birth rates subsequently will decline. This underscores the irony of past and current efforts to reduce these threats in that initial success may only slow a process of decline and even more actions will be required to reverse the decline and prevent the extinction of this species. Recovery of the Hawaiian monk seal depends upon a range of comprehensive actions detailed in this Recovery Plan, as well as the full participation and support of all federal, state and private stakeholders. These actions should be pursued aggressively to prevent the extinction of this species, and funding decisions should give highest priority to actions that will contribute directly to mitigating impacts and sources of mortality that reduce survival rates of Hawaiian monk seals, particularly females and juveniles.

In order to preserve the future reproductive potential for recovery, one of the highest priorities being pursued by NMFS is the development of a captive care program to nutritionally supplement juvenile female seals. The goal of the program will be to increase the survival of female seals during the critical juvenile life stages that are now experiencing low survival. This will likely be a combined effort of NMFS and animal care organizations. A workshop on the development of a 10-year captive care plan was held in June 2007. Without such efforts, the loss of young females will significantly decrease the recovery potential of the species, as there will not be enough females in the population.

CURRENT SPECIES STATUS: The Hawaiian monk seal was listed as an endangered species pursuant to the Endangered Species Act (ESA) on November 23, 1976 (41 FR 51611) and remains listed as endangered. The species has a recovery priority number of one, based on the high magnitude of threats, the high recovery potential, and the potential for economic conflicts while implementing recovery actions. Based on recent counts, the current population is approximately 1200 individuals. Since the publication of the last Recovery Plan for Hawaiian monk seals over two decades ago (Gilmartin, 1983), much has been done to reduce the impact of many of the most direct, and obvious, causes of decline. Nonetheless, the present total population of the species is small and declining. The population is already so small as to be in the range where there is concern about long-term maintenance of genetic diversity.

HABITAT REQUIREMENTS AND LIMITING FACTORS: The Hawaiian monk seal has the distinction of being the only endangered marine mammal whose entire species range – historical and current – lies within the United States (however the species has been sighted outside the U.S. Exclusive Economic Zone). The majority of the population of monk seals now lies in the NWHI with six main breeding sub-populations. The species is also found in lower numbers in MHI where the population size and range both appear to be expanding. The main terrestrial habitat requirements include: haul-out areas for pupping, nursing, molting, and resting. These are primarily sandy beaches, but virtually all substrates are used at various islands.

Monk seals also spend nearly two-thirds of their time in marine habitat. Monk seals are primarily benthic foragers (Goodman-Lowe 1998 et al.), and will search for food in a broad depth range up to 500 m and over different substrates (Parrish et al., 2000, 2002, in review). The food available in their marine habitat seems to be a limiting factor to population growth in the NWHI, with the greatest impact of food limitation being on the survival of juvenile and yearling seals, age of sexual maturity, and fecundity.

RECOVERY GOAL: The goal of this revised recovery plan is to assure the long-term viability of the Hawaiian monk seal in the wild, allowing initially for reclassification to threatened status and, ultimately, removal from the List of Endangered and Threatened Wildlife.

RECOVERY STRATEGY: While recommendations within this report are many and detailed, there are four key actions required to alter the trajectory of the Hawaiian monk seal population and to move the species towards recovery:

1. Improve the survivorship of females, particularly juveniles, in sub-populations of the NWHI. To do this requires the following:

   - maintaining and enhancing existing protection and conservation of habitat and prey base;
   - targeting research to better understand the factors that result in poor juvenile survival;
   - intervening where appropriate to ensure higher survival of juvenile and adult females;
   - continuing actions to protect females from individual and multiple male aggression and to prevent excessive shark predation; and

- continuing actions to remove marine debris and reduce mortality of seals due to entanglement.

2. Maintain the extensive field presence during the breeding season in the NWHI. Field presence is critical not just to the monitoring and research efforts, but also to carry out the active management and conservation of Hawaiian monk seal sub-populations in these areas.

3. Ensure the continued natural growth of the Hawaiian monk seal in the MHI by reducing threats including interactions with recreational fisheries, disturbance of mother-pup pairs, disturbance of hauled out seals, and exposure to human and domestic animal diseases. This should be accomplished with coordination of all federal, state, local and non-government parties, volunteer networks, and increased outreach and education in order to develop a culture of co-existence between humans and seals in the MHI.

4. Reduce the probability of the introduction of infectious diseases into the Hawaiian monk seal population.

RECOVERY CRITERIA: The population will be considered for a reclassification as "threatened" if all the following three conditions are met:

Downlisting Criteria:

1. aggregate numbers exceed 2,900 total individuals in the NWHI

2. at least 5 of the 6 main sub-population in the NWHI are above 100 individuals and the MHI population is above 500

3. survivorship of females in each subpopulation in the NWHI and in the MHI is high enough that, in conjunction with the birth rates in each subpopulation, the calculated population growth rate for each subpopulation is not negative.

Threats-based Criteria:

Factor A. Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range
Criteria: Measures are in place to manage human factors affecting food limitations, habitat loss and contaminants in the NWHIs. Management measures are also in place to a) minimize human disturbance of monk seals that haul-out on beaches in the MHI, and b) protect major monk seal haul-out habitat in the MHI.

Factor B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes
Criteria:

1. Procedures, including data collection and analyses, are in place to evaluate and ensure that scientific research on Hawaiian monk seals, including their

observation, handling, and instrumentation, will not cause significant adverse impacts on monk seal survival, behavior, or population growth.

2. Procedures are in place to ensure that any proposed NWHI operations that may increase seal disturbance or threaten survival will be reviewed and carefully scrutinized, and that all applicable laws protecting monk seals and their habitat have been used and enforced.
3. Management and permitting measures are in place to ensure that people, including scientists and research teams, visiting the Midway Islands or any other atoll in NWHI do not disturb monk seals or restrict their haul-out habitat in ways that could adversely affect monk seal survival, behavior, or population growth.

Factor C. Disease or Predation
Criteria:

1. Credible measures for minimizing the probability of introduction of diseases to any of the NWHI subpopulations, or the spread of diseases from the MHI to the NWHI, or importation of diseases that are not yet present in Hawaii are in place.
2. Contingency plans are in place to respond to a disease outbreak or introduction should this occur.
3. Research measures are in place to monitor population size, vital rates, and possible disease outbreaks or disease introductions, in all the subpopulations.
4. Management measures are in place to minimize shark predation and are demonstrably effective at maintaining predation sources at low enough levels to be consistent with continued meeting of the birth rate and survivorship criterion.

Factor D. Inadequacy of Existing Regulatory Mechanisms
Criteria: Measures are in place to manage fishery interactions and are demonstrably effective at reducing these threats and maintaining fishery-related sources of mortality or stress at decreasing or low levels that are consistent with continued meeting of the birth rate and survivorship criterion.

The principle, direct fishery interaction threat currently facing monk seals are MHI recreational fisheries, particularly gillnets and shore-cast gear, which are managed by the State of Hawaii and known to cause monk seal mortalities. Two monk seals drowned in recreational gillnets on Oahu within the past year. Gillnets will still be used in other areas, and enforcement of the new regulations will be important to ensure that the threat is actually reduced. There is a continuing need for intervention for Hawaiian monk seals in the MHI to remove embedded hooks from recreational fishing; however this effort does not remedy the interaction problem itself. More management measures and enforcement of those measures are needed to ensure that this serious threat is reduced.

Factor E. Other Natural or Manmade Factors Affecting Its Continued Existence
Criteria:

1. Management measures are in place to control male aggression, entanglement, biotoxins, and other sources of human-caused mortality or stress. These measures are demonstrably effective at maintaining these threats at low enough

levels to be consistent with continued meeting of the birth rate and survivorship criterion.

2. The causes of the anthropogenic threats to the species are clearly identified and are well-enough understood to be controlled or mitigated, and any newly identified threats are controlled adequately before downlisting.

Delisting Criteria:

The population will be considered for a delisting if the downlisting criteria continue to be met for 20 consecutive years without new crucial or serious threats being identified.

ACTIONS NEEDED: The following 14 categories of actions are necessary for the recovery of the Hawaiian monk seal:

1. Investigate and mitigate factors affecting food limitation
2. Prevent entanglements of monk seals
3. Reduce shark predation on monk seals
4. Minimize the risk of exposure to or spread of infectious disease
5. Conserve Hawaiian monk seal habitat
6. Reduce Hawaiian monk seal interactions with fisheries
7. Reduce male aggression toward pups/immature seals and adult females
8. Reduce the likelihood and impact of human interactions
9. Investigate and develop response to biotoxin impacts
10. Reduce impacts from compromised and grounded vessels
11. Reduce the impacts of contaminants
12. Continue population monitoring and research
13. Create and implement a main Hawaiian Islands Hawaiian Monk Seal Management Plan
14. Implement the Recovery Plan for the Hawaiian Monk Seal

Estimated Cost of Five-Year Recovery Efforts (in thousands):

	FY 01	FY 02	FY 03	FY 04	FY 05	Subtotal	Total
Crucial Threats							
1. Food limitation	*1,920*	*1,900*	*1,900*	*1,900*	*1,900*	**9,520**	
2. Entanglement	*1,260*	*1,260*	*1,260*	*1,260*	*1,260*	**6,300**	
3. Shark predation	*300*	*300*	*300*	*300*	*300*	**1,500**	
Subtotal – Crucial Threats							**17,320**
Serious Threats							
4. Infectious diseases	*605*	*585*	*585*	*585*	*585*	**2,945**	
5. Habitat loss	*250*	*50*	*50*	*0*	*0*	**350**	
6. Fishery interaction	*200*	*200*	*200*	*200*	*200*	**1,000**	
7. Male aggression*	*	*	*	*	*	**0**	
8. Human disturbance	*800*	*800*	*800*	*800*	*800*	**4,000**	
Subtotal – Serious Threats							**8,295**
Moderate Threats							
9. Biotoxins	*250*	*125*	*125*	*75*	*75*	**650**	
10. Vessel groundings	*0*	*0*	*0*	*0*	*0*	**0**	
11. Contaminants	*50*	*0*	*0*	*0*	*0*	**50**	
Subtotal – Moderate Threats							**700**

*** All included in other costs**

Essential Long-term Recovery Actions							
12. Monitoring & Research	*1,550*	*1,600*	*1,650*	*1,550*	*1,550*	**7,900**	
13. MHI Management Plan	*200*	*200*	*150*	*150*	*150*	**850**	
14. Implement Recovery Plan	*170*	*170*	*170*	*170*	*170*	**850**	
Subtotal – Essential Long-term Recovery Actions							**9,600**

TOTAL ALL ACTIONS	***7,555***	***7,190***	***7,190***	***6,990***	***6,990***	**35,915**	**35,915**

ESTIMATED COST OF RECOVERY (FIRST 5 FISCAL YEARS): $35,915,000
ANTICIPATED DATE OF RECOVERY: The time to recovery is not predictable with the current information, but the best case scenario (which is extremely improbable given recent trends) is that the population could grow to the stipulated total population size in the NWHI within 12 years, and the stipulated numbers in the MHI could be reached within 34 years. Provided that the threats-based criteria have also been met, this would elevate the population to a "threatened" classification. The population may be considered "recovered" if the downlisting criteria continue to be met for 20 consecutive years. Therefore, the total time to recovery is anticipated to be 54 years. The Total Estimated Cost of Recovery can be calculated by multiplying the estimated cost of FY 05 ($6,990) for the next 49 years. Then add that sum to the estimated cost for the first five fiscal years (in Table above). Realistically, the population is not expected to recover in the foreseeable future. In the future, if more is learned about the causes for the current continuing decline, it should be possible to make more informative projections about the time to recovery, and its expense.
TOTAL ESTIMATED COST OF RECOVERY (54 YEARS): $378,425,000

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ACRONYM LIST

The following is a list of acronyms use throughout the plan

BiOp- Biological Opinion
CRED – Coral Reef Ecosystem Division (part of PIFSC)
DDT - dichlorodiphenyltrichloroethane
DEIS – Draft Environmental Impact Statement
DLNR – Department of Land and Natural Resources
DOCARE – Department of Conservation and Resource Enforcement
EEZ – Exclusive Economic Zone
EIS – Environmental Impact Statement
ESA – Endangered Species Act
FAD – Fish Aggregating Device
FFS – French Frigate Shoals
FMP – Fisheries Management Plan
FWS – Fish and Wildlife Service
GnRH – Gonadotropin Releasing Hormone
HINWR – Hawaiian Islands National Wildlife Refuge
HMS – Hawaiian monk seal
HMSRP – Hawaiian monk seal recovery plan
HMSRT – Hawaiian monk seal recovery team
IDT – Initial Defecation Time
LORAN – Long-range navigation
MDY – Midway Islands/Atoll
MHI – Main Hawaiian Islands
MMC – Marine Mammal Commission
MMPA – Marine Mammal Protection Act
MMRP – Marine Mammal Research Program
MPA – Marine Protected Area
my – Million years
mya – million years ago
NGO – Non-government organization
NMFS – National Marine Fisheries Service
nmi – Nautical miles
NOAA – National Oceanic and Atmospheric Administration
NOS – National Ocean Service
NWHI – Northwestern Hawaiian Islands
OC - Organochlorine
PBR – Potential Biological Removal
PCB – Polychlorinated biphenyl
PFAD – Private Fish Aggregating Device
PHR – Pearl and Hermes Reef
PIAO – Pacific Islands Area Office
PIFSC – Pacific Islands Fisheries Science Center
PIRO – Pacific Islands Regional Office
PMNM – Papahanaumokuakea Marine National Monument
PSZ – Protected Species Zone

PVA – Population Viability Analysis
TDR – Time-depth recorder
UME – Unusual Mortality Event
USCG – United States Coast Guard
VMS – Vessel Monitoring System
WNV – West Nile Virus
WPRFMC - Western Pacific Regional Fishery Management Council

I BACKGROUND

Congress passed the Endangered Species Act (ESA) of 1973 (16 USC 1531 *et seq.*) to protect species of plants and animals endangered or threatened with extinction. The National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Fish and Wildlife Service (FWS) share responsibility for the administration of the Act. NMFS is responsible for most marine mammals including the Hawaiian monk seal**.** Section 4(f) of the ESA directs the responsible agency to develop and implement a Recovery Plan, unless such a plan will not promote the conservation of a species. NMFS has determined that a Recovery Plan would promote the conservation of the Hawaiian monk seal.

This original draft of the Recovery Plan was written by the Hawaiian Monk Seal Recovery Team (HMSRT) at the request of the Assistant Administrator for Fisheries to promote the conservation of the Hawaiian monk seal and submitted to NMFS for review. The recovery team includes experts on marine mammals from the private sector, academia, and government, as well as experts on endangered species conservation and other stakeholders. The goals and objectives of the Plan can be achieved only if a long-term commitment is made to support the actions recommended here.

A. Brief Overview

Modern pinnipeds are divided into three families: the Otariidae (fur seals and sea lions), the Odobenidae (walrus), and the Phocidae, which includes two sub-families: the Phocinae – northern true seals, and the Monachinae—the monk seals, elephant seals and the Antarctic phocids. The ancestor of modern pinnipeds probably lived along the coast of present-day California, some 23 million years ago (mya) (Berta et al., 1989). The genus *Monachu*s includes three geographically widely separated species: the Mediterranean monk seal, *Monachus monachus*; the Caribbean monk seal, *Monachus tropicalis*; and the Hawaiian monk seal, *Monachus schauinslandi*. Considered the most primitive of all living phocid species, monk seals have anatomical features that resemble those of the earliest monk seal fossils from 14-16 mya. Additional support for this theory has been based on morphological characteristics such as ear regions (Repenning and Ray, 1977), molecular and genetic analysis (Arnason et al., 1995), and fossil evidence using physical and ecological factors (Demere et al., 2003). This species represents a unique evolutionary branch important for the understanding of seals. The Caribbean monk seal became extinct during the last 50 years (Kenyon, 1977, but see Boyd and Stanfield, 1998), and the status of the Mediterranean monk seal is precarious.

The Hawaiian monk seal represents the best hope for overall survival of an evolutionarily important lineage. It is not clear when monk seals reached the Hawaiian Islands (Repenning and Ray, 1977). However, the Hawaiian monk seal possesses some primitive anatomical features (Ray, 1976; Barnes et al., 1985) that suggest monk seals may have made their way to Hawaii as early as 14-15 mya (Repenning et al., 1979). A more recent study found mitochrondial and nuclear DNA evidence that shows the species first split from its Monachinae ancestors between 11.8 and 13.8 mya (Fyler et al. 2005).

Prior to the enactment of the Marine Mammal Protection Act (MMPA) in 1972 and the ESA in 1973, the Hawaii Department of Land and Natural Resources regulated all issues regarding the NWHI as they pertained to Hawaiian monk seals. Under the MMPA, monk seal management became a federal responsibility and the NMFS became the responsible federal agency. While the MMPA preempted direct state management of marine mammals, the monk seal continues to be listed as endangered under Hawaii State law and is protected under Hawaii's statutes and administrative rules.

In 1976, the Hawaiian monk seal was designated as "depleted" under the MMPA, and as "endangered" under the ESA. Both the MMPA and ESA have mechanisms to encourage management for population growth and recovery and to prohibit any form of monk seal "take," except for limited exceptions authorized under federal permits. See Appendix C for a survey of existing federal legal protections for the Hawaiian monk seal. The ESA authorized the appointment of an HMSRT, which was formed in 1980 and charged with developing a recovery plan.

The Hawaiian monk seal has a recovery priority number of one, based on criteria in the Recovery Priority Guidelines (55 FR 24296, June 15, 1990) that describes a high magnitude of threats, high recovery potential, and the potential for economic conflicts while implementing recovery actions. The magnitude of threats is considered to be high based on the rapid population decline that has persisted for over 20 years. Although our understanding of the most serious threat of food limitation is improving, the recovery potential is also high because the mitigation of other critical threats are known and in place. One such example is that the species' current core habitat in the NWHI is well-protected, and if foraging conditions improve, then recovery can be expected. In addition, the recovery potential can be considered high because the MHI represent a large amount of under-occupied habitat, which could support a larger population of seals if appropriate management actions were in place. Finally, economic conflicts exist with fishery interactions and entanglement threats to the monk seals.

The first Recovery Plan for the Hawaiian Monk Seal was completed in 1983 and the HMSRT, as it was then constituted, held its last meeting in 1984. A second HMSRT was appointed but never met. In 1989, the HMSRT was reconstituted and reconvened, and it met nearly every year through spring 2001, with its primary function to review management and research activities aimed at recovery and to make recommendations to NMFS. A new HMSRT was appointed in fall 2001 and charged with preparing this revised recovery plan.

The first Recovery Plan (Gilmartin, 1983) emphasized 1) identification and mitigation of factors causing decreased survival and productivity; 2) characterization of habitat, including foraging areas; 3) assessment and monitoring of population trends; 4) documentation and mitigation of negative effects from human activities; 5) implementation of conservation-oriented management actions; and 6) development of educational programs to enhance public conservation efforts. In addition, three subsequent three-year work plans were developed (Gilmartin, 1990; 1993a, b) that dealt with issues including 1) mitigating the effects of male aggression behavior at Laysan and Lisianski islands; 2) monitoring the main reproductive sub-populations; 3) actions intending to facilitate the recovery of monk seals at Pearl and Hermes Reef (PHR), Midway and Kure atolls; 4) implementing a research and management plan for French Frigate Shoals (FFS); and 5) analysis and publication of data. A plan specific to addressing the monk seal male aggression problem was also developed (Gilmartin and Alcorn, 1987). Gilmartin and Antonelis (1998) recommended recovery actions for the Midway monk seal population.

B. Species Description

Newborn pups of both sexes are covered with black lanugo (fetal hair) and weigh approximately 14-17 kg (Kenyon and Rice 1959, Wirtz 1968). Some pups have small white patches of pelage. Near weaning, following the lanugo molt, pups become silvery gray, usually darker on the dorsum. Following the annual molt, juveniles, subadults, and adults are a silvery gray. Monk seals slowly become a light brown with yellow-brown ventral pelage; older adults may have darker brown ventral coloration.

At weaning, pups will weigh 50-100 kg. Gilmartin et al. (pers. comm.) have examined early post-weaning mass loss data in pups, and Craig and Ragen (1999) show mass changes between weaning and age two. Mass loss in post-weaned phocid pups, including monk seals, is a normal part of their life history.

Few adults have been weighed or measured, so a complete growth curve is not available, (but see Reif et al., 2004). Rice (1964) suggested that adult females weigh approximately 205 kg and are about 2.3 m long, whereas the average adult male is smaller at about 170 kg and 2.1 m. Sexual dimorphism, with females larger than males, is normal among monachine seals, with the exception of the elephant seals (Kovacs and Lavigne 1986).

Initial studies of genotypic variation (Kretzmann et al., 1997) suggest that the species currently is characterized by low genetic variability, minimal genetic differentiation among sub-populations and, perhaps, some naturally occuring local inbreeding. The potential for genetic drift should have increased when seal numbers were reduced by European harvest in the 19th century, but any tendency for genetic divergence among sub-populations is probably mitigated by the inter-island movements of seals. Additional microsatellite DNA analysis tested additional primer sets from more individuals, only confirming the lack of genetic variation in the Hawaiian monk seal (Kretzmann et al., 2001). It was concluded that the long-term evolutionary history of the species as well as recent human impacts are both possible sources for the extremely low genetic variation observed.

C. Distribution and Habitat

When monk seals arrived at the Hawaiian Islands, they found an archipelago quite different from today. Geologically, the NWHI range in age from about 30 million years (my) in the west to 7.5 my in the east (MacDonald et al., 1983). The NWHI are much older than the MHI, which are less than 6 my. Several new islands have been formed during the period that monk seals have inhabited the archipelago, and others have greatly changed their character. For monk seals, Hawaii's archipelago facilitated establishment over time of a number of semi-isolated island-based sub-populations, collectively comprising what is termed a metapopulation (Hanski and Gilpin, 1991). The earliest record of Hawaiian monk seals in the Hawaiian Islands indicated that they were present prior to European contact in about 1400-1760 AD (Rosendahl, 1994)

Monk seals are found throughout the NWHI including the population's six main reproductive sites in the NWHI: Kure Atoll, Midway Islands, Pearl and Hermes Reef, Lisianski Island, Laysan Island, and French Frigate Shoals (Fig. 1.C.1.). Smaller breeding sub-populations also occur on Necker Island, and Nihoa Island, and monk seals have been observed at Gardner Pinnacles and Maro Reef. Monk seals are now also found throughout the MHI, where births have been documented on most of the major islands (Baker and Johanos, 2004). Additional sightings and at least one birth have occurred at Johnston Atoll. In addition to these sightings, a juvenile male and eleven adult males were translocated to Johnston Atoll (nine from Laysan Island and two from FFS) over the past 20 years.

While the Hawaiian monk seal is considered to be a single population, research and recovery activities focus on individual island/atoll populations within the meta-population. The different sub-populations have exhibited varying degrees of demographic independence, with some areas having considerable levels of independence and other areas having higher degrees of migrations, such as the western three sub-populations. Current variability among the subpopulations probably reflects a combination of different recent histories, changes in the level of human disturbance, and varying environmental conditions (Gerrodette and Gilmartin, 1990; Ragen, 1999; Polovina, 1994; Polovina et al., 1994). To fully understand the factors causing declines and to develop appropriate conservation policies and management, an understanding of the status and dynamics of each subpopulation is required.

1. Summary of Island History and Abundance

Western Three Sub-populations

Pearl and Hermes Reef (PHR), Midway Islands, and Kure Atoll constitute the three westernmost sub-populations of Hawaiian monk seals in the NWHI. There is a higher degree of migration among the western sub-populations compared to the more isolated sub-populations at Laysan, Lisianski and French Frigate Shoals (FFS). As a result, population growth has sometimes been influenced more by immigration than by intrinsic growth. Several recent cohorts (groups of individuals born in the same year) at all three sites indicate that survival of juveniles has declined. In some cases, these sites may be considered as a single complex when addressing certain research and management issues. Because they do have some site-specific conservation and management issues, the western sites will be discussed individually below, but their demographic interconnectedness must be kept in mind.

On June 15, 2006, the NWHI Papahanaumokuakea Marine National Monument (PMNM) was established by Presidential Proclamation 8031 (71 FR 51134, August 29, 2006; 71 FR 36443, June 26, 2006) authorized by section 2 of the Act of June 8, 1906 (16 U.S.C. 431), the "Antiquities Act." The area includes the NWHI Coral Reef Ecosystem Reserve, the Midway National Wildlife Refuge, the Hawaiian Islands National Wildlife Refuge, and the Battle of Midway National Memorial. This is the largest marine reserve in the nation, and the largest marine protected area in the world, receiving the nation's highest form of marine environmental protection. The PMNM designation will enable these activities:

- Preserve access for Native Hawaiian cultural activities;
- Provide for carefully regulated educational and scientific activities;

- Enhance visitation in a special area around Midway Island;
- Prohibit unauthorized access to the monument;
- Phase out commercial fishing over a five-year period; and
- Ban other types of resource extraction and dumping of waste.

Kure Atoll

Kure Atoll, at the northwestern end of the archipelago, is the world's northernmost coral atoll. About 9.5 km in diameter, Kure is a typical atoll comprising one major island, Green Island, and one or more smaller sand spits. Kure is approximately 91 km northwest of Midway and 2,177 km northwest of Honolulu. Beginning in 1837, a series of shipwrecks on the atoll reefs undoubtedly had a major impact on the monk seal population at Kure since the shipwrecked crews often turned to the seals as a major food source. For instance, the crew of the *Parker* reportedly killed 60 seals while stranded on Green Island in 1842-43, and the crew of the U.S.S. *Saginaw* killed at least 60 seals there in 1870 (Clapp and Woodward, 1972).

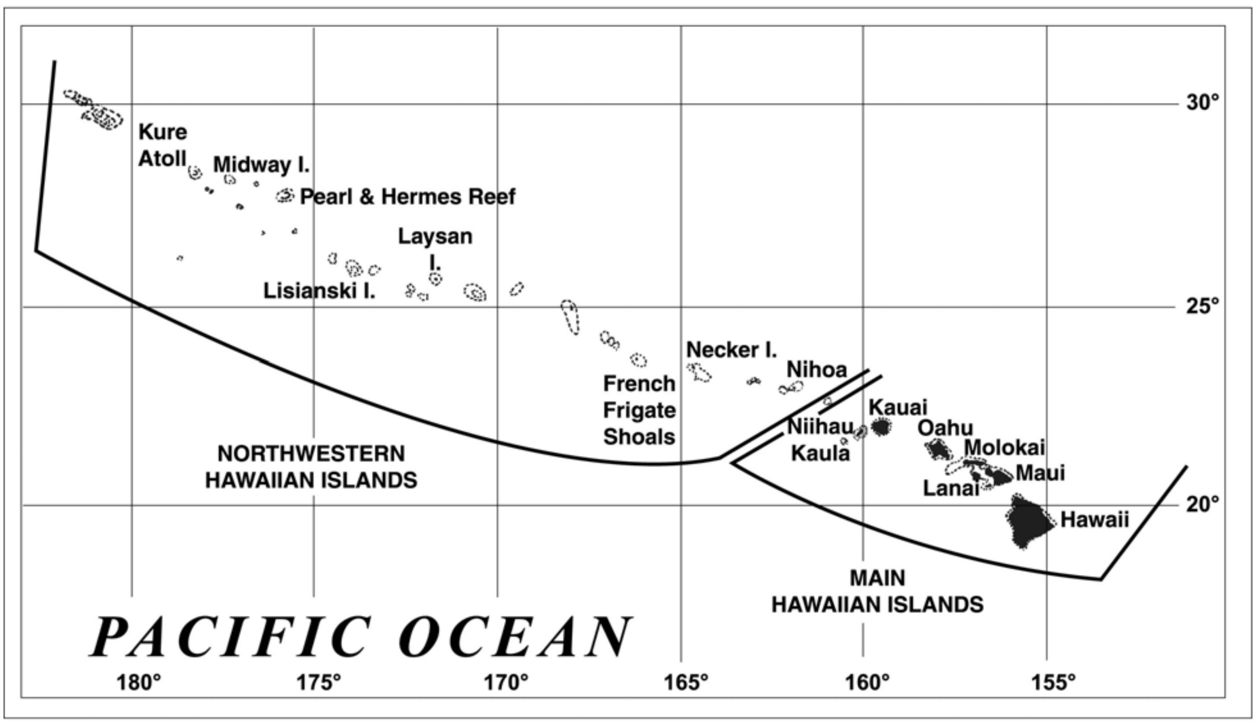

Figure I.C.1. Map of the Hawaiian Islands. Source: NMFS.

Establishment of a 20-person U.S. Coast Guard (USCG) long-range navigation (LORAN) station at Kure in 1960 resulted in a significant disturbance of the seal population on Green Island beaches caused by the residents and their dogs and vehicles (Johnson et al., 1982; Kenyon, 1972). The number of seals at Kure Atoll declined abruptly in the late 1950s and early 1960s following the construction and occupation of a USCG LORAN station on Green Island (Gerrodette and Gilmartin, 1990; Kenyon, 1972). Kenyon (1972) attributed this decline to human disturbance, which caused adult females to abandon prime pupping habitat. Pup survival fell first (Wirtz, 1968), followed by a decline in recruitment of breeding females and the development of an age structure skewed toward older animals (Johnson et al., 1982). The sex ratio of adults also became heavily biased toward males (Reddy and Griffith, 1988), and seals were observed with wounds indicating multiple male aggression. Some of this disturbance was reduced in the late 1970s when NMFS worked with the USCG to remove dogs, limit vehicle use on the beaches, and establish "off-limits" areas. Births declined steadily from the late 1970s to the mid 1980s, and only one pup was born in 1986 (Reddy, 1989; Gerrodette and Gilmartin, 1990).

Beginning in 1981, during the spring and summer months, the NMFS Pacific Islands Science Center (PIFSC), Marine Mammal Research Program (MMRP) conducted monk seal recovery projects directed at increasing survival of young seals. These continued until the USCG closed the LORAN station and left the site in 1992. The MMRP encouraged the USCG to reduce beach activities and avoid monk seals. This effort resulted in a change in behavior of the station personnel that resulted in fewer disturbances to the seals and better pup survival (Gerrodette and Gilmartin, 1990; Gilmartin, pers. comm.). USCG personnel removed an undetermined number of sharks during their occupation of Kure Atoll, which also may have improved monk seal survival. Since 1992, the atoll has only been occupied during MMRP and State of Hawaii summer field camps. Kure Atoll is under State of Hawaii ownership and is managed as a State of Hawaii Wildlife Refuge.

A beach count is a count of all seals found on an island, or on all islands within an atoll during a single mid-day observation. NMFS has established standardized protocols for conducting these counts since the early 1980s. Generally, at least eight counts are conducted per season at each sub-population, and the mean of those counts serves as a trend index for long-term comparisons. During 1983-2000, Kure beach counts increased at 5% per year, declined sharply in 2000-2001 and have since slowly increased. Cohorts born at Kure since 2000 have generally suffered from high juvenile mortality.

The increase in this sub-population until 2000 has been attributed to two factors. First, human disturbance at prime pupping areas was reduced by changes in USCG regulations on beach activities and by the presence of MMRP biologists who encouraged USCG personnel to reduce disturbance of seals (Gilmartin et al., 1986). In July 1992, the LORAN station was closed, and by September 1993 the atoll had been vacated. Second, between 1985 and 1995, 54 immature female seals originally from FFS were released at Kure. By the early 1990s, a few of those females had reached reproductive maturity and were producing offspring. A recent genetic analysis using microsatellite DNA found evidence of low genetic variation and heterozygote deficit in the seal population at Kure Atoll (Kretzmann et al., 2001). These results are a possible indication that inbreeding may be occurring.

Midway Islands

Located approximately 2,100 km northwest of Honolulu, Midway Islands consist of two major islands (Sand and Eastern), small sand islets, and a fringing coral reef. Midway was discovered in 1859 and claimed by the United States. Since that time, there has been considerable interest in the use of Midway for various purposes. These activities resulted in a significant alteration of the physical environment. The Midway sub-population of Hawaiian monk seals was depleted by the late 1800s, but recovered at least partially in the first half of the 1900s (Hiruki and Ragen, 1992; Kenyon and Rice, 1959). Projects included an initial but unsuccessful effort in 1870 to blast a ship channel through the coral reef, the installation in 1902 of a cable station (which led to the introduction of various species of plants and animals and the importation of an estimated 9,000 tons of topsoil for use in gardening), and the construction of an airport in 1935 by Pan American Airways. Midway's role during World War II is well known. The large post-World War II military contingent at Midway peaked at about 3,500 people, but was reduced from 1,600 to fewer than 250 in 1978. At that time, assignment to Midway became "unaccompanied" and families were no longer allowed to go with the service member – causing the schools and main support operations to close.

The highest recorded beach counts of Hawaiian monk seals were made in 1957-1958 (mean of 56 seals), but within a decade, the seals had essentially disappeared. Only one seal was seen during an aerial survey in March 1968 (Kenyon, 1972). Seals were observed at Midway Islands occasionally and only in low numbers during the 1980s. In the 1980s, the Navy requested FWS to take an active role in wildlife management at Midway. During 1982, over 250 civilian personnel replaced the military personnel for facilities maintenance. NMFS was added to that management regime in 1988 when the Navy entered into a cooperative agreement, resulting in the creation of an "overlay" national wildlife refuge managed by FWS and the Naval Air Station.

In the early 1990s, seals began to appear in increasing numbers, mostly immigrants from PHR and Kure Atoll (Eberhardt and Eberhardt, 1994), and births increased. This situation continued until 1996 when the Navy transferred the atoll to the FWS. The FWS immediately closed almost all of the atoll's beaches to human access to reduce the potential for monk seal disturbance. The FWS entered into an agreement with a contractor to maintain the island's infrastructure and assist with runway operations. The contractor was allowed to operate diving, fishing, and ecotour concessions, with a maximum of 100 guests and 100 contract workers theoretically allowed on the island at any one time, which is still the maximum number of people allowed on the island. The concessions never reached the planned numbers of island guests, and the contractor withdrew from the agreement in 2002. Today, the FWS has a small staff and volunteer presence at the atoll and there is a contractor to manage critical support needs of about 50 people living on this island to maintain commercial emergency airport operations.

From 1995 to 2000, mean beach counts increased steadily, and have declined thereafter. Similar to the Kure subpopulation, recent cohorts have experienced low juvenile survival. During 1997-2000, the Hawaii Wildlife Fund conducted a three year, year-round, monk seal population monitoring program at Midway as recommended in the Midway recovery action plan (Gilmartin and Antonelis, 1998). This time period covered the post-Navy occupation, pre-ecotour operations and the first two years of the contractor-operated tour activities. Observations detected the high rate of migrations between Midway and the neighboring atolls of Kure and PHR (Gilmartin et al., 1999). Beach counts doubled and number of births increased during these years, and births were documented for the first time on the human-occupied Sand Island. Additionally, a high fraction of hauled-out seals was documented using the north and east fringing reefs during good weather and sea conditions. Immigrations to the atoll and increased hauling on Sand Island were attributed to the reduction in human disturbance following the FWS beach closures. Midway has a higher fraction of transient seals than any other NWHI site because of its proximity to Kure and PHR (Gilmartin et al., 1999).

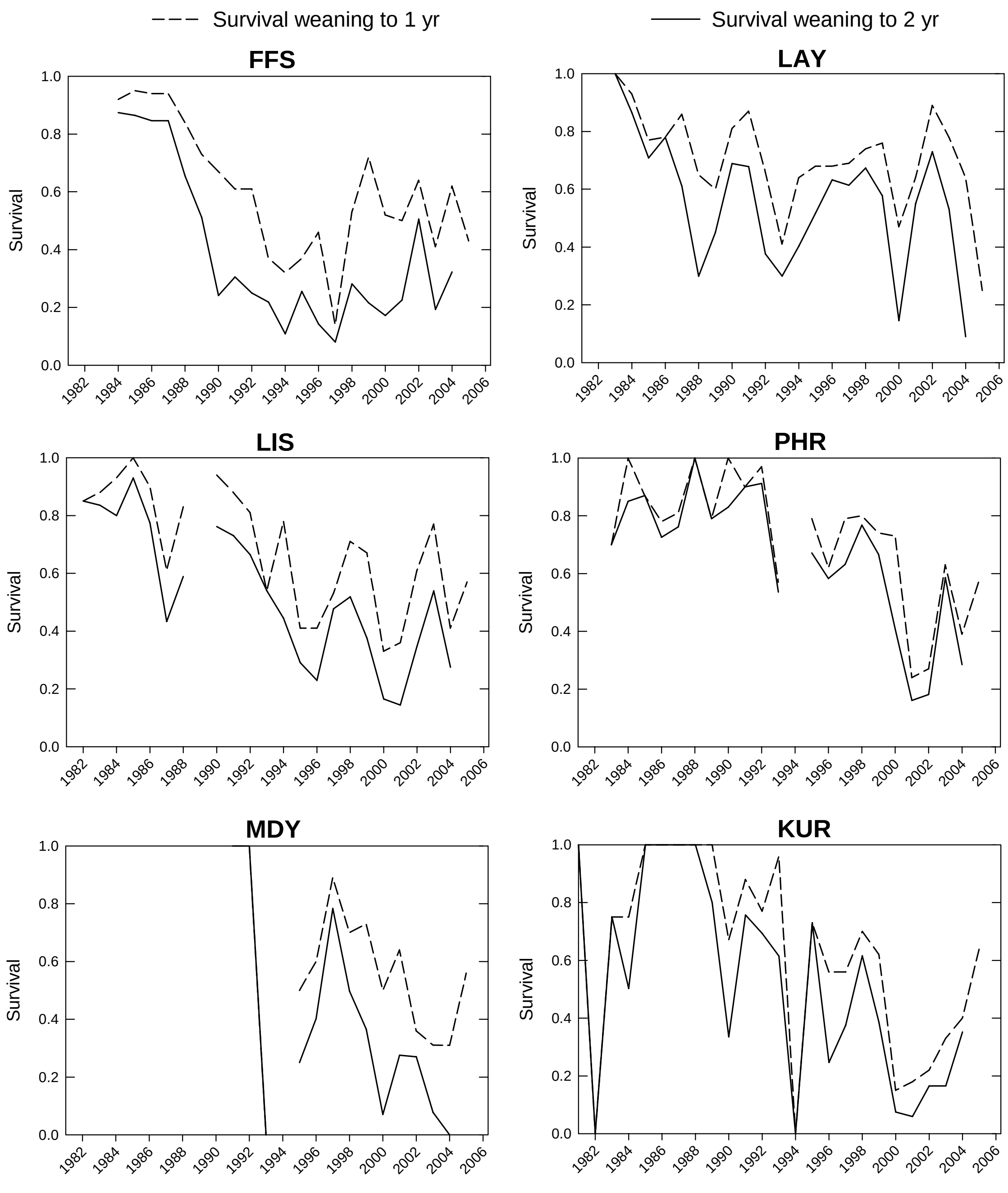

Figure I.C.2. Survival of weaned Hawaiian monk seal pups to age 1 and 2 years at the six main NWHI sub-populations. Source: NMFS.

Pearl and Hermes Reef (PHR)

The first land area southeast of Midway, is PHR, a low coral atoll made up of as many as eight islets, five of which are permanent. The reef encloses an elliptical lagoon, approximately 32 km by 18 km. The reef was unknown prior to 1822, when two British whaling ships, the *Pearl* and the *Hermes*, ran aground there on the same day. The atoll was visited in 1859 by a sealing expedition and by a vessel collecting turtles, bêche-de-mer (sea cucumbers), and albatross in 1882. Beginning in 1902, Japanese feather poachers came to the NWHI and illegally took thousands of albatross, but the full extent of their poaching at PHR is not known. From 1926 to 1930, fishing operations for pearl oysters led to the construction of several buildings on the atoll's Southeast Island. This base was abandoned in October 1931, and U.S. forces destroyed the buildings during World War II. Sometime during 1961, a U.S. military operation from Midway, acting without a permit, occupied the atoll and left behind a steel observation tower and several 55-gal drums, some filled with fuel. The atoll is now unoccupied except for MMRP and FWS field camps.

The number of monk seals at PHR declined by as much as 90% after the late 1950s. The cause of the decline is unknown, but it may have been related to human disturbances associated with military excursions from Midway in the 1950s and 1960s (Woodside and Kramer, 1961; Kramer, 1963). Beach counts increased from the mid-1970s until 2000, with a 6% average annual rate of increase during 1983-2000. As at Kure and Midway, both beach counts and juvenile survival have tended to decline since 2000. The prime reproductive cohorts (ages 7-20) remain well-represented at PHR, but recent declines in juvenile survival have depleted the younger cohorts (ages 1-3). This raises concerns that this sub-population may soon experience age-structure problems similar to those currently at FFS. Using the survival rates estimated from 2001-2003, the intrinsic growth rate is now approximately 0.87, less than the 1.0 required for a stable population. However, a recent genetic analysis of the monk seal population structure at PHR revealed a higher level of genetic variation and heterozygous individuals in the NWHI (Kretzmann et al., 2001). From these results, it was presumed that male mating success may be contributing to this pattern of genetic variation.

Lisianski Island

Lying about 1,667 km northwest of Honolulu, Lisianski Island is a low, sandy island measuring approximately 1.8 km long and 1.0 km wide. It lies near the north edge of Neva Shoal, a large area varying in depth up to 10 fathoms. The island was discovered in 1805 by Capt. Urey Lisianski, a Russian explorer, and it was the site of a number of shipwrecks during the 19th century. Stranded crews from these ships often relied on monk seals, as well as turtles and birds, as a source of food. During the same period, Lisianski was visited by expeditions harvesting fish, turtles, guano, bêche-de-mer, and sharks, as well as monk seals. More concentrated exploitation of the island took place during the period 1904-10 by Japanese feather poachers, but this activity was apparently halted by 1911. Subsequent visits to Lisianski appear to have been limited to those by fishermen, survey parties, and scientific expeditions. Lisianski is only occupied during MMRP monk seal field camps.

Beach counts at Lisianski Island declined sharply after the late 1950s and have remained relatively low and stable since the early 1970s. It would appear that this sub-population is well below historical carrying capacity and should have considerable potential for growth. Reasons for the lack of recovery at Lisianski are unknown. Since 1982, the number of pups born has been variable but low, as has been the number of immature seals. The adult sex ratio has been strongly male-biased, mostly due to a preponderance of older males. Recently, the sex ratio has been decreasing, and in 2002, the sub-population included 1.3 adult males per adult female (Higgins and DeCamp., in prep.). Multiple-male aggression has been observed at Lisianski (e.g., Johanos and Kam, 1986), but only two deaths are known from this cause since 1984. Single male aggression has accounted for the documented deaths of some weaned pups. As with the debris problem discussed below, the full impact of male aggression is not known.

Marine debris from fisheries and other sources may have contributed to the lack of population growth at Lisianski Island. During the period from 1982-1998, monk seals at this site had the highest rate of entanglement of any NWHI sub-population (Henderson, 1990, 2001). Although only four deaths due to entanglement have been confirmed, the full extent of mortality related to marine debris remains unknown.

Another factor contributing to the lack of growth is relatively low fecundity. Preliminary analyses suggest that the reproductive rate at Lisianski may be more similar to FFS than to Laysan Island. Additionally, recently weaned pups at Lisianski tended to be smaller than at other NWHI sub-populations, and survival rates of pups, juveniles, and subadult seals have been lower. These findings are similar to observations at FFS and suggest that food limitation may be the underlying cause for the lack of recovery at this atoll (Craig and Ragen, 1999).

Laysan Island

Laysan Island, the largest land area in the NWHI, is a coral-sand island enclosing a hyper-saline lake. The island is about 2.8 km long and 1.7 km wide, and it is partially surrounded by a fringing reef. It lies approximately 213 km east of Lisianski Island. Laysan is thought to have been discovered by a U.S. vessel, but details are unknown. The first well-documented visit was by the Russian ship *Moller* in 1828. An account of an 1857 visit by the Hawaiian vessel *Manuokawai* included notes of the presence of seals on Laysan. The biota of the island remained relatively undisturbed until the late 19th century. By the turn of the century, the activities of sealers and guano miners had seriously affected the Laysan monk seal population by nearly eliminating it. These activities were followed in 1909-10 by intensive harvesting of bird skins and feathers by the Japanese, who carried out an additional poaching raid in 1915. Since that time, visits to Laysan have primarily been those of survey parties and scientific expeditions. The island has been occupied since 1991 by FWS volunteers and seasonally by a MMRP field camp.

The abundance of monk seals at Laysan Island declined significantly after the late 1950s. While numbers have increased somewhat during the past decade, this sub-population is still far below its historical high. The causes of the decline prior to the late 1970s are unknown. A mass mortality involving at least 50 seals occurred at Laysan in 1978 (Johnson and Johnson, 1981), and while the cause was not conclusively determined, ciguatera was suspected (Gilmartin et al., 1980). Abundance tended to increase from 1995 to 2000, and has subsequently declined.

Some of the decline in abundance was probably due to female mortality caused by male aggression. The adult sex ratio was male-biased at Laysan in the late 1970s–1990s (Johnson and Johnson, 1978; Alcorn and Buelna, 1989; Johanos et al., 1987). From 1982 - 1994, 63 deaths of seals older than pups were confirmed; of those, 45 died as a result of male aggression (Hiruki et al. 1993a and b; B. Becker, pers. comm.). Twenty-six of the 63 were adult females, and 23 of those animals died from male aggression. During the years from 1983-1994, an average of at least 4% (range 0%-13%) of Laysan Island adult females was lost annually due to injuries related to male aggression (Johanos et al., 1999).

In contrast to FFS, juvenile survival has been relatively good at Laysan Island for most cohorts (Figure I.C.2). Exceptions include 15% survival of the 2000 cohort from weaning to two years of age, and record low survival of 1-3 yr old seals during 2006. Much of this mortality is believed to have been related to food limitation. Age-specific birth rates at Laysan Island are also more favorable compared to FFS. The underlying cause for the lack of recovery of this island population is not understood.

French Frigate Shoals (FFS)

FFS is an atoll, open to the west and partially enclosed by a crescent-shaped reef to the east. It lies about midpoint in the Hawaiian Archipelago. The largest land area in the shoals is Tern Island (about 34 acres), and a number of smaller islets, including Whaleskate and Trig which are mentioned later in the Plan, are scattered along the westerly reef of the crescent (totaling 44 acres). The shoals were discovered by the French in 1786, and claimed by the United States in 1859. The reported discovery of guano deposits that same year aroused some excitement among investors, but the quantity of guano on FFS was never sufficient to make mining worthwhile. In 1882, however, a vessel chartered by a U.S. company visited the atoll and departed with a cargo of shark (flesh, fins, and oil), turtle (shells and oil), bêche-de-mer, and bird down. During the 1930s, the U.S. Navy used the area extensively for training exercises. Following the Battle of Midway during World War II, an airbase was established on Tern Island, and construction of a LORAN station was begun in 1944 on East Island. When the airbase was closed in 1946, fishermen from Hawaii began to use the facilities. The East Island LORAN station was in operation until it was decommissioned in 1952. At that time, a new LORAN station located at Tern Island was activated and operated by the USCG until mid-1979. The FWS has occupied the facility since that date with a small staff, which is augmented by MMRP, other agencies and private projects throughout the year.

The largest monk seal sub-population is currently found at FFS, but this was not always the case. Human disturbance caused by the U.S. Navy during 1942-1948, and by the USCG during 1944-1952 on East Island, depressed that sub-population (Rice, 1960; Fiscus et al., 1978; Gerrodette and Gilmartin, 1990). After the military left East Island, the FFS sub-population grew rapidly until the mid 1980s. The USCG remained on Tern Island (but not East Island) at FFS, until 1979. Following their departure from FFS, a dramatic increase occurred in seals hauling on Tern Island (Schulmeister, 1981). In 1986, the mean count at FFS (excluding pups) was 284 (NMFS, unpub. data), approximately 6-8 times higher than it had been in the late 1950s.

Since 1989, beach counts at FFS have declined by 75%, and the annual number of births dropped from a high of 127 in 1988, to 39 in 2006 (Figure I.C.3). The most severe demographic changes have been decreased survival rates of immature animals (Craig and Ragen, 1999), including a decline in survival from birth to weaning (Figure I.C.4). Survival from weaning to age two years also declined from almost 90% in the mid-1980s to as low as 8% in 1997 (Figure I.C.2). These factors have contributed to a pronounced age structure imbalance in which young adult seals are severely under-represented (Figure I.C.5.). This paucity of young seals means that the sub-population will decline further in coming years as there will be fewer new females reaching maturity.

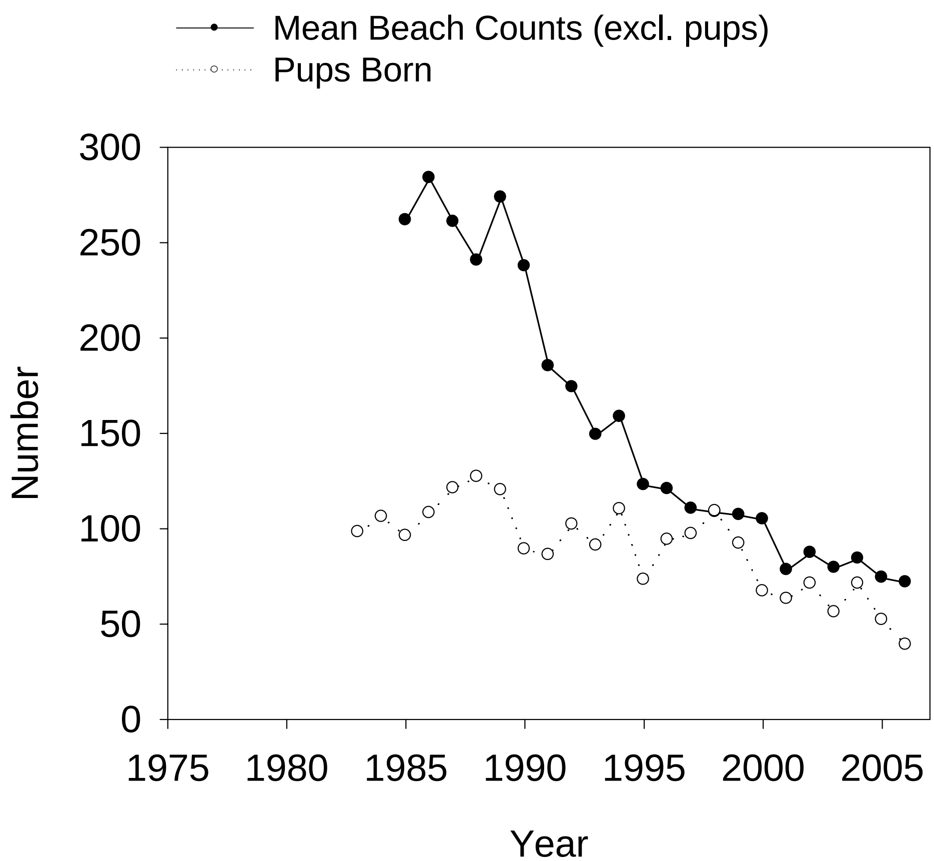

Figure I.C.3. Mean Hawaiian monk seal non-pup beach counts and pups born at FFS.

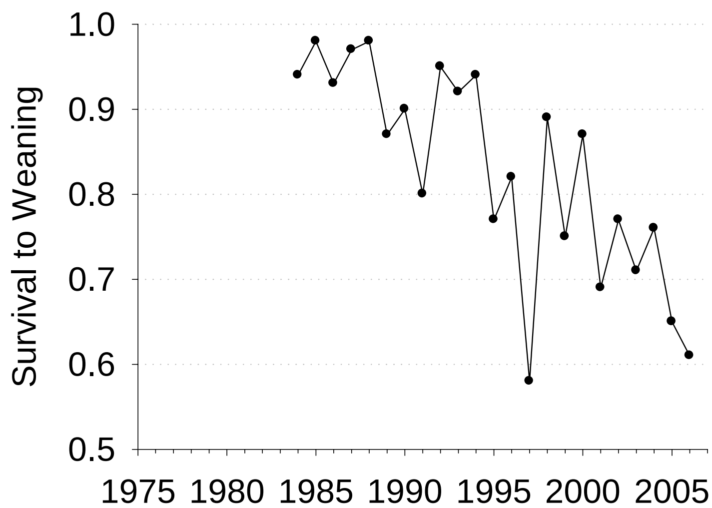

Figure I.C.4. Survival from birth to weaning for Hawaiian monk seals at FFS. Source: NMFS.

The factors responsible for poor juvenile survival at FFS are being investigated. In addition to shark predation, evidence suggests that decreased prey availability is the major factor. As early as 1991, researchers detected an exceptionally high proportion of juvenile and subadult seals in emaciated condition (Gilmartin, 1993a). Pups and immature seals born at FFS in the early 1990s tended to be smaller than seals of the same age at Laysan Island, and smaller size at weaning was correlated with lower survival from weaning to age 2 (Craig and Ragen, 1999). After 1995, the decline in weaning sizes at FFS moderated, and early survival has generally improved slightly since 1999 (Figure III.B.3). Nonetheless, the survival rates of pups and juveniles continue to be well below their historic rates.

Several factors, alone or in combination, may have caused the food limitation that has affected monk seals at FFS (Craig and Ragen, 1999). Ecosystem-wide productivity decreased in the late 1980s and early 1990s, probably due to a decadal scale oscillation in oceanographic conditions (Polovina et al., 1994). This appears to have resulted in declines in the abundance of coral reef fishes at FFS (DeMartini et al., 1996). Monk seal population growth during the 1960s, 1970s, and 1980s may have brought the sub-population to carrying capacity. Hence, while the impact of oceanographic events may have affected monk seals throughout the NWHI (Polovina et al., 1994), the combination of a population at carrying capacity and decline in fish abundance, may have magnified the impact of ocean productivity oscillations at FFS. In addition, during the last three decades, lobster fishing occurred on banks near FFS. While monk seals are known to eat lobsters, the importance of lobster in the monk seal diet has not been quantified and is the subject of ongoing studies.

Specific mortality agents, perhaps indirectly related to food limitation and resulting in poor physical condition, have reduced survival of juvenile seals at FFS. Data from 1984 - 1994 suggest that the number of severe injuries attributable to shark predation increased substantially after 1987 (Bertilsson-Friedman, 2002), especially at Trig Island. Most FFS pups were born at Trig Island after Whaleskate Island, once the main pupping islet in the atoll, gradually eroded and eventually disappeared between 1994 and 1999. Adult male aggression

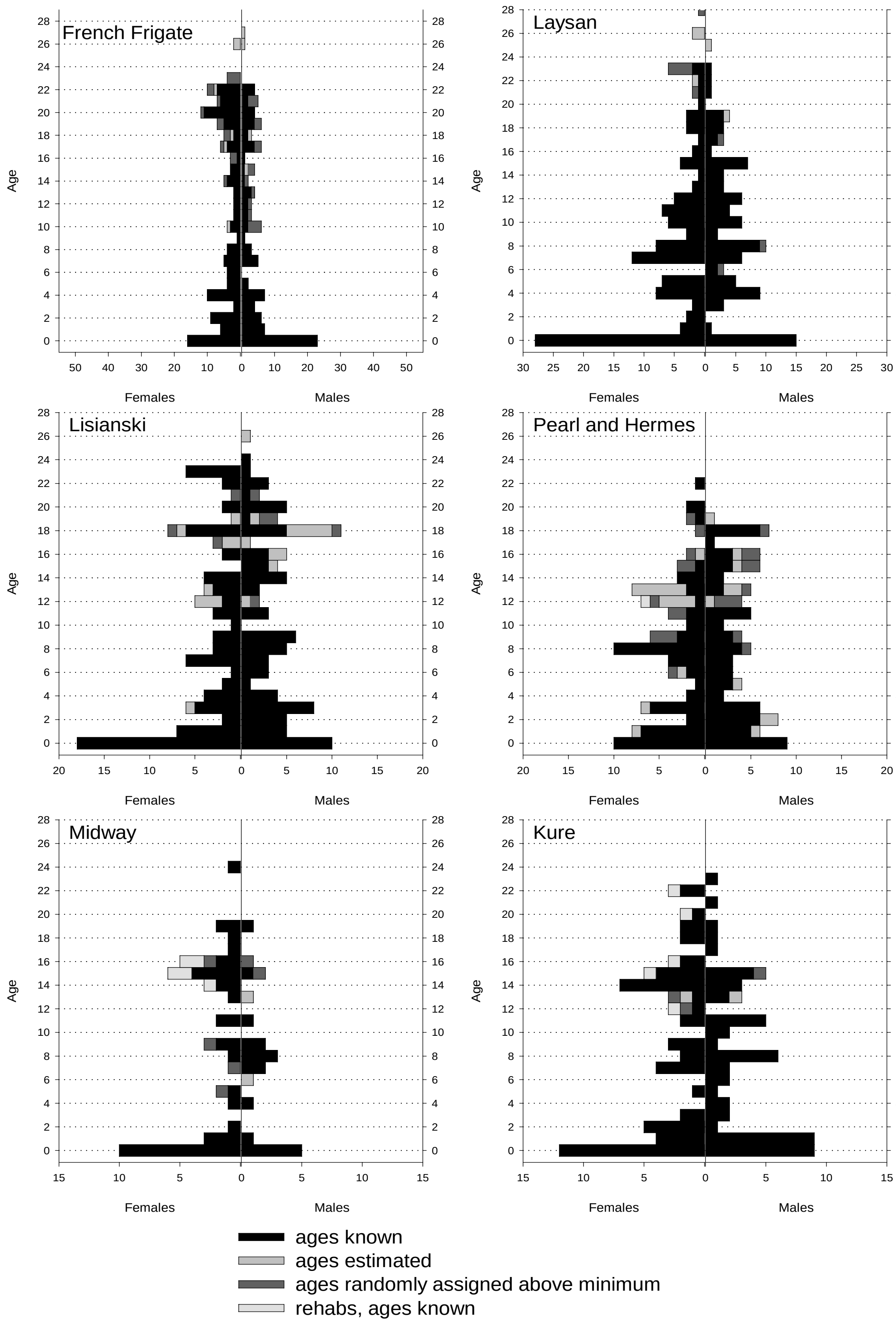

Figure I.C.5 Age and sex structure of the six main NWHI subpopulations of Hawaiian Monk Seals in 2006. Source: NMFS.

also accounted for some of the juvenile mortality during the 1990s. Three males killing pups at or near the time of weaning were removed by euthanasia (one in 1991) or by translocation to Johnston Atoll (two males in 1998). Entanglement in marine debris also contributes to an unknown amount of mortality (Henderson, 2001).

In addition to poor immature survival, the onset of reproduction is later and the mean fecundity for mature females is lower at FFS compared to Laysan Island (see Life History section, p. I-24). The factors causing this low reproductive performance are unknown, but may be related to the nutritional factors described above. Low fecundity coupled with the expected paucity of reproductively active females in coming years indicates that a prolonged decline in abundance at FFS is likely.

The respective importance of the various causes of the decline at FFS is not known with certainty. Regardless of the underlying causes, the high mortality of juveniles and the consequent loss of reproductive potential will significantly impede recovery of this sub-population.

Necker and Nihoa Islands

Necker Island, about 1.1 km long and 0.5 km wide, is a rocky, is a J-shaped island consisting of two parts connected by a low isthmus. Its European discovery is credited to a French navigator, La Perouse, in 1786, but prehistoric habitation of the island was noted about 1879 by one of the early landing parties. Ships periodically visited the island during the mid- and late-1800s, but heavy seas often thwarted landings. During the period of feather poaching by the Japanese early in the 20th century, patrol vessels visited Necker, but no evidence of molestation of the birdlife was seen. Observations of seals at the island suggest that the species has occurred there regularly for at least a century, although likely for much longer. Necker Island is uninhabited and only rarely visited by humans.

Nihoa Island, the easternmost of the NWHI, is a precipitous remnant of a volcanic peak, about 500 m long and ranging in width from roughly 100 to 350 m. Nihoa was discovered by Europeans in 1779, though, like Necker Island, there is evidence of prehistoric human occupation. Over the years, difficulties in landing on the steep slopes of Nihoa have restricted visits and may be one reason that feather poachers did not attempt to exploit the island. During the 1960s, military personnel involved in a project to establish astronomical stations in the NWHI, occupied Nihoa briefly. Since 1980, births have been recorded during occasional visits. This island is usually only visited by FWS staff, other researchers, and Hawaiian cultural expeditions.

The number of monk seals at Necker and Nihoa islands is relatively low and the potential for growth at both locations may be limited by the lack of suitable terrestrial habitat (Westlake and Gilmartin, 1990). In 2002-2006, combined beach census totals for Necker and Nihoa ranged from 32-45 animals. Much of the shorelines of both islands is rocky, inaccessible, and surrounded by often turbulent nearshore waters, although Nihoa has some sandy beach habitat that appears well suited for use by monk seals. Opportunities for scientists to visit these islands are infrequent and brief, so abundance cannot be enumerated and assessment of pup production is incomplete. An apparent increase in the number of seals at Necker and Nihoa islands until approximately 1990 may have been due to an influx from FFS (Finn and Rice, 1994; Ragen and Finn, 1996). Since few animals are tagged at Necker and Nihoa Islands, it is not possible to assess the rate of emigration from these islands. Given the proximity of these islands to the MHI, more information is needed about the movements and eventual fates of monk seals using Necker and Nihoa, as these islands could serve as a gateway for disease transmission throughout the entire meta-population.

Main Hawaiian Islands

Most of the extant Hawaiian monk seals live in the NWHI. However an increasing number of sightings and births have recently occurred in the MHI, where no systematic surveys were conducted prior to 2000. Kenyon and Rice (1959) present a handful of MHI seal sightings from the first half of the 20th century. The earliest seal documented in the MHI was reportedly killed by Hawaiians in Hilo Bay on the island of Hawaii, and subsequently eaten (H.W. Henshaw, in Dill and Bryan, 1912), though Rosendahl (1994) reported evidence of monk seal remains dating to between 1400 and 1760 on the island of Hawaii. There are eight primary MHI, and numerous small islets and offshore rocks. Seals have been observed on each of the main eight islands. There were at least 45 seals in the MHI in 2000 and at least 52 in 2001, based on aerial surveys of all MHI coastlines supplemented by sightings of seals from the ground (Baker and Johanos, 2004). These counts are well below total abundance because they do not account for animals in the water, and not every seal on land can be detected. In 2005, the total number of unique seals identified was 77 (Carretta et al. draft 2007 Pacific Stock Assessment Reports). This number is based upon non-systematic sightings of tagged and naturally marked individuals, and likewise is probably well below true abundance. Moreover, annual births in the MHI have evidently increased since the mid-1990s. It is possible that Hawaiian monk seals may be re-colonizing the MHI, which was likely part of their historic range. Regardless, the MHI habitat appears to be favorable for continued increases of this endangered species.

While monk seals have been seen on all the MHI, the largest number is likely on Niihau (a privately owned island where ground access for research activities is currently unavailable), and the number of sightings tends to decrease moving to the southeast along the island chain. Overlaying this pattern is a tendency for seals to frequent remote areas where human presence or access is limited. Births in the MHI appear to have become more frequent since the mid-1990s. Births have occurred almost exclusively in relatively remote areas, and only a few females are known to have given birth on popular public beaches.

Increasing numbers of monk seals in the MHI are very important for recovery of the species if another functional subpopulation can be added to the overall metapopulation. Seals hauled out on beaches of the MHI, especially mothers with pups, are likely to be disturbed by humans and animals, and a high degree of public awareness, public cooperation, and effective regulatory enforcement is needed to manage such haul-out events. A critically important concern for seals in the MHI is the potential to contact diseases such as leptospirosis and toxoplasmosis from wild and domestic animals that could be transmitted to seals in the NWHI. Conflicts between seals and fishermen, boaters, and divers also are conservation concerns.

There were a number of challenges that were discussed at length at the Marine Mammal Commission sponsored "Workshop on the Management of Hawaiian monk seals on the beaches of the Main Hawaiian Islands" held on Kauai in October 2002 (Marine Mammal Commission [MMC], 2002). In March 2006, a "MHI Hawaiian Monk Sea Management Meeting" was held on Oahu as the first step to develop a management plan for the MHI. Five discrete issues were discussed: Emerging diseases; Pups in streams; Pupping on popular beaches; Stranding response; and Habituation/Displacement. This agency-level meeting included representatives from the NMFS Pacific Islands Regional Office (PIRO), the NMFS Pacific Island Fisheries Science Center (PIFSC) Marine Mammal Research Program (MMRP), the State of Hawaii Department of Land and Natural Resources (DLNR) and Department of Conservation and Resource Enforcement (DOCARE), Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS), and the National Park Service.

2. *Summary of Current Abundance*

The methods used to derive estimates of monk seal abundance, and the abundance at each site, are as follows (see Table I.C.1):

- Main reproductive sub-populations in the NWHI of FFS, Laysan, Lisianski, PHR, Midway Islands, and Kure Atoll: total enumeration of individuals when possible, otherwise capture-recapture estimates or minimum abundance (Baker 2004; Baker et al. 2006).

- Necker and Nihoa Islands: corrected mean beach counts made during most recent five years at Necker and Nihoa Islands. A correction factor (2.89 ± 0.06, NMFS unpubl. data) derived from observations at the main reproductive sites is applied.

- MHI: Minimum abundance consisting of the total number of uniquely identifiable seals observed alive during a calendar year. Sightings are non-systematic and collected by NMFS, and reported by volunteers, partner agencies and the general public.

- Abundance data presented are as up to date as possible, reflecting information through 2006 in the NWHI and through 2005 in the MHI.

Table I.C.1. Estimated 2006 monk seal abundance for each population segment (Source: NMFS) N_{min} calculated at Necker and Nihoa Islands according to the methods of Wade and Angliss (1997).

Site	Estimation Method	N	Std Dev	N_{min}
FFS	Minimum	246	NA	246
LAY	Minimum	221	NA	221
LIS	Total enumeration	194	NA	194
PHR	Minimum	177	NA	177
MDY	Minimum	60	NA	60
KUR	Minimum	118	NA	118
Necker	Corrected beach counts	37.3	15.9	26
Nihoa	Corrected beach counts	71.7	19.2	57
Main HI	Minimum*	77	NA	77
TOTAL		1,202		1,176

*MHI minimum is the total unique individuals identified in 2005.

The most accurate method of determining Hawaiian monk seal abundance is total enumeration, though this cannot be achieved at all sites. By analyzing the "discovery curve" (accumulation of new individuals sighted over time during a field season) a determination is made as to whether total enumeration has been achieved at each of the main NWHI subpopulations each year (Baker et al. 2006). At those locations, the majority of individual seals can be identified by flipper-tags that have routinely been applied to weaned pups since the early 1980s, bleach marks placed annually, and by natural features such as scars and distinctive pelage patterns (Harting, et al., 2004). When total enumeration is not achieved, closed population capture-recapture abundance estimates (using Program CAPTURE) are obtained using capture histories accumulated during systematic surveys within the field season (Baker 2004). In some cases, the capture histories are such that no capture-recapture model is appropriate, and minimum abundance is used based upon the total unique individuals identified. The methods used for Necker, Nihoa and the MHI are less reliable, but are the best that can be done under current budget and logistical constraints. Because the other population segments represent relatively small proportions of the total population, errors in their abundance estimates do not greatly distort the estimated total population size.

The best estimate of the total population size in 2006 is 1,202 seals. These data can also be used to determine a minimum population estimate (N_{min}) for the total population that accounts for the statistical uncertainty in the abundance estimates, as is done for Stock Assessment Reports required by the Marine Mammal Protection Act (Wade and Angliss, 1997). Using that procedure, minimum population size estimate for the total population is the sum of these estimates, or 1,176 seals (NMFS data).

3. Long-Term and Recent Population Trends

Total abundance estimates cannot be used for characterizing long-term trends because sufficient field effort in the NWHI has not been consistently undertaken at all sites and years.

Instead, a measure of long-term trends is derived from the mean of all of the beach counts that have been conducted with varying frequency since the late 1950s. As mentioned in previous sections, a beach count is a count of all seals found on an island, or on all islands within an atoll in a single mid-day observation of all haul-out areas. NMFS has established standardized protocols for conducting these counts, and at least eight counts are conducted per season at each sub-population with the mean of those counts serving as a trend index for long-term comparisons. These beach counts provide a useful index because the general methods used during these 45 years are comparable.

A consideration when interpreting the mean beach counts is that the ratio of mean beach counts to the total population size is likely variable over space and time. That is, all of the factors that might cause the proportion of animals on the beach to vary over time (for example, weather, time spent foraging, etc.) are not all known or well characterized, and hence appropriate correction factors have not been determined. Eberhardt et al. (1999) concluded that "beach counts may be very poor guides to year-to-year trends. The beach counts are, however, valuable indicators of long-term trends."

The first range-wide surveys of Hawaiian monk seals were conducted in the late 1950s (Kenyon and Rice, 1959; Rice, 1960). Additional counts were conducted at Midway Islands in 1956-1958 (Rice, 1960) and at Kure Atoll in 1963-1965 (Wirtz, 1968). Surveys were repeated throughout the 1960s and 1970s, and while the methods were not standardized, complete beach counts are roughly comparable. These results suggest that the species declined by about 50 percent between the late 1950s and the mid 1970s (Kenyon, 1973; Johnson et al., 1982). Beach counts of non-pups (juveniles, sub-adults and adults) declined by 66% between the years 1958 and 2006 (Fig. I.C.6).

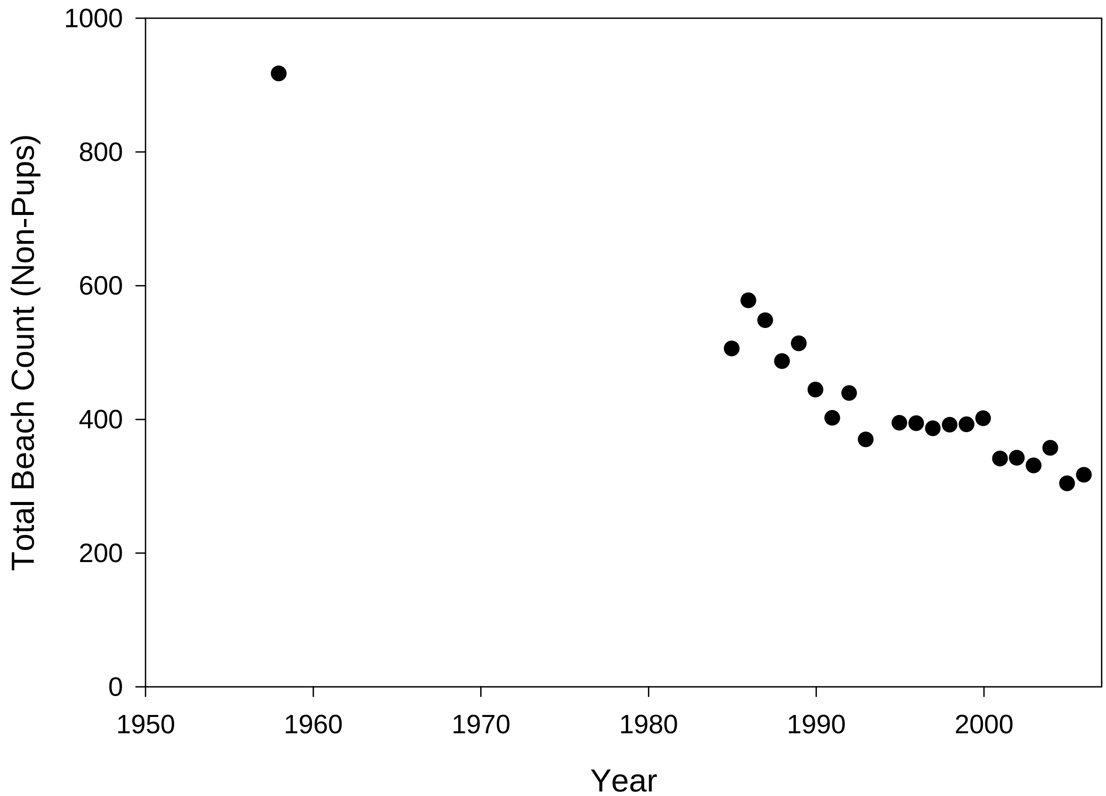

Figure I.C.6. Historical trend in mean beach counts (non-pups) of Hawaiian monk seals at the six main reproductive sub-populations. Source: NMFS.

There are no historic data for estimating population size prior to the surveys of the 1950s or to estimate carrying capacity. Polynesian settlement (approximately 300 AD) probably excluded monk seals from the main Hawaiian Islands, constraining them to the NWHI where there is only evidence of Polynesian presence at Necker and Nihoa Islands (Rauzon, 2001)). In the MHI, seven monk seal sightings were documented from 1928-1956 (Kenyon and Rice, 1959). Niihau residents reported that seals appeared there in the 1970's (Baker and Johanos, 2004). In an effort to reduce male aggression in 1994, 21 adult seals were translocated to the MHI from the NWHI, accounting for a small portion of seals sighted among those that naturally occur in MHI (Hiruki et al., 1993a; Starfield et al., 1995; Baker and Johanos, 2004).

The surveys of the NWHI in the 1950s may have occurred too soon after WWII for the population to have recovered from any presumed impacts associated with military activities, and, in fact, some military presence was still having a negative effect on the monk seals at that time. All that is known is that during the very limited window of data availability, the largest counts observed at most islands were obtained around 1958. Three exceptions to this were FFS, where the maximum count was obtained in 1985, Necker where the maximum was obtained in 1977, and Nihoa where the maximum was obtained in 1991. Across all sites in the NWHI, the sum of the maximum counts, totaled 1541, corresponding, after a very uncertain correction, to a potential population peak of some 3000 individuals.

More recently, non-pup beach counts declined rapidly from 1985 – 1993, and then became relatively stable until the current decline began in 2001. Presently, total abundance at the six main NWHI subpopulation is declining at a rate of -3.9% yr^{-1} (95% CI = -4.8% yr^{-1} to -3.0% yr^{-1}) (Figure I.C.7, NMFS).

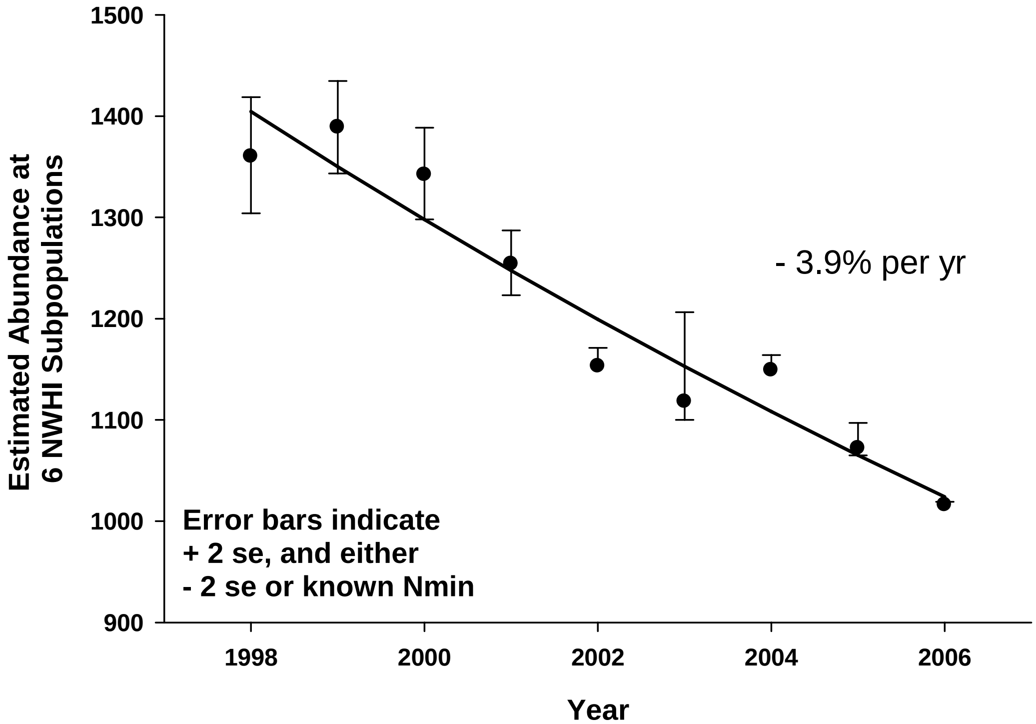

Figure I.C.7. Trends in abundance of Hawaiian monk seals at the six main NWHI sub-populations combined, 1998-2006. This graph does not include abundance estimates for Necker, Nihoa or the main Hawaiian Islands. Error bars indicate + 2 standard errors and either – 2 standard errors or known minimum abundance. The fitted trend line reveals an estimated decline of 3.9% per year (NMFS).

The long-term combined trend at the main NWHI sites (Figure I.C.6) masks a diversity of trends within the individual sub-populations (Figure I.C.8). The population dynamics at the different subpopulations have varied considerably, and current demographic variability among the island populations probably reflects a combination of different histories of human disturbance and management (Gerrodette and Gilmartin, 1990; Ragen, 1999), and varying environmental conditions (Polovina et al., 1994; Craig and Ragen, 1999, Baker and Thompson 2007, Baker et al. in press). For instance, most of the sub-populations declined following 1958, but the degree and duration of those declines varied. The exception was FFS, which grew rapidly from the early 1960s to the late 1980s, when the population collapsed with non-pup beach counts declining by 70% during 1989-2001. Populations at Laysan and Lisianski Islands have remained relatively stable since approximately 1990, though the latter has decreased slightly.

Contrary to trends at the above sites, the sub-population at Kure Atoll grew at an average rate of 5% per year after 1983, due largely to decreased human disturbance, increased survival of young seals, and the introduction of rehabilitated female juveniles from FFS. The sub-population at PHR increased at approximately 7% per year during 1983-1999. This annual growth rate is the best indicator of the maximum net productivity rate (R_{max}) for this species. Finally, Midway Island was formerly largely unavailable to monk seals due to intensive human presence, but the small Midway seal population, aided by protective management policies and immigration, increased after 1990. During 1992-1997, monk seal use of the atoll's beaches increased dramatically, as did births. However, after 2000, all three of the western sub-populations have shown indications of decline in abundance, apparently due to low juvenile survival.

The decline at FFS is of particular consequence to the welfare of the overall population because this site once accounted for over 50% of the total non-pup beach counts among the six main NWHI sub-populations. While that proportion has now dropped to approximately 25% of its observed peak, FFS remains the single largest sub-population.

Population monitoring visits to Necker and Nihoa Islands are infrequent and brief, so enumeration is not possible at these sites. Counts of seals at those islands tended to increase from approximately 1970 - 1990 (Figure I.C.9). The increase in counts may have been due to an influx of seals from FFS, which was growing at that time. Since then, counts at Necker have declined, mirroring the trend at FFS. Nihoa counts have been variable and perhaps increasing slightly, suggesting trends at this island are not as dependent upon FFS. During a seven-day period at Necker Island in 1993, 14 tagged seals were sighted, all of which had been marked as pups at FFS (Finn and Rice, 1994). During the same period, 12 tagged seals were sighted at Nihoa Island, 10 of which were from FFS (Ragen and Finn, 1996).

The number of documented monk seal sightings in the MHI increased during the 1990s. Historical abundance data for the MHI are limited, as there were no systematic surveys of monk seals conducted prior to 2000. Documentation of births in the MHI has become more frequent. The known number of annual births in the MHI before and during the 1990s was usually zero and never exceeded 4, but at least 10 births have been recorded each year since 2003 (Baker and Johanos, 2004).

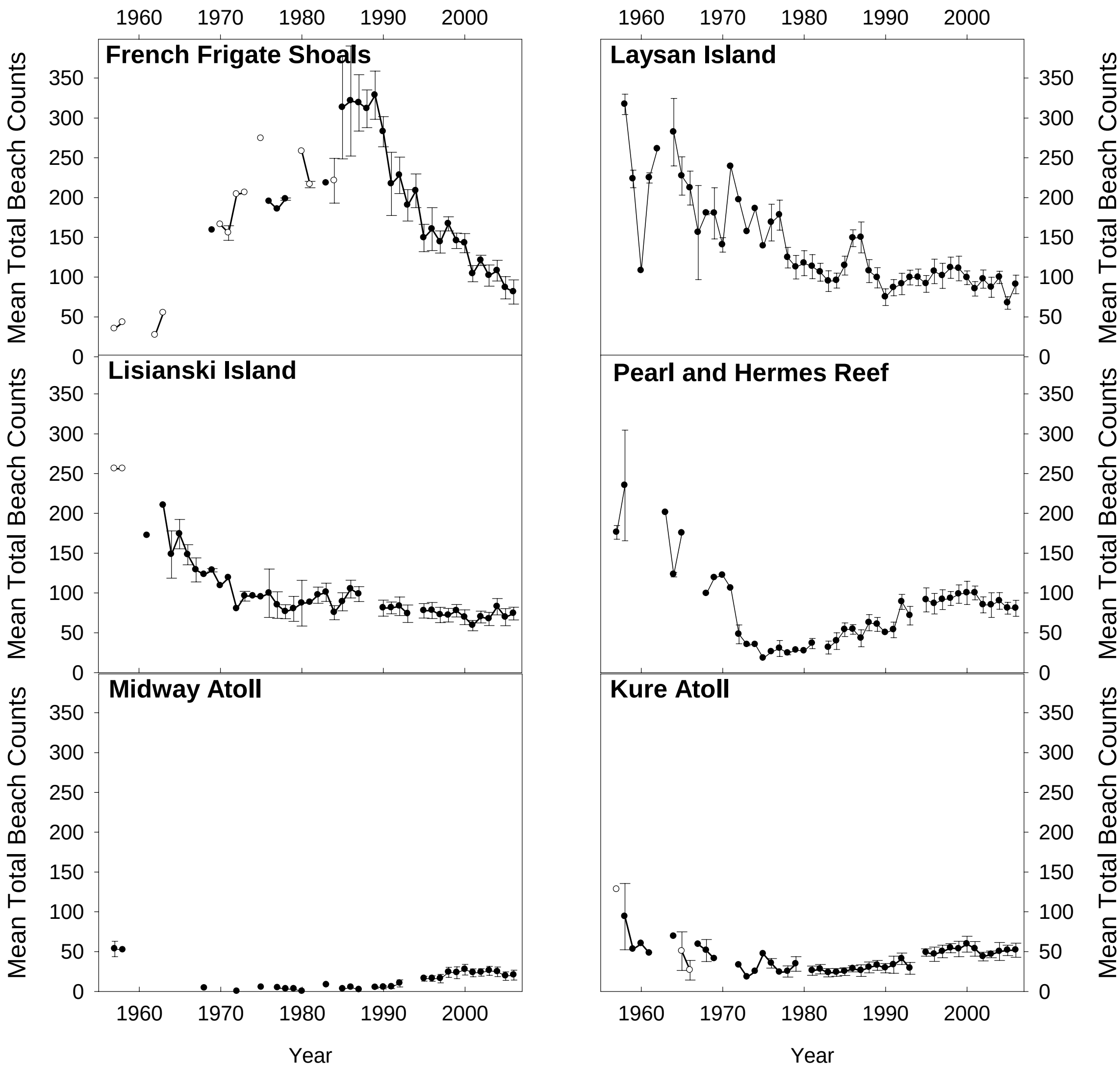

Figure I.C.8. Trends in mean total beach counts (±sd as measure of variation in counts) of Hawaiian monk seals at the six main NWHI sub-populations. Closed circles represent reliable counts made with standardized methods. Open circles represent counts which were in some way less reliable (incomplete or varying methods). Source: NMFS.

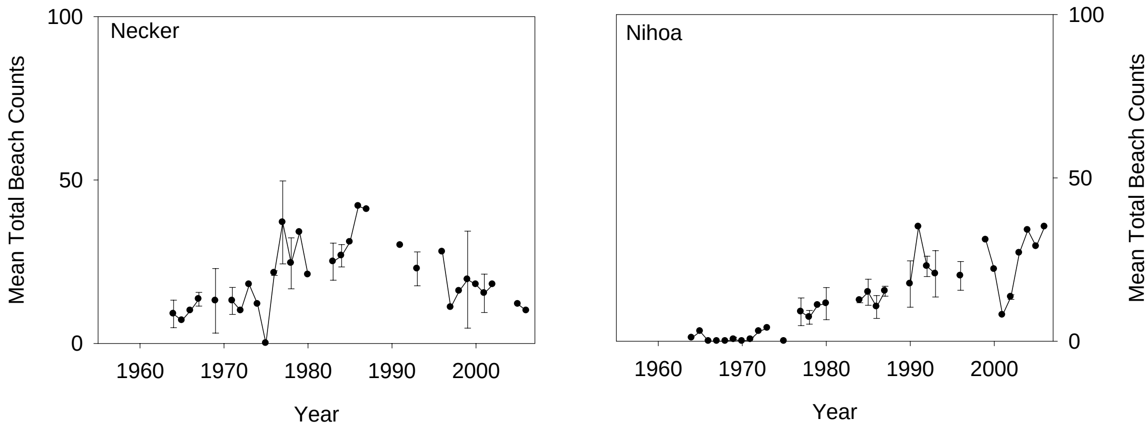

Figure I.C.9. Mean total beach counts (±sd) of Hawaiian monk seals at Necker (left) and Nihoa (right) Islands. Source: NMFS.

D. Life History

1. Reproduction and Behavior

Monk seal births have been documented in all months of the year (NMFS, unpubl. data), but are most common between February and August, peaking in March and April (Johnson and Johnson, 1980; Johanos et al., 1994). Pregnant females select a site, usually the same each year, for parturition (Westlake and Gilmartin, 1990) and give birth to a single offspring. On average, pups nurse for 5-6 weeks (Boness, 1990; Johanos et al., 1994; Johnson and Johnson, 1978, 1984; Kenyon and Rice, 1959), and weigh 50-100 kg at weaning (Kenyon and Rice, 1959; Craig and Ragen, 1999).

As with many phocids (Kovacs and Lavigne, 1986), female monk seals usually fast and remain with their pups throughout the nursing period. Nursing monk seal mothers are generally intolerant of other adult seals, including other mothers with pups (Kenyon and Rice, 1959; Boness, 1990). But, they often appear not to distinguish consistently their own from others' pups, as evidenced by the occasional switching of pups, especially when pairs occur close together (Johnson and Johnson, 1978; Boness, 1990). Also, a mother may foster another pup if her own becomes lost or dies (Alcorn and Henderson, 1984; Gerrodette et al., 1992). Switching or fostering of pups appears to have minimal effects on first year survival (Boness, 1990) in cases where the pups are of comparable size. When the pups are of greatly disparate size at the time of exchange, the larger pup will likely nurse longer than the mean nursing time and the smaller pup will nurse for less time than normal and be weaned at a low weight with reduced survival probability.

Weaning occurs when the mother abandons her pup and returns to the sea to resume feeding. Over the next few months, she will regain a considerable amount of the mass lost during lactation. About 3-4 weeks after weaning her pup, she will mate and, 5-6 weeks later, she will haul out again for 10-14 days or more to molt. On average, females that do not give birth in a given year will molt a month earlier (Johanos et al., 1994).

In recent years, less than 200 Hawaiian monk seal pups are born annually with pup production varying by island and by year. At Laysan and Lisianski Islands where field observations typically encompass the entire birthing season, an average 68% of known reproductively mature females pup each year (Johanos et al., 1994).

Females give birth for the first time between the ages of five and nine. Data on age-specific birth rates are available for some sub-populations (Figure I.D.1). Results show that reproductive parameters vary substantially among sub-populations. The most striking difference from data available through 2001 is the relatively high fecundity at Laysan Island compared to FFS and Lisianski Island. At Laysan, maturation occurs approximately 1-4 years earlier than at the other sites. Since the onset of sexual maturity in pinnipeds usually coincides with the attainment of some percentage of final body size (Laws, 1956), the observed delay at both FFS and Lisianski is consistent with the smaller weaning sizes observed at both of those sites (Craig and Ragen, 1999; NMFS unpublished data) and is indicative of poorer nutritional conditions for adult and immature seals when compared to Laysan.

The maximum fecundity attained by mature females is also higher at Laysan (Figure I.D.1). Although sample sizes for ages 15 and older are very small, the data suggest a senescent decline in fecundity past an age somewhere between 10 and 15 years at both Laysan and FFS (Figure I.D.1). That pattern is not yet evident at Lisianski. Age-specific reproductive rates have not been determined for the other three atolls (Pearl and Hermes, Midway, and Kure) because field seasons do not encompass the entire pupping seasons at these sites. However, based on the number and age of females at those atolls and the total number of pups produced, it appears that fecundity is somewhat lower than that of Laysan Island, but probably not as low as at FFS (Harting, pers. comm.).

Age of sexual maturity for males is unknown, but their size and behavior suggest that they reach maturity at approximately the same age as females. Little is known about male reproductive success because mating occurs at sea and is rarely observed. A small number of observations indicate the males mount the females' back by grasping her sides with his foreflippers and biting her back. Bite marks or injuries on the dorsum of some females provide the only external evidence that mating might have occurred. The average interval between weaning and observed mating injuries is 26 days (Johanos et al., 1994).

The reproductive behavior of male seals can be a serious concern because of multiple male aggression. Such aggression occurs when a number of males gather and repeatedly attempt to mount and mate with a single seal (e.g., Johanos et al., 1990). The victim, which may be an adult female or an immature animal of either sex, is often severely injured, dies of infection or some other direct result of the injuries, or is killed by sharks (Hiruki et al., 1993a, and b). A related phenomenon called single male aggression is often directed toward pups at or near the time of weaning and juvenile seals. In those cases, a lone male attempts to mount a pup, inflicting serious injury or death. Most of the documented mortality associated with single male aggression is caused by suffocation or drowning, but pups have also died as a result of infected wounds caused by the attack.

In general, monk seal aquatic behaviors include thermoregulatory cooling, resting, playing, mating, and foraging. Mating behavior has not been commonly observed and the only records of monk seal copulation have been in the waters off Laysan Island on three occasions: once about 5 m offshore and twice approximately 1 km offshore (Johnson and Johnson 1981, Shallenberger, personal communication). Video camera deployments on adult male monk seals have indicated that while in the water they spend 34% of their time resting, 9% interacting socially, and 57% of their time foraging and traveling (Parrish et al., 2000).

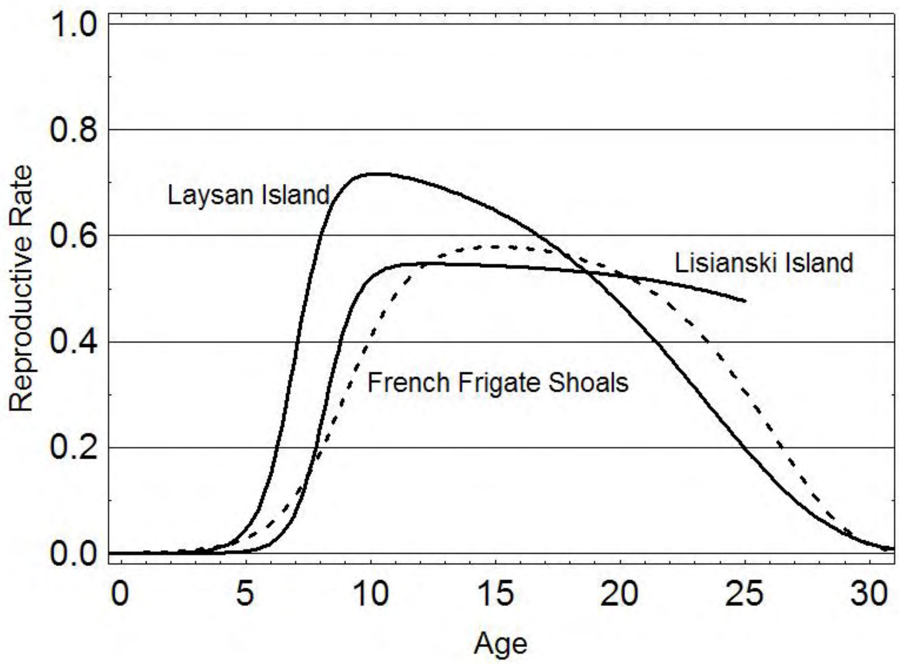

Figure I.D.1. Age-specific reproductive rates for Hawaiian monk seals at FFS, Laysan Island, and Lisianski Island. Curves are reproductive functions to fit observed reproductive frequencies for known-age seals pooled over all years. Figure is modified from Harting et al., 2004.

2. *Physiology*

While the physiology of many pinniped species has been studied in detail, comparatively little physiological research has been done on Hawaiian monk seals. The two broad areas of physiological study have been digestion and reproduction. Much of our working knowledge of Hawaiian monk seal physiology is extrapolated from studies of other non-endangered, closely related, pinniped species such as northern elephant seals.

All Hawaiian monk seals, except pups, undergo a catastrophic molt, shedding the pelage and the outer layers of skin (Kenyon and Rice, 1959). Pups begin to molt late in the nursing period, shedding their black natal pelage and replacing it with silver gray adult fur over several weeks (Kenyon and Rice, 1959).

For the pup, weaning marks an abrupt and critical transition to independence. In the months following weaning, the pup must learn to live and forage independently. In the process, the pup will lose a considerable amount of the mass gained during nursing. Until they begin foraging, two to four months after weaning, pups lose 0.33% of their weaning body mass per day (Gilmartin, pers. comm.). At FFS, for example, pups in the 1990-1992 cohorts had a mean mass at weaning of 62.7 kg, a mean length of 125.9 cm, and a mean axillary girth of 102.7 cm. By the end of the first year, these same pups had gained about 10 cm in length, but lost about 10 kg in mass and 10 cm in axillary girth (Craig and Ragen, 1999). Such a growth pattern during the first year is not unusual among seals (McLaren and Smith, 1985).

Digestive physiology

Initial defecation time (IDT) and rate of passage of digesta were reported by Goodman-Lowe et al. (1997). Using chromic oxide and frozen corn markers, IDT averaged 14 hours (range 9.5-19 hrs). The rate of passage using single pulse chromic oxide was approximately 39 hours. Both results are much longer than in other pinnipeds. Helm (1984) measured IDT in northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina richardsi*), and California sea lions (*Zalophus californianus*). The mean for these three species was less than five hours.

Assimilation efficiency, digestive efficiency, metabolizable energy, and nitrogen retention have been measured in three captive male monk seals (Goodman-Lowe, 1999). Chromic oxide markers were used in four experimental diets of herring (*Clupea harengus*), the control diet, and three test diets consisting of flagtail (*Kuhlia sandvicensis*), squid (*Loligo* sp.) and lobster (*Panulirus marginatus*). The addition of each of the three test prey to herring decreased the digestibility of gross energy. Assimilation efficiency of gross energy was 96.1% for herring, 73.8% for flagtail, 94.1% for squid, and undetermined for lobster. Digestive efficiency and metabolizable energy were high and were positively correlated with the amount of gross energy consumed. Nitrogen retention was highest in the squid–herring diet (33.2 g/day), followed by the lobster-herring diet (11.5 g/day), the flagtail-herring diet (6.0 g/day) and the control herring diet (5.7 g/day).

In another study, it was determined that the average daily metabolic rate measured using double labeled water (mean of two animals = 2,924 kcal/day) was comparable to other phocids of similar body mass (Dunn, 1990).

Reproductive physiology

Most pinnipeds inhabit highly seasonal temperate, sub-polar, and polar regions, exhibit delayed implantation and are more or less synchronous in mating and pupping. Hawaiian monk seals are an exception in that pupping is not synchronous (whether delayed implantation occurs is not known). Serum testosterone concentrations in four captive seals were lowest in January (0.09 ng/ml) and highest in June (1.78 ng/ml), which supports observations that Hawaiian monk seals are seasonal breeders but with a much extended season (Atkinson and Gilmartin, 1992). A similar seasonal pattern of total androgen concentrations was found in the saliva of six captive Hawaiian monk seals (Theodorou and Atkinson, 1998). Adult males sampled during the breeding season at Laysan Island showed similarly high serum testosterone levels (Atkinson et al. 1998).

In an effort to mitigate deaths of juveniles and adult females due to multiple male aggression, the feasibility of using a gonadotropin-releasing hormone (GnRH) agonist to suppress circulating testosterone levels in problem males has been investigated. Yochem et al. (1991) showed that testosterone levels increased briefly, then decreased for several weeks in adult male harbor seals injected intramuscularly with a depot-form GnRH agonist. The associated drop in circulating testosterone levels was correlated with a reduction of socio-sexual behavior in harbor seals, but was not permanent. The testosterone levels measured in these seals during the following breeding season were within normal limits. Four captive, adult male Hawaiian monk seals treated with GnRH, showed an initial brief increase in circulating testosterone, followed by an inhibitory effect lasting 7-8 weeks. Plasma testosterone concentrations were within normal ranges by the following spring (Atkinson et al., 1993). Subsequent attempts to electro-ejaculate these GnRH treated males showed abnormally low sperm concentrations (Atkinson and Gilmartin, pers. comm.), although the methods that were used may have been responsible. Wild, adult male monk seals were given intramuscular injections of microlatex beads of the GnRH agonist, D-Trp6-LHRH, at a total dose of 7.5 mg to determine its effect on circulating testosterone. Atkinson et al. (1998) reported significant suppression of circulating testosterone in wild monk seals after this treatment, and similarity of serum testosterone levels in captive seals and wild seals (Atkinson et al., 1998). Treated wild seals did not appear to be more vulnerable to aggression from untreated seals.

Some female Hawaiian monk seals have begun ovarian cycling as early as age four, and have given birth at age five after an estimated 10-11 months gestation (Johanos et al., 1994). The estrous cycle is estimated at approximately 35 days (Pietraszek, 1992). Circulating progesterone concentrations in a captive female persisted for 17-20 days (Pietraszek and Atkinson, unpublished data). Unlike most phocid seals, a captive female Hawaiian monk seal appeared to be polyestrous based on hormone patterns sampled from blood, saliva, and vaginal swabs (Pietraszek and Atkinson, 1994). Concentrations of progesterone and estrone sulfate, and the periodic appearance of vaginal cornified epithelial cells indicated consecutive estrous cycles of 32-38 days in duration. Plasma and saliva progesterone and estrone sulfate correlated well. These hormone concentrations were similar to measurements obtained from the bioimpedance technique. Vaginal cytology and bioelectrical impedance apparently reflected physiological changes associated with the estrous cycle. More research is needed to confirm the conclusion that monk seals are polyestrous since only one captive female seal was studied.

Reproductive status was investigated in nine female seals that died as a result of male aggression. During this study, reproductive morphology indicated that the uterine body and both horns were significantly shorter in nulliparous seals than in parous seals. Seven of the nine dead seals were identified as periovulatory on the basis of gross ovarian morphology at the time of death, suggesting that attacks on adult females are not random, but rather focused on parous females (Atkinson et al., 1994). Iwasa and Atkinson (1996) examined ovaries from 14 NWHI female monk seals from 0-24 years of age, and provided the first description of ovarian histology for the species. They also obtained results indicating that Hawaiian monk seals were polyestrous.

3. Feeding Ecology

Diet

Monk seals feed on a wide variety of fishes, cephalopods, and crustaceans. They are considered foraging generalists that prey primarily on benthic and demersal prey (Rice, 1964; MacDonald, 1982; Goodman-Lowe, 1998; Parrish et al., 2000). Goodman-Lowe (1998), using an analysis of identifiable parts of prey in scats and regurgitate from monk seals, showed that fishes occurred most frequently (78.6%), followed by cephalopods (15.7%) and crustaceans (5.7%). However, this method may not reliably detect the occurrence of some species, such as lobster (Gilmartin, pers. comm.). Thirty-one families of fishes were identified, the most common of which were: Labridae, Holocentridae, Balistidae, and Scaridae. Cephalopod prey included seven species of octopus and 19 species of squid. Significant diet differences were detected in both the teleost and cephalopod component of the diet among years, islands, age, and sex groups, with juveniles foraging for species hiding in sand or under rocks during the day. Recent information also indicated that monk seals forage in beds of precious coral below 300 m in the subphotic zone, which are habitat for known monk seal prey items such as eels (Parrish et al., 2002). Additional research to identify prey species is currently underway using several methods including: collection of potential prey and monk seal blubber samples for fatty acid analysis; CRITTERCAM recording of foraging behavior; correlation of dive/depth location profiles with potential prey species habitat; and continued development and refinement of a digital image database of prey remains for fecal analyses. A CRITTERCAM is a self-contained video camera developed by National Geographic Television, in collaboration with NMFS, which has been mounted with epoxy on monk seals to record foraging behavior.

E. Habitat Use

1. Terrestrial Habitat

Haul-out areas for pupping, nursing, and resting are primarily sandy beaches, but virtually all substrates, including emergent reef and shipwrecks, are used at various islands. Monk seals also use the vegetation behind the beaches, when available, as a shelter from wind and rain. Pups are born on various substrates. However, sandy beaches with shallow protected water near shore seem to be preferred habitat for pupping and nursing (Westlake and Gilmartin, 1990).

2. Marine Habitat

Monk seals spend approximately two-thirds of their time in the water (MMRP, unpublished data). Monk seals are primarily benthic foragers (Goodman-Lowe et al., 1998), and will search for food in coral reef habitat and on substrate composed of talus and sand on marine terraces of atolls and banks to depths exceeding 500 m (Parrish et al., 2000, 2002, 2005). Monk seal feeding has been observed in reef caves that also appear to be used for rest and for refuge from predators (Taylor and Naftel, 1978). Seals have also been observed breathing from air bubbles trapped on cave ceilings suggesting that this may be a possible means of extending a seal's underwater time (Ittner, pers. comm.). Recent information suggests that monk seals forage in precious corals below 500 m in subphotic zones (Parrish et al., 2002).

Studies of movements and dive patterns of monk seals have provided important information on monk seal habitat use while at sea. Early studies at Lisianski Island using archival depth recorders suggested that monk seals typically are not deep divers with most of recorded dives less than 100 m (DeLong et al., 1984; Schlexer, 1984). This study may be male biased because sampling took place during breeding season or it may not be representative of the wider population. Subsequent studies have indicated a more extended depth range and a high degree of inter-individual variability.

Between 1996 and 2003, the movements and diving patterns of 147 Hawaiian monk seals were monitored with satellite-linked radio transmitters at the six breeding colonies in the NWHI, including 42 adult males, 35 adult females, 29 juvenile males, 14 juvenile females, 12 weaned male pups, 15 weaned female pups (Abernathy and Siniff, 1998; Stewart, 2004a, b; Stewart and Yochem, 2004a, b, c; Figure I.E.1). Spatial dispersal of foraging seals indicated that they forage extensively within the atoll lagoons at FFS, PHR, Midway Islands, and Kure Atoll, and on the outer slopes of those atolls and seaward of Laysan and Lisianski Island. Seals also ranged to and evidently foraged along the submarine ridges between those atolls and islands and at virtually all nearby seamounts. Most frequently, seals dove to depths less than 150 m, though there were secondary diving modes at various depths up to 500 m. Dive depth varied with the age and sex of the seals and with location. Apparent foraging locations varied among seals, with some of the variability perhaps owing to sex and age of seals. Distances traveled to forage from haul out sites also varied with a seal's age and sex as well as the seal's colony of origin. Seals ranged from less than one km up to 217 km (Abernathy, 1999; Stewart, 2004a, b; Stewart and Yochem, 2004a, b, c). Preliminary analyses suggest that the geographic and vertical habitats that Hawaiian monk seals use to forage in the NWHI may vary temporally and spatially, with the variation in extent of physical substrate, prey community composition, species' abundance, and demographic composition of monk seals at the colonies.

Parrish et al. (2000) attached CRITTERCAMS to 24 adult and subadult male monk seals at FFS. The CRITTERCAMS recorded the habitat depth and bottom type at locations where monk seals were seen capturing prey items. Parrish et al. (2000) found that the diurnal pattern of foraging by male adults occurred mainly at the 60 m isobath. A few seals foraged at depths of more than 500 m.

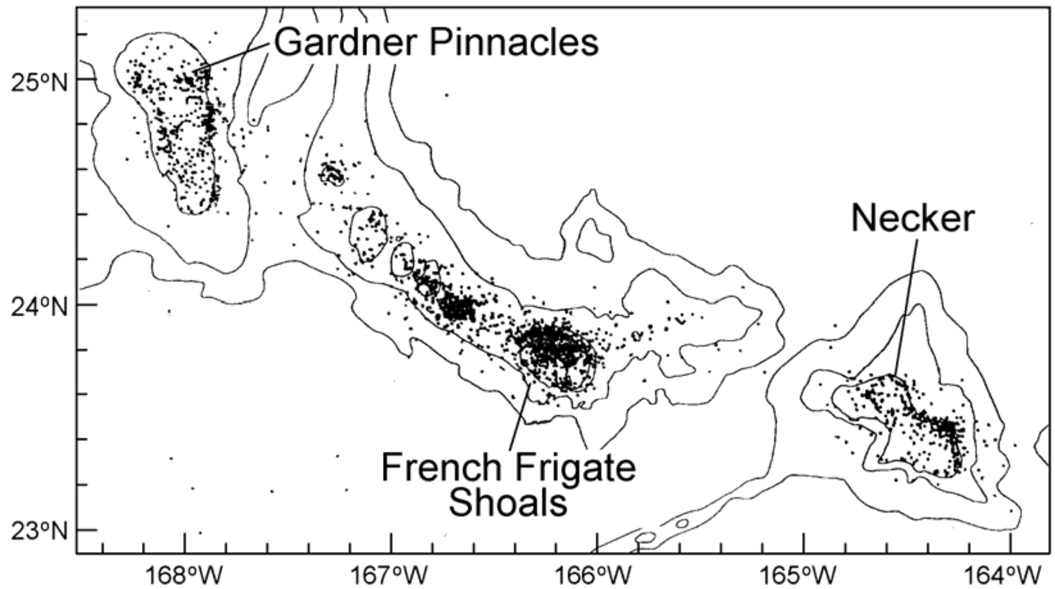

Fig I.E.1 – Locations of satellite-tagged monk seals around FFS (from Abernathy, 1999)

Recent studies have focused on characterizing juvenile monk seal habitat use and foraging behavior at FFS using CRITTERCAMS. Results indicated that juvenile seals forage in the same habitats commonly used by adults, but may lack the size and strength to forage as successfully as their adult counterparts (Parrish et al., 2005). Additionally, thirteen weaned pups were instrumented with time-depth recorders (TDRs) at FFS in 1999 and 2000, and the results of the study indicated that most dives occurred at depths less than 200 m, but occasionally some exceeded 200 m. Substantial variability among the pups in depth, duration, and temporal patterns of dives was noted. Seals between 2-3 years foraged mostly at shallow depths of 10-30 m. The survivorship of the juvenile seals appeared strongly linked to their use of the sand community and oceanographic dynamics.

In 2005, 11 monk seals in the MHI were tracked using satellite-linked radio transmitters. Preliminary results from these studies indicate seals dive primarily within the 200 m isobath and remain close to shore (Littnan et al., 2006). Interisland movements were demonstrated by several animals. Home ranges for monk seals in the MHI (34 - 800 km^2) were much smaller than seals in the NWHI (163 - 7400 km^2) (NMFS, unpublished data).

Prey assessment

Since 1995, abundance of shallow water (< 20 m) reef fish has been surveyed at FFS and Midway Islands, in part as a potential indicator of changes in abundance of monk seal prey. However, it is doubtful that these surveys reliably index monk seal prey abundance. The surveys are conducted annually by NMFS and are designed to detect changes of 50% or greater in fish densities (DeMartini et al., 2002). To date, surveys have not indicated any statistically significant changes in reef fish abundance at either site (DeMartini et al., 2002; DeMartini et al., 1999; DeMartini et al., 1996). The surveys have been modified and expanded to include all of the NWHI under the Coral Reef Ecosystem Division (CRED) at the PIFSC. In addition to monitoring the abundance of coral reef fishes, these investigators collaborate with other agencies to conduct annual assessments of various biotic and abiotic components of the NWHI. Small net surveys on sand substrate in typical monk seal foraging habitat seem to be a promising technique of future assessment of prey resources (Parrish et al., 2005). Baited camera drop surveys and the use of sonar technology are also being evaluated for future estimation of monk seal prey availability and abundance. As yet, no research or monitoring effort has been identified that will effectively measure or index monk seal prey abundance at the major breeding atolls.

F. Critical habitat

In 1980, NMFS completed a draft Environmental Impact Statement (EIS) that proposed monk seal critical habitat be extended out to the 10 fm isobath adjacent to pupping and haul-out islands in the NWHI. The following year the lobster fishery was prohibited in waters less that 10 fm around the NWHI and within 20 nm of Laysan Island. A supplemental EIS to designate critical habitat for the monk seal was prepared in 1984. By 1986, the EIS of the Hawaiian Islands National Wildlife Refuge (HINWR) was completed by the FWS, and critical habitat was designated at all beach areas, lagoon waters, and ocean waters out to a depth of 10 fm around Kure Atoll, Midway Islands (except Sand Island), PHR, Lisianski Island, Laysan Island, Gardner Pinnacles, FFS, Necker Island and Nihoa Island (April 30, 1986, 51 FR 16047). However, concerns raised by the MMC, HMSRT and non-governmental organizations prompted NMFS to reopen the comment period on the critical habitat EIS, and in 1988, critical habitat was extended to include Maro Reef and waters around previously recommended areas out to the 20 fm isobath (53 FR 18988, May 26, 1988; 50 CFR 226.201).

Actions authorized, funded, or carried out by federal agencies that may have an impact on critical habitat must be consulted upon in accordance with section 7 of the ESA, regardless of the presence of Hawaiian monk seals at the time of impacts. Impacts on these areas that may affect primary constituent elements such as prey availability must be considered when analyzing whether habitat may be adversely modified.

G. Threats Assessment Summary

Hawaiian monk seals are severely vulnerable to natural and anthropogenic factors that may affect their continued existence and recovery, especially due to their very small population size. The threats impacting Hawaiian monk seals have been assessed based on severity and magnitude, as well as the scope and geographic range. Determining which threat has higher concern regarding its current and potential impact to Hawaiian monk seals will improve the ability to implement effective management actions and increase the probability for a successful recovery. An assessment of the threats was conducted by scientists and managers involved in the development of this plan, and the threats were classified in the following categories (See Table I.G.1):

Crucial:

- Food limitation
- Entanglement
- Shark predation

Crucial threats are ongoing sources of mortality that are apparent at most sites in the NWHI. A crucial threat that is regulating the population growth in the NWHI is food limitation (Craig and Ragen, 1999; Yochem et al., 2004). At FFS, the juvenile survival has declined most dramatically with significantly smaller pup and juvenile sizes, consistent with signs of food limitation. In recent years, low juvenile survival, in part due to food limitation, has been evident at all NWHI subpopulations. This situation contrasts with the MHI, where pups tend to wean much larger than in the NWHI, and where thin animals are rarely observed. Because most of the monk seal population occurs in the NWHI, this threat is of highest concern.

Hawaiian monk seals have one of the highest documented entanglement rates of any pinniped species, and marine debris and derelict fishing gear are chronic forms of pollution affecting the NWHI. There is serious concern for the entanglement of monk seals especially since the number of monk seals found entangled has not changed nor has there been a reduction in the accumulation rates of marine debris in the NWHI. There has been a significant increase in shark predation on monk seal pups born at FFS, where shark related injury and mortality of pre-weaned pups have been conspicuously higher than at other sites. Based on field observations, shark predation may also be compromising recovery at Midway and Kure.

Serious:

- Infectious diseases
- Habitat loss
- Fishery interaction
- Male aggression
- Human interaction

Serious threats are ongoing impacts with the potential for a range-wide concern. Mortality events in the NWHI have led to concern about the presence of diseases in monk seal populations. Moreover, recent MHI monk seal deaths have heightened concern about monk seal exposure to diseases that they have not previously encountered, such as leptospirosis, toxoplasmosis, West Nile virus, etc. The lack of antibodies in monk seals to these diseases makes them extremely vulnerable to potential infection. While the frequency of disease outbreaks may be rare, their potentially devastating effects, should they spread throughout the population makes infectious diseases a serious threat.

The loss of terrestrial habitat is a significant issue of concern in the NWHI, especially habitat loss due to environmental factors such as storms and sea level rise that could further exacerbate this problem in the future. While some habitat loss (e.g., the subsidence of Whaleskate Island at FFS) has already been observed, sea level rise over the longer term may threaten a large portion of the resting and pupping habitat in the NWHI (Baker et al., 2006).

Due to management actions, direct and indirect fishery interactions between commercial fisheries and Hawaiian monk seals in the NWHI are currently limited or nonexistent. However, monk seals in the MHI have required intervention due to embedded hooks from recreational fishing and recent mortalities in gillnets have occurred.

The primary identified cause of adult and immature female mortality affecting the recovery potential in the monk seal population during the 1980s and early 1990s, was injury and often death caused by multiple male aggression (especially at Laysan and Lisianski Islands). Attacks by single adult males have also resulted in several monk seal mortalities, occurring at most or all locations and involving behavior which ranges from normal pinniped male harassment of younger animals to an aberrant level of focused aggression, especially directed toward weaned pups. Most recently, this emerged as a serious issue at FFS in the late 1990s. While this threat tends to be episodic, it is usually limited in geographic area at any given time, and the methods for mitigating it have been successful, this is still considered a serious threat.

Monk seals in the NWHI avoid beaches for breeding where people have often disturbed them, but sightings of monk seals in the MHI have increased, resulting in increased human interactions where tourists and residents can view monk seals hauled out on beaches, thereby increasing the concern about harassment of seals. Recent successful monk seal pupping events on popular MHI beaches have occurred, despite the major management challenges with regards to staff, volunteers, resources, public outreach and collaboration. Disturbance of seals on MHI beaches may limit seals' ability to make use of habitats. If the MHI population grows, both in absolute number and proportion of total abundance, disturbance will become a larger management challenge.

Moderate:

- Biotoxins
- Vessel groundings
- Contaminants

Moderate threats have possible, localized impacts, but are not considered to be a serious or immediate cause of concern. In 1978, a significant number of Hawaiian monk seals died on Laysan Island, and high levels of ciguatoxin and maitotoxin were detected in the livers of two seals. Subsequent satellite remote sensing in Hawaiian monk seal habitat has indicated the potential impact for dangerous algal blooms which could contain harmful species. However, biotoxins have not been confirmed as a cause of mortality, and this is considered a relatively less serious threat. In addition, monk seals may potentially be injured or killed by vessel groundings that result in the release of hazardous materials, including oil or fuel spills, rotting bait, lost gear that creates entanglement hazards, and human disturbance resulting from a grounding incident. These events are typically episodic and affect only a limited area when they occur. To date, no seal mortalities have been attributed to vessel groundings. Finally, Hawaiian monk seals are exposed to organochlorines with concentrations of polychlorinated biphenyls (PCBs) found in biological samples. Different contaminants originating from human occupation of the NWHI have been identified in monk seal habitat. However, the effects of these compounds on monk seal health, reproduction and survival are unknown. Levels observed in monk seals are not elevated when compared with other North Pacific pinnipeds.

The classification of the threats is a valuable tool that facilitates the recovery planning process, especially when there are multiple, potentially interacting threats. These threats will now be discussed in the order they are presented above.

The following are identified as **threats** to the recovery of the Hawaiian monk seal. Each threat corresponds to an **ESA Listing Factor**: A-The present or threatened destruction, modification, or curtailment of its habitat or range; B-Overutilization for commercial, recreational, scientific, or educational purposes; C-Disease or predation; D-The inadequacy of existing regulatory mechanisms; E-Other natural or man-made factors affecting its continued existence. The **mechanism** of each threat either directly reduces the survivorship of monk seals, indirectly reduces survivorship, or a combination of both. The **most vulnerable age-classes** are listed for each threat, as well as the **frequency** of each threat's occurrence. The **certainty** of the threat's impact is rated as high is there is strong certainty that the issue is a threat to monk seals and low if it is not certain that it is a serious threat. This information is used as evidence to rank the **relative impact** of the threats as Crucial, Serious or Moderate. Finally, the **potential for mitigation** is evaluated and ranked as low, medium or high.

Threat	ESA Listing Factor	Mechanism	Most Vulnerable Age-Class	Frequency of Threat Occurring	Certainty of Impact	Relative Impact to Recovery	Potential for Mitigation
Food limitation	A	Direct	Pups & Juveniles	High	High	Crucial	Low (in field) High (captive care)
Entanglement	E	Direct	Pups & Juveniles	High	High	Crucial	Medium
Shark Predation	C	Direct	Pups	High	High	Crucial	Medium
Infectious Disease	C	Direct	All Age-classes	Low	Low	Serious	Low
Habitat Loss	A	Indirect	All Age-classes	High	High	Serious	Low
Fishery Interaction	D	Direct & Indirect	All Age-classes	Medium	High	Serious	Medium
Male Aggression	E	Direct	Immature & Adult Females	Low	High	Serious	Medium
Human Interaction	B	Direct	All Age-classes	Medium	High	Serious	Medium
Biotoxins	E	Direct	All Age-classes	Low	Low	Moderate	Low
Vessel Groundings	A	Indirect	All Age-classes	Low	Low	Moderate	High
Contaminants	A	Direct & Indirect	All Age-classes	Low	Low	Moderate	Low

1. Crucial Threats

a. Food limitation

Demographic and other trends observed to varying degrees at several of the NWHI monk seal sub-populations indicate that food limitation may be playing a primary role in regulating population growth. Declines have been observed in the beach count abundance index (FFS, Lisianski), and cessation of previously steady increases in population size (PHR, Midway, Kure), at a time when protection against disturbance and direct take is thought to have been effective. In some cases, these changes in abundance are preceded by or simultaneous with reduced juvenile survival. In at least two populations (FFS and LIS), relatively low age-specific reproductive rates (including delayed maturity) have been observed. Finally, even though fewer quantitative data are available and analyzed, there are indications that relatively poor body condition in various age classes is associated with declining populations. All these factors are consistent with either episodic or chronic prey limitation. While additional monitoring and more complete demographic analyses will undoubtedly help elucidate the relative importance and mechanisms involved in limiting growth, current data suggest that food limitation may play a critical role in preventing recovery of the Hawaiian monk seal (see demographic trend figures in this document; see also Carretta et al., 2002; Craig and Ragen, 1999).

Juvenile survival has declined most dramatically at FFS, but has decreased at many other sub-populations to varying degrees and with different timing (Craig and Ragen, 1999). Although consistent with food limitation, other factors such as predation or entanglement might also account for reduced survival of young monk seals. More evidence of food limitation comes from the time series of axillary girth and standard length measurements taken at most sites. These data show that pup and juvenile sizes were significantly smaller at FFS compared to Laysan, while the former was declining (Craig and Ragen, 1999). The measures of girth are taken within two weeks after weaning. As nursing monk seal females are thought not to feed, and milk is the only source of nutrients for pups during lactation, the size at weaning provides a measure of maternal energy investment in offspring during lactation, and it also reflects prenatal investment (e.g., Boness and Bowen, 1996). Viewed in this way, when offspring size declines, it suggests that females may have had less energy to invest perhaps as a result of reduced foraging success prior to parturition (Bowen et al., 2001; Antonelis et al., 2003).

Food limitation in adult females could also be expressed through reduced pup production. Mean age-specific birth rates of Hawaiian monk seals are low compared to rates in some other phocid species (e.g., Bowen et al., 1981; Hammill and Gosselin, 1995), which were estimated during periods of reduced population size where it is unlikely that those species were food limited. For example, mean late-term pregnancy rates in harp seals (*Phoca groenlandica*) were about 94% during the 1960s and 1970s, when the population was reduced (Bowen et al., 1981). However, the mean pregnancy rate declined significantly during the late 1980s and through the 1990s as population numbers roughly doubled (Sjare et al., 1996; DFO, 2000). The decline in pregnancy rates of harp seals has been interpreted as a density dependent response to reduced per capita food availability that caused changes in the condition of adult females, as well as that of juveniles (Chabot et al., 1996). Thus, by analogy, the low birth rate in monk seals may be indicative of food limitation in adult females.

It is worth noting a strongly contrasting situation in the MHI. While juvenile survival rates there are unknown, MHI pups wean at very large sizes (average girth and length exceeds the 95th percentile observed in the NWHI), and, notably, animals appear to be in good physical condition. This suggests that adult female monk seals giving birth at the MHI are not food limited (Baker and Johanos, 2004).

In general, determining the causes and consequences of possible food limitation in pinnipeds is difficult. Documenting the impact of food limitation on monk seals is no less challenging, given their broad geographic distribution and high species diversity of prey. For example, if food limitation forces the seals to spend more time foraging and/or to forage more widely, this could increase their exposure to predation or entanglement. Although food limitation is a difficult question to address, there are a number of lines of evidence that point to food limitation in juvenile monk seals. Therefore, understanding the consequences of foraging behavior and diet on the physical condition and probability of survival of juveniles is critical to the development of management actions that might increase population size and growth rate.

Competition with fisheries

In some cases, seals and fisheries exploit similar species. However, no study of ecological competition between fisheries and seals has looked at a seal population as small as that of the monk seal living in small island ecosystems. Recent studies indicate that monk seals forage within and adjacent to the atolls and islands where they haul out, and infrequently at locations at sea several hundred kilometers from the atolls. A number of fisheries have operated within the monk seal foraging range (see Fisheries Interaction information later in this section). Direct interactions have been documented with the longline, bottomfish, nearshore recreational and lobster fisheries. However, as indicated above, indirect interactions through ecological competition between fisheries and monk seals are very difficult to assess.

Fisheries, including the lobster fishery and bottomfish fishery, are known to take prey items of the monk seal. The lobster fishery in the NWHI is closed and will remain closed as a result of the Presidential Proclamation declaring the PMNM. The bottomfish fishery in the NWHI will permanently close in June 2011, also as a result of the Presidential Proclamation establishing the PMNM. NMFS has attempted to investigate the extent to which monk seals are dependent on the NWHI lobster stock. Diet studies (fecal analysis and fatty acid studies) indicate that lobster is only a minor component of the monk seal diet. However, as discussed above, the investigation is being conducted at a time when the lobster resource is depleted, and therefore possibly less represented in the present diet than if the study had been conducted previously.

Recent studies using fatty acids have indicated that deeper slope species, including several species of commercially targeted bottomfish, are important in the monk seal diet. In fact, a larger proportion of the diet is comprised of these deep-water species than was previously believed. However, the level of interaction between monk seals and the existing commercial bottomfish fishery in the Hawaiian Archipelago is unknown.

Further complicating the issue of possible ecological competition between fisheries and seals is that seals in the NWHI, where fishing effort and extraction is low, are the animals experiencing food limitation, low survival, and starvation. While in the MHI, where fishing effort and extraction is high, seals are apparently foraging very successfully and pups are recorded with high weaning weights and high survival.

Oceanographic change

Changes in climate and oceanographic conditions may affect pinnipeds by changing availability of their prey. For example, the effects of the El Niño Southern Oscillation events on fur seal, sea lion, and harbor seal populations along the west coast of South and North America are well known (Trillmich and Ono, 1991). Off the Atlantic coast of Namibia in 1993-1994, an intrusion of warm, low-oxygen content water resulted in the virtual disappearance of many fish species from the continental shelf, and resulted in mass mortality of Cape fur seal (*Arctocephalus pusillus pusillus*) pups (Anonymous, 1998).

There can be little doubt that the prey base of monk seals undergoes considerable variation driven by environmental fluctuations. Climate changes in the central North Pacific from the mid 1970s to the 1980s appear to have reduced productivity by 30%-50% at various trophic levels (Polovina et al., 1994). The trend for the density of reef fishes declined by an average of 27% between 1980-1983 and 1992, but it could not be determined if this value was different than zero due to the low statistical power (0.80) of the analysis (DeMartini et al., 1996). In the 1980s, the survival rate of monk seal pups declined by varying degrees from about 90% to 40% in 1992 (Polovina, 1994), coincident with a change in climate. It is conceivable that the lower system productivity at this time caused adult females to have lower foraging success, resulting in pups with smaller size at weaning and lower survival. However, it may be that food availability for juveniles is the primary bottleneck, as Craig and Ragen (1999) found in the mid-1990s when even large weaned pups at FFS had very poor subsequent survival. Weaned pup size was greatest following El Niño events at Laysan and FFS, further suggesting a possible linkage between oceanographic change and female foraging success prior to parturition (Antonelis et al., 2003). Oceanographic change may also result in changes in the number or distribution of monk seal predators causing changes in seal survival rates.

Competition with other predators

While interspecific competition may affect the foraging success or demography of pinnipeds, it is extremely difficult to measure the strength of competition, particularly in non-experimental situations (Kareiva and Levin, 2002). Even in terrestrial ecosystems, where the interactions of large predators and their prey are more easily observed and measured, the strength and impact of competition within predator guilds is difficult to evaluate (Woodroffe and Ginsberg, 2005).

The NWHI support a large number of predatory fish that compete with monk seals for food. The size of these predator populations (sharks and jacks) are difficult to estimate, but studies indicate that predator populations are quantitatively important and are likely to influence the structure of the coral reef fish community (Sudekum et al., 1991, Friedlander and DeMartini, 2002; Parrish and Boland, 2004). Apex predators were estimated to comprise 54% of the total fish biomass in the NWHI, where the apex predators were significantly larger and more abundant than in the MHI (Friedlander and DeMartini, 2002). Since many of these predators grow to body sizes comparable to monk seals and larger, and since available diet studies indicate the apex predators are eating the same prey as the seals, it is reasonable to expect interspecific competition. Baker and Johanos (2004) postulated that the excellent condition of seals in the MHI may, in part, reflect the relative dearth of competing predators due to human take of sharks and jacks.

Studies using seal-borne video cameras have documented sharks and jacks routinely competing for the same prey items on which monk seals attempt to feed. Typically the prey items are quickly snatched by competitors (particularly jacks) after the monk seal flushes the prey from cover. The jacks and sharks appear to know that the monk seals are adept at "spooking" prey from their hiding spots, and frequently are in close escort of the monk seals on their foraging trips in order to exploit the monk seals' ability to dig in the sand and flip over rocks to reveal hiding prey (Parrish, in prep). Actual stealing of prey items from the monk seals' maul has not been observed. Although, there have been a number of instances where jacks and sharks have physically "bullied" monk seals that are handling fish. The available data suggest that other predators could reduce the foraging success of monk seals through interference and exploitive competition. Presumably, the impact of such interspecific competition for food would be the most severe on young monk seals as they are less able to defend their catch against competitors and may be less proficient at locating profitable foraging habitat and capturing prey.

The PIFSC hosted a second Hawaiian Monk Seal Foraging Workshop from March 7-8, 2005, at the East-West Center on the campus of the University of Hawaii at Manoa. The Workshop consisted of monk seal researchers and a panel consisting of international scientists with a wide range of research expertise. The objectives of the workshop were to:

1) Review the status of research and data analysis relevant to the demography and foraging ecology on Hawaiian monk seals in the NWHI and MHI, focusing on work conducted since the first Foraging Workshop

2) Engage an invited independent panel of experts (Review Panel) on foraging ecology to provide feedback and recommendations on:

A) Apparent gaps in the extant knowledge of foraging ecology relevant to management and conservation of Hawaiian monk seals,

B) Additional research that might resolve those gaps to the extent that it would assist the PIFSC and NOAA in constructing and implementing a species Recovery Plan and in designing a Hawaiian Monk Seal Foraging Plan to guide further research on the foraging ecology and demography of this species,

C) Integration of various research elements into a multi-disciplinary plan for the investigation of Hawaiian monk seal foraging ecology, and

D) Specifically identifiable, feasible (fiscally, ethically and scientifically) and testable hypotheses.

A list of recommendations resulted from the discussions of the Review Panel with PIFSC and contracted research scientists during the presentation of research programs and other discussions. The participants recognized several elements (e.g. quantifying diet, identifying foraging habitat, estimating carrying capacity, explaining population trends) to consider for proceeding with theoretical and empirical studies of the foraging ecology of Hawaiian monk seals relative to demography and population recovery.

b. Entanglement

Hawaiian monk seals have one of the highest documented entanglement rates of any pinniped species, and marine debris and derelict fishing gear are chronic forms of pollution affecting the NWHI. There is serious concern for the entanglement of monk seals especially since the number of monk seals found entangled has not changed nor has there been a reduction in the accumulation rates of marine debris in the NWHI.

Marine debris/derelict fishing gear and entanglements

Since the 1960s, durable and resilient plastic materials have replaced natural fibers in the maritime industry. The increased use of plastics, polypropylene, nylon nets and line has resulted in a corresponding increase of derelict debris on beaches in the NWHI (Henderson, 2001). Plastics enter the ocean in runoff from land, by the dumping of trash directly into the ocean, or from the incidental loss of fishing gear and other objects from ships (Shaw and Day, 1994). The Hawaiian Archipelago is situated in the convergence zone of the North Pacific subtropical gyre, and flotsam is carried towards the islands by wind-driven currents, sea surface movements generated by wave energy, and circulation of water from the eastward flowing North Pacific Current to the westward flowing North Equatorial Current (Donohue, 2001). There is some indication that more debris is deposited by a strengthening of the convergence zone in Hawaiian waters during El Niño southern oscillation events (Donohue et al., 2001).

Despite international law prohibiting the intentional discard of debris from ships at sea from the International Convention for the Prevention of Pollution from Ships (MARPOL), recent marine debris removal studies suggest that derelict fishing gear is a chronic form of pollution affecting the NWHI (Donohue et al., 2001). The MARPOL Convention is the main international convention covering the prevention of pollution of the marine environment by ships from operational or accidental causes. It is a combination of two treaties adopted in 1973 and 1978 and updated by amendments through the years. Additional research indicates that since the adoption of the MARPOL Annex V in 1989, the number of monk seals found entangled has not changed nor has there been a reduction in the accumulation rates of marine debris on the NWHI (Henderson, 2001). Annex V of MARPOL is the amendment intended to reduce solid waste pollution from ships, in part by prohibiting ocean dumping of plastics. This legislation came into effect in 1989 and was ratified by more than 70 nations. Most of the derelict fishing gear and marine debris collected and documented in the NWHI is clearly from fishing or other maritime industries, and most net debris appears to be trawl webbing. Because no trawl or gillnet fishing occurs in the NWHI, it is assumed that virtually all debris has been transported by ocean currents from distant fisheries around the North Pacific Ocean.

Marine debris and derelict fishing gear have been well documented to entangle monk seals, and monk seals have one of the highest documented entanglement rates of any pinniped species (Henderson, 1984, 1985, 1990, 2001). Once entangled, unless a seal can free itself or is freed by researchers, the animal may suffer from 1) increased hydrodynamic drag while swimming and pursuing prey, 2) severe wounds that may become infected and lead to secondary complications and death, 3) severance of vital tissues, particularly in the neck and head region, and 4) death by strangulation, drowning, starvation or shark attack.

Entangled monk seals were first observed in 1974 (Henderson, 1984). Since the inception of the MMRP beach debris removal program in 1982, the incidence of entangled monk seals at breeding sites of the NWHI has been well documented, and field staff continues to disentangle seals. Estimates of entanglement rates are based almost exclusively on observations of animals encountered on shore. However, interactions between monk seals and marine debris also occur at sea and at other times of the year when researchers are not in the field. Therefore, observed entanglement rates are presumably conservative estimates (Henderson, 1990).

Historically, monk seals have become entangled in net, line (including monofilament nylon line), net/line combinations, straps, rings (including hagfish or eel traps), and other random items such as discarded lifejackets, buckets (portion of rims), bicycle tires, rubber hoses, etc. (Henderson, 1990). The number of monk seals in different age classes observed entangled in various debris items can be seen in Figure I.G.1 (Henderson, 2001). Proportionally, pups (including newly weaned pups) are most often observed entangled (Henderson, 1985, 1990, 2001). Between 1982 and 1988, pups comprised 11% of the population, yet accounted for 42% of observed entanglements. Conversely, during the same time period, adults comprised 49% of the population and 16% of all entanglements (Henderson, 1990). Together, all immature seals account for nearly 80% of all observed entanglements, but only 46% of the total population (Henderson, 2001).

Between 1982 and 2006, a total of 268 entanglements of monk seals were documented, including 118 in fishing gear. There were 57 serious injuries (including 32 from fishing gear) and 8 mortalities (including 7 from fishery items). From 1982 – 2000, there was an estimated minimum rate of 2.3 serious injuries or deaths per year attributable to fishery related marine debris (from Bottomfish FMP, DEIS and NMFS unpublished data). As there is no basis for estimating the frequency of undetected entanglements, it is not possible to estimate total mortality attributable to entanglement.

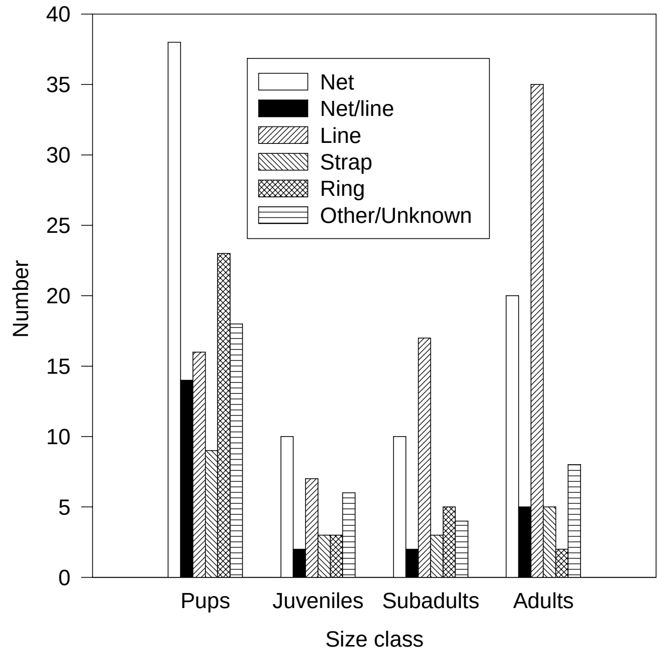

Figure I.G.1 Number of Hawaiian monk seals observed entangled in each type of debris item in the Hawaiian Islands, 1982-2006. Source: NMFS.

Of the 268 animals found entangled, 183 were released, 69 escaped unaided, 8 died (Table I.G.2.), and 8 were not released, with their fate unknown. The number of annual entanglements has varied during the 25-year history of the program (Figure I.G.2.), with a documented high of 25 incidents in 1999 that represented 1.7% of the total population (Donohue et al., 2001). Despite annual efforts by MMRP staff to remove entanglement hazards from beaches, entanglement rates continued to increase until large-scale management efforts to remove debris from the habitat of the monk seal was initiated in 1999. In 2000, the number of entanglements decreased markedly (Figure I.G.2.), although this number has subsequently increased and is a cause for concern.

Table I.G.2. Known deaths of Hawaiian monk seals from entanglement in marine debris, 1982–2003.

Year	Location	Description
1986	FFS	Weaned male tangled in wire which was relic of USCG or Navy; in water
1987	Lisianski	Pup (uncertain if nursing or weaned) dead in net/line aggregate onshore
1987	FFS	Juvenile dead in net/line aggregate onshore
1988	Lisianski	Weaned pup dead in large trawl net onshore
1995	PHR	Bones of adult found scattered in line awash onshore
1997	FFS	Subadult dead in trawl net on reef
1998	Laysan	Weaned pup dead in trawl net on nearshore reef
2002	Lisianski	Nursing pup dead in line; drowned in shallow water

Source: NMFS-HL unpublished data 2003

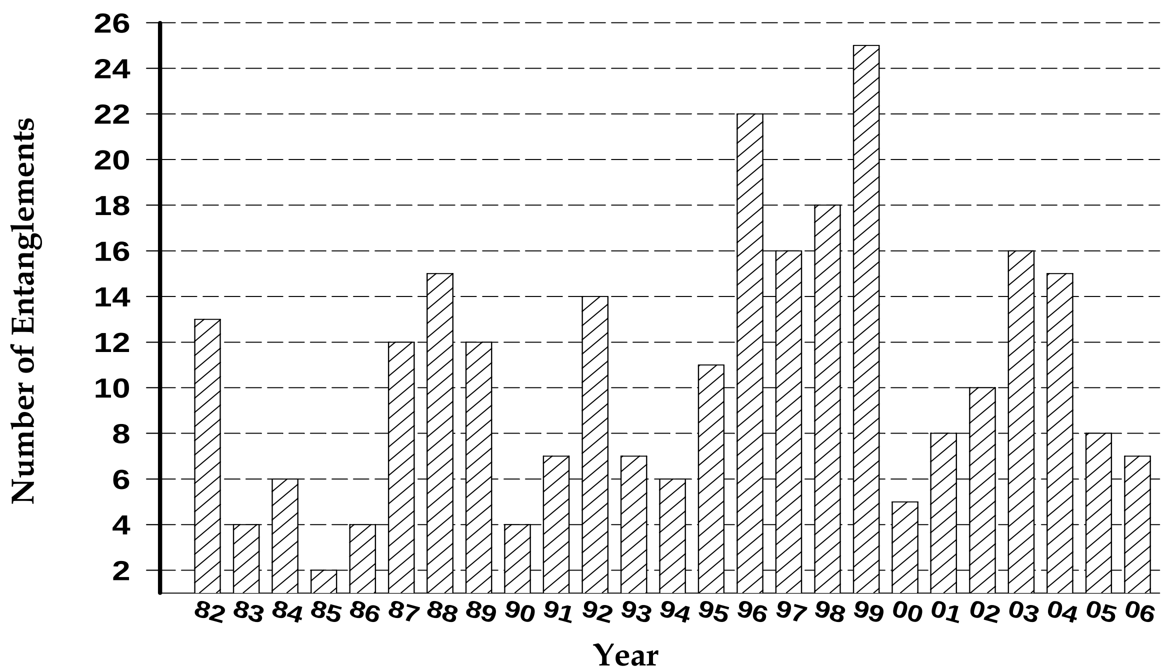

Figure I.G.2. Number of Hawaiian monk seal entanglements observed, 1982-2006. Source: NMFS/MMRP unpublished data.

Although pups are most susceptible to entanglements, those locations with the most births do not have the most entanglements (Henderson, 1990, 2001). Of the six monk seal subpopulations of the NWHI, the Lisianski subpopulation has had the most entanglements, even though it does not consistently accumulate the highest amounts of potentially entangling debris on shore nor does it have the largest seal subpopulation (Henderson, 1990, 2001). Henderson

(1990) suggested that the high entanglement rate at Lisianski Island is a result of the windward location of pupping areas, thus locally exposing young seals to more debris than their counterparts at other islands.

Conservation Efforts - Mitigation of entanglement

The removal of entanglement hazards, marine debris and derelict fishing gear from the NWHI has been a major management objective of MMRP. In addition, the reduction or elimination of human disturbance impacts to monk seals has been a significant management objective of NMFS in the NWHI. Throughout the 20-year history of the MMRP (1980-present), field camp personnel have actively disentangled 162 seals. Field camps with boats (FFS, PHR, Midway, Kure Atoll and occasionally Laysan) also remove debris from marine habitats when possible and have located and released seals entangled offshore. During field studies, all occurrences of entangled individuals are recorded, including seals with fresh entanglement scars that were not previously observed. Seals are manually restrained to remove entangling gear, and incidents of entanglement and severity of any injuries obtained are documented. The entangling gear, or a sample thereof, is also collected and catalogued.

Between 1982 and 2003, MMRP field camp personnel documented, enumerated, cataloged, and measured entanglement hazards collected from beaches and items that washed ashore during a field season. Prior to 1998, entanglement hazards were destroyed (i.e., burned) at each field site (Henderson, 2001). However, since 1999, potentially entangling debris have been collected, inventoried, and then transported to Honolulu for disposal.

The collection and catalogue of entanglement hazards throughout MMRP's history have identified the distribution and accumulation rates of nets that wash ashore at each island location, and sections of the islands that accumulate debris. In addition to MMRP staff efforts, in 1996-1997, the PIFSC conducted an in-water marine debris clean-up operation. Those efforts recovered 4,368 kg of derelict fishing gear and confirmed that significant amounts of derelict fishing gear were present on the coral reefs of the NWHI. In 1997, FWS and the Hawaii Wildlife Fund initiated a multi-year beach and reef debris clean-up project at Midway. Large-scale efforts toward a marine debris removal program were initiated in 1998 when NMFS organized a multi-agency clean up to remove derelict fishing nets and other debris from the reefs surrounding FFS and PHR (Donohue, 2003).

During the period from 1996-2006, the entire multi-agency debris survey and removal effort led by PIFSC, resulted in over 510,675 kg (511 metric tons) of derelict net gear being removed from the coral reef ecosystems of the NWHI (S. Balwani, pers communication). In 2001, the Coral Reef Ecosystem Division (CRED) was established in the PIFSC with the support of NOAA's Coral Reef Conservation Program to provide comprehensive coral reef ecosystem assessment, monitoring, and mapping for the U.S. Pacific Islands. As part of this effort, CRED leads a multi-agency Marine Debris Removal Project, which included a five-year, large-scale effort to mitigate marine debris impacts in the NWHI. CRED now conducts maintenance level operations in an attempt to keep up with annual accumulation.

c. Shark predation

Shark injuries and scars from old injuries can be seen on many monk seals, and shark predation has been observed occasionally (Bertilisson-Friedman, P.A.K., 2002; Wirtz, 1968; Taylor and Naftel, 1978; Balazs and Whittow, 1979; Johanos and Kam, 1986; Alcorn and Kam, 1986; Hiruki et al., 1993a). Most of these earlier attacks were believed to be from tiger sharks.

In recent years, there has been a marked increase in shark predation on monk seal pups born at FFS (Hawn, 2000; Hayes, 2002; NMFS, 2003, 2004, 2005). At Trig and Whaleskate Islands, the number of known or suspected predation mortalities (including both observed kills and inferred losses) peaked in 1997-1999, with 18-28 probable mortalities each year, and declined thereafter, with less than 10 possible mortalities in each of the last five years. It was thought that the problem may have resulted from learned behavior practiced by a few individual sharks at Trig and Whaleskate Islands, thereby spreading to other islets in the atoll in subsequent years. Atoll-wide, the number of known or suspected mortalities has been more-or-less stable during the last five years, with 8-12 losses each year. These losses account for 15-21% of the annual cohort born at FFS (19% in 2005). While this is a significant problem, Galapagos shark predation on nursing pups appears to be limited to FFS at this time.

Observations with similar effort at other subpopulations in the NWHI indicate that shark related injury and mortality of pre-weaned pups occurs primarily at FFS (NMFS, unpublished data). Fortunately such predatory behavior on nursing pups has not spread to other breeding sites, but shark predation on older-aged seals remains a known but poorly understood cause of mortality. Field observations on the frequency of shark injuries to seals of all age classes at PHR, Midway, and Kure from 1995 - 2004 suggest "per capita" shark predation may also be compromising recovery more at Midway and Kure than at Pearl and Hermes Reef (NMFS unpublished data). In 2002, nine shark attacks were recorded from Midway, two from Kure, and zero from PHR (Baker and Johanos, 2004). Also, Bertilisson-Friedman (2002), reported a higher rate of shark injuries to all age classes of seals at FFS when compared to Laysan and Lisianski.

Conservation Efforts - Shark predation mitigation

Shark predation is a natural phenomenon and is recognized as an important part of the ecosystem. Nonetheless, shark predation is considered a threat because of the small population of Hawaiian monk seals and past declines. Preliminary shark predation and tagging studies at FFS began in 1999. During the 2000-2003 field seasons, ten sharks were removed at Trig Island, and the number of pups killed by sharks at that site dropped to six in 2000, nine in 2001, and three in 2002 and 2003. Attempts to mitigate shark predation on pups also included hazing sharks away and employing lethal removal techniques from Trig Island in 2000 and 2001, and six Galapagos sharks attempting to prey on pups were removed by hook and line. However, these efforts were only temporarily successful and compromised subsequent attempts to cull sharks using standard fishing techniques with hook and line. In 2002 and 2003, hazing was discontinued because it made the sharks wary and difficult to catch, and an additional four Galapagos sharks were removed by hook and line and harpoon. These efforts have been associated with a reduction in the number of monk seals taken by sharks (including both confirmed and inferred losses) from 28 in 1997 to 3 in 2003.

However, proportional losses of pups to sharks at FFS have not been decreasing in recent years due to an overall reduction in the total number of pups born. In 2003, predation on pre-weaned pups increased at other sites within the atoll, raising the concern that concentrating the hazing and removal activities at one location in the atoll had displaced some of the problem to other locations within atoll. For this reason, it will be necessary to expand future mitigation efforts to other pupping sites at FFS to reduce the spread of this shark behavior. This also suggests that hazing may prove counterproductive, and that lethal removal needs to be carried out with minimal false starts. To further enhance post-weaning survival, pups were relocated from Trig Island to other sites within the atoll (e.g., Gin Island) where little or no shark predatory behavior had been observed.

Atoll-wide, the number of shark attacks and mortalities has declined since the peak in 1997-1999. However, as predation has decreased at Trig Island, it has tended to increase at the other sites, so that Trig Island now accounts for a smaller proportion of the total (atoll-wide) shark predation documented each year. Most of the apparent increase at sites at FFS other than Trig Island belongs to the "shark-inferred" category (unexplained pup disappearances with no indication of other compromising factors). If these disappearances are attributed to predation, then in 2003 over 30% of the pups born at sites other than Trig Island were victims of predation (non-fatal attacks or mortalities). Clearly, this trend is of grave concern to the conservation of monk seals at FFS.

2. Serious Threats

a. Infectious diseases

Mortality events in the NWHI have led to concern about the presence of diseases in monk seal populations. Moreover, recent MHI monk seal deaths have heightened concern about monk seal exposure to diseases that they have not previously encountered, such as leptospirosis, toxoplasmosis, West Nile virus, etc. The lack of antibodies in monk seals to various viruses makes them extremely vulnerable to potential infection. While the frequency of disease outbreaks may be rare, their potential devastating effects, should they spread throughout the population, makes infectious disease a serious threat.

Current knowledge of infectious diseases impacting Hawaiian monk seals is based on results of epidemiological surveys of live animals sampled when apparently healthy animals were necropsied in association with die-offs (Gilmartin et al., 1980; Aguirre et al., 1999; Aguirre, 2000), and necropsy examinations of individual dead monk seals (Gilmartin et al., 1980; Banish and Gilmartin, 1992b). To date no epidemics of infectious disease have been identified. A review of the causes of mortality of a sub-set of seals did not reveal infectious disease as a significant cause of overall mortality (Banish and Gilmartin, 1992b). However, there have been three events during which mortality or reproductive failure raised concern over the potential role of disease: a die-off of at least 50 seals on Laysan Island in 1978, a cluster of four aborted fetuses on Laysan Island in 2000, and a die-off of at least 11 seals throughout the NWHI in 2001 (Antonelis et al., 2001). In 2001, the discovery of four dead seals on Laysan Island within one week led to the declaration of an unusual mortality event (UME) of monk seals in that year. The cause of the high mortality was not determined, although six carcasses examined were emaciated with no evidence of underlying disease. Since 2000, juvenile survival has generally remained low at five sub-populations. The epidemiological studies have revealed spatial differences in some hematological and morphological data between subpopulations in the NWHI. Although the differences are not considered individually clinically significant, the lower lymphocyte and eosinophil counts, and shorter body length may reflect differences in subpopulation health and nutritional stress (Aguirre, 2000; Reif et al., 2004).

Infectious diseases known to cause significant morbidity in other pinniped species in the Pacific Ocean include leptospirosis, which causes recurrent epidemics in California sea lions, tuberculosis in fur seals, phocine herpesvirus-1 in young or stressed harbor seals and *Otostrongylus circumlitis* in northern elephant seals (reviewed in Kennedy-Stoskopf, 2001; Dunn et al., 2001). There have been three documented sightings of Northern elephant seals in the Hawaiian Islands, potentially transmitting infections from California pinniped populations to Hawaiian monk seals (Tomich, 1986; unpublished PIFSC sighting references). A tagged juvenile, female elephant seal was observed and photographed at Midway Atoll by George Balazs in February 1978. The seal was originally tagged on San Miguel Island, and the tag numbers were reported. In 2002, a yearling male was captured by NMFS on the Big Island, and after repeated health surveys, it was returned to California where it was tracked after release (Braun, NMFS, pers. comm.). Another yearling male was photographed on Molokai in 2006 (Schofield, NMFS, pers. comm.).

While disease effects on monk seal demographic trends are uncertain, there is concern that diseases of livestock, feral animals, pets or humans could be transferred to naive monk seals in the MHI and potentially spread to the core population in the NWHI (Yochem et al., 2004). Increased use of the MHI by monk seals increases the risk of their exposure to infectious diseases currently present in humans and animals on the main islands, such as leptospirosis. Leptospira bacteria are found in many of Hawaii's streams and estuaries and are associated with livestock and rodents. Recent diagnoses support that in August 2003 and August 2005, the necropsies of two free-ranging monk seals on the island of Hawaii identified the presence of Leptospira bacteria, whose role in the cause of death was not determined and whose presence has not been previously found in the species (Braun, NMFS, pers. comm.). *Leptospira sp*. has been identified on the tissues with immunoflourscence and PCR techniques (NMFS laboratory results). Leptospirosis is a serious concern for Hawaiian monk seals, and the full extent of its threat to monk seals is not well understood.

Viruses that can cause epidemics resulting in dramatic mortality of pinnipeds, but not reported in the North Pacific to date, include morbilliviruses (which have been detected in the North Pacific, in dolphins – see Reidarson et al., 1998) and influenza. In 1999, the West Nile Virus (WNV) was introduced into the United States. WNV has now spread to and remains as a continuing pathogen to animals and humans in 47 states. It is anticipated by the Center for Disease Control to reach Hawaii in the not too distant future. WNV caused the deaths of captive harbor seals and one captive monk seal at Sea World, Texas, in 2004 (Dalton, pers. comm.). The lack of antibodies to these viruses in monk seals makes them potentially extremely vulnerable to infection.

Routes of potential exposure to serious infectious diseases include other marine mammals infected with an agent, terrestrial domestic, feral and wild animals, or humans.

Stressors, such as poor nutrition, may result in the activation of sub-clinical, previously undetected disease. Ticks are common on wild birds in the Hawaiian Islands, and could be sources of tick born diseases such as Q fever, erlichiosis, and tularemia. The tick *Ornithodorous capensis* has been associated with a variety of symptoms in humans on the islands, and is referred to as Laysan Fever, for which the etiology remains unknown (Yoshimoto, 1994). The possible impact of this disease, if any, on monk seals is unknown.

Although exposure to ciguatoxin was associated with the 1978 event at Laysan (Gilmartin et al., 1980), and malnutrition with the 2001 event (Antonelis et al., 2001), the role of any infectious disease in mortality and reproductive failure has yet to be demonstrated. A condition resulting in ocular lesions and blindness in ten captive seals has also raised concerns over the potential effect of infectious diseases. Although in this case, the etiology was not determined, and the environmental conditions in captivity could have contributed to the syndrome.

Serological results suggest that monk seals have been exposed to caliciviruses, herpesviruses, adenoviruses, *Chlamydia psittaci*, *Brucella* spp. and *Toxoplasma gondii*. Herpes virus inclusion bodies and Hepatozoan cysts have been identified in Hawaiian monk seal histological tissue sections. Toxoplasmosis has been identified as the cause of death in two adult seals: one on Kauai in January 2004 (Braun, NMFS, pers. comm.; Honnold et al., 2005) and a second on Oahu in September 2005 (Braun, NMFS, pers. comm.; Dubey et al., 2004). Cats, domestic and feral, are a common source of toxoplasma. The other organisms themselves have not been isolated, but caliciviral RNA (Poet et al., 1993) and herpesvirus DNA (Goldstein et al., 2003) have been identified in swabs from monk seals. Their effects on monk seal health remain unknown. These pathogens are known to cause abortion in other mammals (Williams and Barker, 2001). *Salmonella* sp., *Edwardsiella tarda*, and *Escherichia coli* have been isolated from feces of live seals (Gilmartin et al., 1980; Aguirre, 2000). Bacterial infections in individual monk seals can result from systemic spread of bacteria from bite wounds, male aggression injuries, and entanglement wounds. Five juvenile seals with these male aggression injuries have been cultured, identifying a mixture of gram positive and gram negative organisms (MMRP, NMFS unpublished data).

The predominant parasites identified in monk seals are gastrointestinal: tapeworms (*Diphyllobothrium* spp.), nematodes (*Contracaecum* spp.), and an acanthocephalan species (Rausch, 1969; Dailey et al., 1988). The effects of these parasites on host health are mostly unknown, although ulceration of the stomach associated with nematode infection has been reported (Whittow et al., 1980) and is a common finding (Braun, NMFS, pers. comm.). Even though internal parasites are not identified as a cause of death, they have been shown to be significant stressors in many other species, and survival rates as well as body condition are known to improve in most domestic species with anthelminic treatment.

Conservation Efforts - Infectious diseases mitigation

Events in health and disease studies of monk seals from 1925 through 1997 were reviewed by Aguirre et al. (1999). Investigations of die-offs, necropsies of individual animals and epidemiological surveys of live animals have been performed on monk seals resulting in a basic understanding of the disease exposure in the population (Gilmartin et al., 1980; Dailey et al., 1988; Banish and Gilmartin, 1992b; Aguirre, 2000; Antonelis et al., 2001). Studies of hematology and serum biochemistry have also been performed to characterize the basic "normal" health parameters of this species (Banish and Gilmartin, 1992a; Sloan, 1999; Reif et al., 2004). A comprehensive epidemiological plan was developed in 1999 with the goals to: 1) establish normal baseline values for morphometric, hematologic, and biochemical parameters within age and gender classes at FFS, Midway Islands and PHR; 2) determine evidence of exposure to specific infectious agents using currently available serologic techniques; 3) attempt isolation of *Salmonella* spp. and other pathogenic enteric bacteria and pathogenic viruses; 4) identify parasite exposure and species of parasites present in fecal material; and 5) provide recommendations regarding translocation strategies between surveyed sub-populations at FFS, PHR, and Midway (Aguirre et al., 1999). The epidemiological studies have revealed spatial differences in some hematological and morphological data that may reflect differences in health status or foraging efficiency between islands (Aguirre, 2000; Reif et al., 2004).

An UME contingency plan has recently been published by PIFSC for the monk seal (Yochem et al., 2004). Protocols have been developed for a variety of procedures including anesthesia, sample collection and banking, and necropsy examinations, and training has been instituted for field staff. Archives of tissues and samples have been developed by sampling all animals sedated for research purposes and by performing complete necropsies on all dead animals found. Cell cultures of skin, brain, lung, kidney and spleen have been established in laboratories for potential future analysis and isolation of pathogens.

b. Habitat loss

All the observed habitat use by monk seals in the NWHI falls within 200 km of islands and atolls (Abernathy, 1999; NMFS, unpublished data), and within this region, they are known to forage on benthic areas to at least 500 m in depth (Parrish et al., 2002). Thus, the areas used extend a significant distance from the occupied islands and involve relatively deep benthic areas, some of which include deep-water coral beds (Parrish et al., 2002). Existing data suggest differences in the habitats used among the various sex and age groups, and also among the various island sub-populations.

During the last 60 years, available hauling habitat at FFS has increased with the U.S. military and USCG departure from East Island, as well as the U.S. military's enlargement of Tern Island and then their abandonment and transfer of that island to the FWS. At one time in its 60-year history, Tern Island's associated sand bars may have been significantly larger than at present. Recent loss of terrestrial habitat is an issue of concern in the NWHI (Antonelis et al., 2006; Baker et al., 2006). The loss of Whaleskate Island reduced the available parturition sites at FFS and resulted in the movement of parturient females to Trig Island, where the density of mother/pup pairs increased dramatically in 1999. High levels of shark predation on pre-weaned pups at Trig Island were documented in the same year, and it has been speculated that frequent female/female interactions led to the separation of mothers and pups, thus facilitating high levels of predation by Galapagos sharks. Future habitat losses at FFS and other sites in the NWHI due to environmental factors such as storms and sea level rise, could further exacerbate this problem (Baker et al., 2006).

The terrestrial habitat that monk seals occupy for pupping and resting has been well documented (Kenyon and Rice, 1959; Westlake and Gilmartin, 1990), and monk seals are vulnerable to human activities in these areas (Gerrodette and Gilmartin, 1990). Most human disturbance potential has been removed from the NWHI monk seal habitat. However disturbance continues to be a threat with the significant increase in research activities in the NWHI as a result of the area's recent PMNM designation. Diligence is needed to ensure that the policies that have led to a reduction in such disturbance are preserved.

Most beaches in the MHI that likely are used by Hawaiian monk seals historically are now used to varying degrees by people for recreational purposes. Some MHI coastal areas of Hawaiian monk seal preferred habitat are being developed or are being considered for development for residential and other types of human use. This creates a potential to displace Hawaiian monk seals to less optimal pupping and foraging areas. Reoccupation of the MHI by Hawaiian monk seals will depend in large part on: (1) the effectiveness of efforts to protect seals from people and animals using popular recreational beaches in the MHI, and (2) the extent to which monk seals are able to use beaches where human access is more limited.

Tern Island sea wall entrapment

In 1942, the U.S. Navy built a sea wall that enlarged Tern Island, FFS, from its original 4.5 hectares (11 acres) to about 16.2 hectares (40 acres) in order to accommodate a landing strip. This aging and deteriorating, sheet metal bulkhead sea wall is a serious entrapment hazard to Hawaiian monk seals. Between 1988 and 2006, 43 Hawaiian monk seals have become entrapped behind the eroding sea wall. Most of those were rescued by FWS and NMFS personnel. However, two subadult male seals died as a result of entrapment (USFWS, 2001). As both the sea wall and island erode, buried debris and contaminants have become exposed creating additional hazards to wildlife.

The FWS has worked for many years to facilitate the construction of a new sea wall to stabilize Tern Island and eliminate the wildlife entrapment hazard (USFWS, 2001). Using a congressional appropriation of about $11 million they reconstructed most of the deteriorated portions of the seawall during the spring of 2004.

Conservation Efforts - Habitat protection

Protection of terrestrial habitat is important for those areas currently occupied by monk seals, and for those areas that might be available for re-colonization, such as beaches on the MHI. An increased number of monk seals are using the MHI. This is a positive development for the enhancement of the monk seal population, but it also poses potentially serious management problems and dilemmas (Baker and Johanos, 2004; MMC, 2002). Management measures were made to ensure that haul-out beaches in the MHI are available for use by the Hawaiian monk seals, of which include workshops on managing monk seals on beaches in the MHI, hiring monk seal coordinators on different islands to monitor hauled-out seals and prevent sources of human disturbance, volunteer monk seal monitoring groups, and the establishment of monk seal protection zones around monk seals on recreational beaches.

In 2000 and 2001, additional protections were provided by the establishment of the NWHI Coral Reef Ecosystem Reserve in 2000 via Presidential Executive Orders 13178 and 13196. The designated waters comprised from 3-50 nmi around the NWHI. Provision of that and a subsequent Executive Order (13196) place specific restrictions on human activities that may occur within the Reserve. In addition, this provision limits the fisheries to those in existence in 2000, and provides for extraction caps on those fisheries.

In September 2005, Hawaii State Governor Lingle designated the NWHI to be a state refuge, eliminating all commercial and recreational fishing in state waters along the 1,200-mile island chain while still allowing Native Hawaiians access for cultural practices. State waters extend three miles around all the islands and atolls from Nihoa, the tiny island beyond Niihau and Kauai to Kure Atoll, the northernmost land mass in the Hawaiian chain. Midway is not included.

In June 2006, the NWHI PMNM (71 FR 51134, August 29, 2006) was established. The boundary of the PMNM includes approximately 140,000 square miles of emergent and submerged lands and waters of the NWHI, providing protection for the Hawaiian monk seals' marine habitat via fishing prohibitions and regulations. As stated earlier, the PMNM provides the highest form of national, marine environmental protection for the Hawaiian monk seals' NWHI marine habitat.

c. Fishery interactions

Due to management actions, direct fishery interactions between commercial fisheries and Hawaiian monk seals in the NWHI are currently limited or nonexistent. However, recently monk seals required intervention due to embedded hooks from recreational fishing throughout the MHI, and monk seal mortalities due to gillnet entanglement have occurred. Many hookings are currently mitigated by collecting seals and removing hooks if possible.

Fishing in the U.S. Exclusive Economic Zone (EEZ; from 3 to 200 nmi from the coastline, see Fig. 1.G.3.) around the Hawaiian Archipelago is managed by NMFS through the advisory of the Western Pacific Regional Fishery Management Council (WPRFMC). There are five Fishery Management Plans (FMPs) that describe how fishing will be managed in the EEZ of the NWHI: the Bottomfish and Seamount Groundfish Fishery FMP, the Pelagics FMP (for fishing outside of a 50 nmi radius Protected Species Zone around the NWHI), the Coral Reef Ecosystems FMP, the Precious Corals FMP, and the Crustacean FMP. The last three of these are pre-empted out to 50 nmi around the NWHI by the protective measures of NWHI PMNM (71 FR 51134, August 29, 2006). Fisheries that operate in the EEZ around the MHI are primarily managed by the State of Hawaii. Those fisheries include the MHI bottomfish fishery, commercial and recreational nearshore fisheries, *akule* fishery, collection for the aquarium trade, and recreational gillnet fisheries.

Monk seal-fishery interactions are classified into two categories: direct and indirect. Direct interactions are those involving active fishing gear of various fisheries, feeding of fishing discards, and entanglement in derelict fishery debris. Indirect interactions are defined as those that result from prey availability reduction due to fishing, impacts of fisheries to important habitat, and impacts to feeding or other behavioral changes. To date, no indirect interactions have been proven between fisheries and monk seals even though some of these fisheries are known to take monk seal prey. However, available evidence is not sufficient to rule out the possibility of indirect competition between monk seals and fisheries.

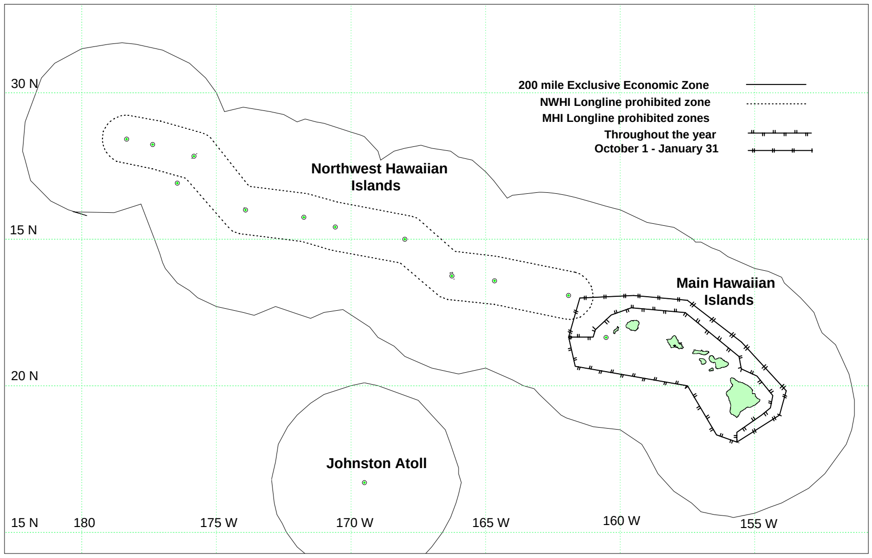

Figure I.G.3. Exclusive Economic Zone (EEZ) of the Hawaiian Archipelago with Protected Species Zone (50 nmi) identified. Note: inner circle around MHI designates winter longline fisheries prohibited area (October 1 to January 31) and outer circle designates summer closures (February 1 to September 30). Map source: Dave Itano, WPRFMC

From 1982-2006, there were 55 recorded instances of seals interacting with active fishery equipment throughout the Hawaiian Archipelago. These comprised 1 entanglement in the bridle of a lobster trap, 5 entanglements in near-shore gillnets, 48 hookings, and 1 seal stealing bait (without becoming hooked) from a nearshore fisherman (Carretta et al., 2005; Bottomfish fishery draft EIS (DEIS); NMFS unpub. data). Some of the hookings have been identified as gear used in the state-managed shore-based *ulua* ("jack", *Caranx* sp.) fishery, while other hooks have been identified as those from the federally managed bottomfish. There is one confirmed report of a hooking of monk seal on bottomfish gear being actively fished, and one hooking of a seal by the longline fishery during active fishing northeast of Kauai in 1994.

Northwestern Hawaiian Islands bottomfish and seamount groundfish fishery

The NWHI commercial bottomfish fishery targets an assemblage of species. The Bottomfish FMP was established in 1986 and updated via amendments. The FMP contains management measures intended to monitor and mitigate interactions between the fishery and protected species including monk seals. The FMP prohibits the use of bottom trawl, bottom-set gillnets, explosives, and poisons in the EEZ of the NWHI. In 1989, the fishery became a limited access fishery with 17 permits allocated per year, and currently is regulated by a "use-it-or-lose-it" permit system. Within the PMNM, established in 2006, no new permits for bottomfishing can be issued, and the fishery must be closed within five years, as mandated by Presidential Proclamation 8031 for the PMNM (71 FR 51134, August 29, 2006).

The Biological Opinion (BiOp) written by NMFS in 2002 found that the bottomfish fishery, as managed under the FMP, may incidentally hook monk seals, and identified seven instances of hookings that could have been attributable to direct interactions with the fishery. The BiOp also determined that one seal would be hooked every 2.9 years, and that one serious injury/mortality would result from a hooking every 6.7 years. This rate is likely a minimum estimate because observer coverage of the bottomfish fishery prior to 2004 was low and because it is unlikely that all hookings are documented. NMFS concluded that few monk seals will be hooked or die as a result of interactions with the NWHI commercial bottomfish fishery, and that any possible "takes" are unlikely to adversely affect the numbers, reproduction, or distribution of the monk seal population. In 2003, NMFS initiated a bottomfish observer program to further evaluate the significance of this interaction. A draft supplemental EIS for the bottomfish fishery management plan has been prepared (NMFS and WPRFMC, 2006).

Nitta and Henderson (1993) evaluated observer data from the bottomfish fishery from 1991-1992 and reported a monk seal interaction rate of one fishery interaction event per 34.4 hours of fishing. This interaction rate did not include any hooking incidents, only the loss of catch or bait with little to no impact from the fishing gear on the animal. Hawaiian monk seals were observed damaging and removing hooked catches, consuming discarded fish and hooked or entangled with various fishing gear types.

Previous data on monk seal prey indicated that there was little overlap of the bottomfish target and bycatch species with the known prey items of monk seals (Goodman-Lowe 1998; Bottomfish Fishery DEIS). It was determined that there was no evidence that monk seals depend on the species targeted or caught incidentally in the fishery, although some overlap between bycatch and monk seal prey is suggested by reports of monk seals stealing catch and discarded fish from fishing vessels. However, recent refinements in fecal analysis and fatty acid signature analysis indicate that these deep slope and sub-photic species are a significant part of the monk seal diet (Longenecker et al., 2006; Iverson et al., in prep). At this is time, it is unknown what level of indirect impact the commercial and recreational bottomfish fisheries may have on monk seal foraging success and population status. Furthermore, some concern has been expressed about the possibility of ciguatoxin poisoning resulting from seals eating fishery discards of species known to be toxic, there is no evidence that this has been a problem, but it has not yet been possible to effectively monitor whether such fed seals may subsequently become ill and die as a result. The fishery has been observed since the fourth quarter of 2003 with 18.3% coverage in 2004 and 25% coverage in 2005, and no interactions with monk seals have been observed.

Pelagic Longline Fishery

Currently, the pelagic longline fishery targets tuna and swordfish, and thus does not directly compete with monk seal for prey. However, the potential exists for interactions with longline gear, including both operating and discarded/derelict gear, which may result in hooking and entanglement hazards.

In 1986, the WPRFMC implemented its Pelagics FMP (PFMP) to manage pelagic fisheries in the U.S. EEZ around the U.S. flag Pacific Islands. The PFMP closed the waters around the NWHI out to a distance of 100 nmi to foreign pelagic fishing vessels, including longliners. A BiOp prepared by NMFS found that the actions in the PFMP would not jeopardize the long-term existence of ESA listed species that occurred in the action area, including monk seals. However, evidence of interactions between longlines deployed by Hawaii-based U.S. longliners and monk seals began to accumulate in 1990, with 3 hooked seals and 13 unusual (i.e. could not be attributed to natural causes) seal wounds. In October 1991, the WPRFMC recommended and NMFS established a permanent Protected Species Zone (PSZ) extending 50 nmi around the NWHI and the corridors between the islands, and the Hawaiian-based longline fishery was prohibited from fishing within the Zone. Only two interactions with the longline fishery have been documented since establishment of the PSZ: a seal with a hook in its jaw at FFS and a logbook report, both in 1994. At present, interactions with protected species are monitored by federal logbooks and observers (>20% coverage for the deep-set fishery and 100% coverage for the shallow-set fishery), and no interactions between the Hawaiian-based longline fishery and monk seals have been observed.

The Coral Reef Ecosystems Fishery Management Plan

The Coral Reef Ecosystems FMP (CRE-FMP) was developed by the WPRFMC to manage coral reefs and coral reef associated resources in the U.S. EEZ around American Samoa, Guam, Hawaii, the Northern Mariana Islands, and the U.S. Pacific Remote Island Areas. The management measures for the NWHI proposed in the CRE-FMP include "no-take" and "low-use" Marine Protected Areas. The EIS and associated biological assessments and consultations for the CRE-FMP concluded that direct interactions of monk seals with existing fisheries in the NWHI are rare, and a low level of risk would remain under all alternatives in the CRE-FMP.

However, impacts to monk seals may be generated from indirect threats by fisheries in the region managed by the CRE-FMP on the poorly understood coral reef food web. Coral reef ecosystems comprise many species that share a long co-evolutionary history. Removal of some species may cause undesirable changes in the environment or abundance of other species through changes in competitive and/or predator-prey relationships. In June 2002, NMFS approved the CRE-FMP, except for those portions that apply to the NWHI due to conflicts between the FMP and provisions of the former NWHI Coral Reef Ecosystem Reserve.

Precious Coral Fishery Management Plan

The precious coral fishery was subject to the measures contained in the Precious Corals FMP, which became effective on September 29, 1983. Since the FMP went into effect, only a single vessel in 1989 attempted to harvest precious corals in the NWHI. Indirect interactions between the fishery and monk seals may occur if the removal of coral compromises the essential habitat of coral-associated fish prey that are consumed by monk seals. Studies have shown that some seals dive deep enough to encounter commercially sought precious coral (Abernathy and Siniff, 1998; Stewart et al., in press), and three seals visited sites with beds of filamentous black coral at moderate depths (80-100m) where they fed on resident fish (NMFS, 2002; Parrish et al., 2002). This suggests that an overlap exists between the foraging habitat of some seals and certain types of deep water precious corals, and that protection of these coral beds will benefit monk seals.

However, the recent Presidential Proclamation 8031 that established the PMNM precluded implementation of this FMP within 50 nmi of the NWHI. The PMNM (71 FR 51134, August 29, 2006) prohibits the removing, moving, taking, harvesting, possessing, injuring, disturbing, or damaging, or attempting to remove, move, take, harvest, possess, injure, disturb, or damage any living or nonliving monument resource. Within the boundaries of the monument, the unauthorized passage of ships, unauthorized recreational or commercial activity, and any extraction of coral are prohibited.

Lobster Fishery

The NWHI lobster fishery began in the late 1970s, and developed rapidly in the early 1980s. Historically, the fishery's effort and landings were concentrated at Gardner Pinnacles, Maro Reef, Necker Island and St. Rogatien Bank (Polovina and Moffitt, 1989). In 1981, to reduce interactions between the fishery and monk seals, fishing operations were prohibited in the NWHI in waters less than 10 fathoms deep.

Under the FMP, annual landings peaked in 1985-1986 but declined until 1993 when the fishery was closed due to low spawning stock biomass of spiny lobster (Haight and DiNardo, 1995). The fishery reopened in 1994, and during 1996-1999, there were 5-9 vessels participating. In June of 2000, NMFS closed the lobster fishery due to uncertainty in the model assumptions used to estimate sustainable lobster harvests and as a precautionary measure to prevent overfishing of the lobster resources (65 FR 39314, June 26, 2000). Currently, this closure status is maintained. NMFS announced the harvest guideline for the NWHI commercial lobster fishery for calendar year 2006 established at zero lobsters, and no harvest of NWHI lobster resources was allowed (34 FR 8846, February 21, 2006). Under the terms and conditions of the PMNM (71 FR 51134, August 29, 2006), any commercial lobster fishing permit shall be subject to a zero annual harvest limit and, thereby, the lobster fishery would remain closed.

There is one record of a direct interaction with the lobster fishery when a monk seal drowned after becoming entangled in the bridle rope of an actively fishing lobster trap. The importance of lobster in the prey assemblage of monk seals was evaluated by MMRP by using quantitative fatty acid signature analysis. Results indicate that lobster comprise a very small portion of the current monk seal diet. Analysis of DNA in the feces of seals to identify presence/absence of lobster species in the diet started in August of 2006.

Recreational Fisheries

Hawaii is one of the few coastal states that does not require a saltwater, recreational fishing license or catch reporting, and consequently, it is difficult to estimate the recreational effort and/or catch. Studies have shown that recreational fishers take a higher diversity of species with a wider variety of gear types than do commercial fishers, and that catch is equal to or greater than the commercial catch for a number of important target species (Hamm and Lum, 1992; Everson, 1994; Friedlander et al., 1995; Friedlander, 1996). Recreational fishing in Hawaii involves not only State residents but also some of the 6.6 million tourists who visit the State annually (WPRFMC, 2002).

The methods used in recreational fisheries vary (spear fishing, surface gillnet, seine net, cast net, net and traps, pole and line, trolling, longlines, and handlines). One of the most popular types of gear is a circle hook with a slide bait swivel on a wire leader. This gear is typically cast from shore and the principle target catch is the *ulua* (jack).

Previously, at least three seals were hooked at Kure Atoll during the time period when the USCG operated a LORAN station at the atoll (Forney et al., 2000). Until spring 2002, recreational fishing was allowed in the lagoon and waters around Midway under an agreement between FWS and a concessionaire. Although no adverse interactions (e.g., entanglements or hookings) with monk seals were reported, a study conducted in 1998 recorded monk seal interactions (i.e., inquisitive juveniles investigating human activity) at six locations during fishing activities (Bonnet and Gilmartin, 1998). No recreational trolling hookings of monk seals are known. Therefore, with the closure of the LORAN station at Kure Atoll in 1992 and the recent establishment of the PMNM by Presidential Proclamation (71 FR 51134, August 29, 2006), recreational fishery interactions in the NWHI will not be a threat to Hawaiian monk seals.

Pursuant to the recent proclamation of a PMNM (71 FR 51134, August 29, 2006), the "removing, moving, taking, harvesting, possessing, injuring, disturbing, or damaging; or attempting to remove, move, take, harvest, possess, injure, disturb, or damage any living or non-living monument resource" is prohibited within the monument with exceptions in the proclamation. A permit may be issued only for recreational activities to be conducted within the Midway Atoll Special Management Area with the conditions that the activity is for the purpose of recreation, the activity is not associated with for-hire operations, and the activity does not involve any attractive use, which is defined in the Proclamation as a means of luring or attempting to lure a living resource by any means. However, according to the Draft Interim Visitor Services Plan for the Midway Atoll Special Management Area and National Widlife Refuge (December 2006), recreational and special ocean use permits will not be authorized for fishing in Midway Atoll.

Recreational and commercial fishing activities in the MHI affect monk seals through direct interactions and possibly indirectly, either through conflict over use of coral reefs or by overfishing. The extensive use of gillnets in the MHI is thought to have caused the localized depletion of reef fish through its effectiveness and non-selectivity (Gulko et al., 2002), and has also resulted in breakage of coral colonies and the bycatch of endangered species, including Hawaiian monk seals. Of 43 monk seal/fishery interactions in the MHI from 1982 - 2006, one seal was found dead in a nearshore gillnet in 1994, a second seal was disentangled by recreational divers from a nearshore gillnet in 2002, and a third seal was temporarily entangled in a nearshore gillnet in 2005, but escaped unaided. In October 2006, a female, juvenile Hawaiian monk seal was found drowned in a gill net about three months after her weaning. In June 2007, an adult male Hawaiian monk seal at Makua Beach on the island of Oahu was found dead and densely wrapped in gill netting. The monk seal drowned in the illegal net that was not properly tagged with identification markers under recent regulations passed by the State of Hawaii in March 2007.

A total of 38 seals have been observed with embedded hooks in the MHI during 1982-2006 (Caretta et al., 2005; NMFS unpub. data). A monk seal was found dead in 1995 with a hook lodged in its esophagus. For most of the interactions, the hooks were not always recovered, and it was not possible to attribute each hooking event to a specific fishery. Among hooks that could be identified, the sources included nearshore fisheries (esp. for *Caranx* sp. in the MHI) in State of Hawaii waters, and bottomfish (handline) fisheries in state and federal waters (NMFS unpub. data).

MHI Bottomfish fishing

The State of Hawaii regulates both commercial and recreational bottomfish fishing within 3 nmi of the MHI. However, proposed measures to address overfishing will likely involve federal permitting of vessels in state waters in the future. The distinction between the commercial and recreational bottomfish fisheries poses a conundrum for fishery managers. Both use the same type of gear (a weighted mainline with circle hooks attached at intervals on sidelines; Haight et al., 1993). While monk seals have been observed near fishing boats, there have been no reported interactions between monk seals and this fishery in the MHI. Indirect interactions with this fishery need to be considered in the light of recent results from fatty acid analysis of monk seal diet (Iverson et al. unpublished data)

Conservation Efforts - Fisheries interactions mitigation

In response to documented injuries to endangered Hawaiian monk seals and several species of sea birds and sea turtles resulting from longline fishing operations in the NWHI, the WPRFMC asked a special inter-agency task force to recommend actions to prevent further harm to protected species. In October 1991, the WPRFMC recommended and NMFS established a permanent Protected Species Zone (PSZ) extending 50 nmi around the NWHI and the corridors between the islands, and the Hawaiian-based longline fishery was prohibited from fishing within the PSZ.

In 1999, a single vessel began targeting sharks in the MHI and NWHI with modified longline gear. Due to the modification, this gear was exempt from the regulations of the PSZ. This fishery laid a one-mile longline on the bottom of the seabed with short gangions and large shark hooks floating above the bottom. The WPRFMC has since defined this gear and banned it in the NWHI in an amendment to the Pelagic Fisheries FMP. While no known interactions between monk seals and this gear occurred in 1999, this fishery was a potential threat to monk seals.

In 2001, bottomfish fishermen in the NWHI bottomfish fishery voluntarily implemented several measures aimed at minimizing interactions with monk seals and other marine mammals. The measures included: pulling up fishing gear anytime that a monk seal is sighted within a ten yard radius; moving fishing stations if monk seals remain in the vicinity for more than two hours; retention of all injured and dead catch and discards at all times to discourage attracting predation by seals, dolphins, sharks and other large predatory fish; discarding offal only after fishing has ceased, and only if monk seals are not present; and, release of all healthy unwanted organisms captured during bottomfishing operations only when monk seals, dolphins, and sharks are absent from the vicinity. As noted previously, the fishery has been observed since 2003 and no interactions with monk seals have been reported. However, these do no take into account potential indirect ecological interactions.

Executive Order 13178 allowed for a cap to be placed on the number of fishing permits and harvest levels for commercial and recreational fisheries. It also called for designating marine preservation areas within which all fishing (except for bottomfishing in some areas) was to be prohibited, limiting harvests of other living and non-living resources, restricting oil and gas development, limiting discharges of materials, and preventing anchoring directly on coral reefs. After an opportunity for public comment, a second Executive Order (No. 13196) was signed on January 2001, finalizing many of these restrictions.

In 2004, NMFS published a final rule to implement the FMP for Coral Reef Ecosystems of the Western Pacific Region (CRE-FMP). The rule established a coral reef ecosystem regulatory area, marine protected areas (MPAs), permitting and reporting requirements, no-anchoring zone, gear restrictions, and a framework regulatory process (69 FR 8336, February 24, 2004). This rule also pertains to the other four western Pacific fishery management plans with respect to fishing activities in the U.S. EEZ of the western Pacific region.

In September 2005, the State of Hawaii implemented a ban on all fishing in their NWHI waters 0-3 nmi from shore. The new rules protect state waters from commercial and recreational fishing, and require an entry permit for all other activities including educational, scientific and cultural. Nine boats are given permits to fish for 'opakapaka, onaga and other species, mostly in federal waters, bringing in 200,000 - 300,000 pounds of fish a year, or about half this type of fish consumed in Hawaii. The harvest is valued at about $1.5 million.

By Presidential Proclamation 8031, the PMNM was established (71 FR 51134, August 29, 2006) and the boundary includes approximately 140,000 square miles of emergent and submerged lands and waters of the NWHI, providing protection for the Hawaiian monk seals' marine habitat via fishing prohibitions and regulations. As stated earlier, the unauthorized passage of ships, unauthorized recreational or commercial activity, and any extraction of coral, wildlife, minerals, and other resources, or dumping of waste are prohibited within the boundaries of the monument. Commercial fishing within the monument will be phased-out over the ensuing five years.

There is a need for mitigation of recreational fishery interactions with monk seals in the MHI, and particular attention should be given to lay gillnets, recreational hook and line fishing, and aquaculture. One of the recreational fisheries in the MHI that currently interact with Hawaiian monk seals is the nearshore *ulua* fishery. In recent years, NMFS has been increasingly successful in identifying and de-hooking seals with embedded hooks around the MHIs, however this effort does not remedy the interaction problem itself.

Lay gillnets also pose a hazard to seals. Two different incidents of Hawaiian monk seals that drowned from densely wrapped lay gillnets occurred in October 2006 and June 2007 on the island of Oahu, indicating the potential mortality from interactions with recreational fishing gear. In March 2007, Governor Linda Lingle of the State of Hawaii approved amendments to the rules that regulate the use of lay gill nets and prohibit their use in certain state waters. Rule changes were part of a long, inclusive process that started with meetings and recommendations of the Gill Net Task Force, which met in 1998-1999. From 2002 to 2006, DLNR held three rounds of statewide public meetings and hearings to get community input on proposed lay net management regulations, based in part on the task force's recommendations. Nine final public hearings on the rule amendments were held statewide in July 2006.

The amended rules require the registration and identification of all lay nets, limit their maximum dimensions, limit their fishing or soak times to not more than four hours in daylight hours only, and require attendance and inspection of nets when fished, limit use to one net per person per day, and prohibit their use in streams and stream mouths. The rule amendments prohibit lay net use in state waters around the entire island of Maui. On Oahu, lay net use is prohibited between Portlock Point to Keahi Point (west of the Pearl Harbor channel), from Mokapu Peninsula to the northern boundary of Bellows Air Force Base, and in Kaneohe Bay seaward between the two ship channels, including Ahu O Laka. The islands of Molokai, Lanai, Kauai and Niihau will not have banned areas for lay net use; however, the new rule addressing registration, size, usage and soak time will apply to these areas. Existing rules in West Hawai'i will continue. Violations of lay net rule are subject to civil (fine of up to $1,000 for a first violation and graduated with subsequent) and or criminal penalties (a petty misdemeanor, subject to a fine of $250 for a first offense and graduated after that

d. Male aggression

The primary cause of adult female mortality affecting recovery potential in the monk seal population during the 1980s and early 1990s was injury and often death of female monk seals caused by multiple male aggression, or "mobbing" attacks (Banish and Gilmartin, 1992b). These attacks occur when a number of males gather and repeatedly attempt to mount and mate with a single seal. Multiple-male aggression is thought to be related to an imbalance in adult sex ratios, with males outnumbering females. When several males attempt to mount and mate with an adult female or immature animal of either sex, injury or death of the attacked seal often results (Carretta et al., 2005). The sex ratio at Laysan Island was skewed to males at a time when Hiruki et al. (1993a) showed females at Laysan were injured by males at three to four times the frequency of that observed at FFS. Hiruki et al. (1993b) reported that the primary effect of adult male inflicted injuries on females was increased mortality. Additionally, a wounded female's reproductive success in the year of injury appeared to be influenced by the severity of her injuries. In 1994, 22 adult males were removed from Laysan Island (bringing the total number of adult males removed since 1984 to 37), and only five seals were thought to have died from multiple male aggression attacks at this site since their removal (1995-2003) (Carretta et al., 2005).

Attacks by single adult males have resulted in several monk seal mortalities. This form of single male aggression occurs at most or all locations and appears to involve behavior which ranges from normal pinniped male harassment of younger animals, to an aberrant level of focused aggression, especially directed toward weaned pups. This was most notable at FFS in 1997, where at least 8 pups died as a result of adult male aggression (Carretta et al., 2005). Many more pups were likely killed in the same way, but the cause of their deaths could not be confirmed.

Conservation Efforts - Male aggression mitigation

Individual males have also injured and killed seals, usually weaned pups of both sexes. Observations and research indicate that male aggression is a learned male behavior, probably associated with male-biased adult sex ratios (Gilmartin and Alcorn, 1987). Death typically occurs either from immediate drowning when pups are mounted in the water or from infections resulting from bite wounds. MMRP has developed guidelines for the assessment and, if necessary, the mitigation of single male aggression through translocation or lethal removal.

Several management actions have been implemented to balance the sex ratio at Laysan Island by removing problem males. In 1984, a group of ten adult males that had been observed attacking females, or whose behavior profile was similar to those that attacked females, were captured on Laysan and transported to Johnston Atoll. One of the ten died prior to release, and of the remaining nine, most were not seen after a few months. The last male was not observed until after a period of 16 months. In 1987, MMRP conducted a workshop and developed a plan to address the multiple male aggression problems (Gilmartin and Alcorn, 1987). Another group of five problem males was removed from Laysan and entered into captivity in 1987 for studies identified in the plan. Modeling efforts (Starfield et al., 1995) and simple decision analysis (Ralls and Starfield, 1995) indicated that removing males from Laysan would likely be helpful to the populations there. Males in the 1987 group were used to define the testosterone cycle in males (Atkinson and Gilmartin, 1992) and to evaluate a drug to suppress testosterone for possible field application to reduce aggressive behavior. The captive trials demonstrated effective testosterone suppression (Atkinson et al., 1993) and a pilot field trial was performed (Atkinson et al., 1998). However, there were severe limitations to effective use of this tool: the drugs were expensive; each male had to be captured and injected a number of times over the course of the breeding season; these repeated captures would have resulted in extensive disturbance to most seals on the island during the breeding season. All of these factors led to reconsideration and cessation of this approach.

In 1994, another 22 males, selected as subordinate males and some of whom had been identified in earlier mobbing attacks, were collected at Laysan and relocated to the MHI in order to remove males that had or would likely injure females and to balance the Laysan Island adult population sex ratio. One died shortly after capture. A significant reduction in deaths due to male aggression followed. None of the males that were moved to Johnston Atoll or the MHI are known to have returned to their original location, though one male brought to the Big Islands in 1994 was sighted on Nihoa in 1996 and again on Oahu in 2000. A few adult males at FFS were observed killing pups, and of these males, one was euthanized and two that killed pups in 1997 were translocated to Johnston Atoll, 870 km to the southwest (Carretta et al., 2005). Subsequently, mounting injury to pups has decreased. None of the translocated males have returned to their original locations, and the occurrence of male-caused injuries and deaths among females and immature monk seals has significantly decreased in all instances (NMFS, 2000). In total, 40 adult male seals were either translocated (32 seals), placed in permanent captivity (5 seals), died during translocation (2 seals), or were euthanized (1 seal). These mitigation efforts successfully reduced the frequency of male-related injuries and deaths to adult females and juveniles of both sexes.

Injuries inflicted by multiple males have been observed at other sites as well, primarily at Lisianski Island where the adult sex ratio is male biased. However, there has been no action taken to remove males involved in mobbing attacks at this location. In recent years, the sex ratio has become more balanced and was estimated at 1.2 males per female in 2003 (NMFS, unpublished data).

e. Human interactions

Hawaiian monk seals in the NWHI avoid beaches for breeding where people have often disturbed them. Sightings of monk seals in the MHI have increased, resulting in increased human interactions where tourists and residents can view monk seals hauled out on beaches, thus creating an increasing concern about harassment of seals. Recent successful monk seal pupping events on popular MHI beaches have occurred, despite the major management challenges with regards to staff, volunteers, resources, public outreach and collaboration. Disturbance of seals on MHI beaches may limit seals' ability to make use of habitats, but it affects only a small portion of the total population. If the MHI population grows both in absolute number and proportion of total abundance, disturbance will become a larger management challenge and more important in terms of the overall population.

Human interactions with monk seals have ranged from unintentional disturbances at haul-out sites, to inflicting deliberate injuries on seals and killing them. Little is known about monk seals or their population status before the 1950s. However, it is generally acknowledged that the species was heavily exploited in the 1800s during a short-lived sealing venture (Ragen, 1999). The *Gambia* reportedly returned to Honolulu with 1,500 skins (although the authenticity of this report has been questioned; Kenyon and Rice, 1959). The last known take of a monk seal by commercial sealers was in 1824 (Bryan, 1915).

Monk seals were harvested for food by shipwreck victims, guano and feather hunters, museum collectors and other transient visitors to the NWHI (Clapp and Woodward, 1972; Amerson, 1971; Amerson et al., 1974; Clapp and Wirtz, 1975; Ely and Clapp, 1973; Gilmartin, 1983; Ragen, 1999). The degree to which other activities (e.g. military activities during and following World War II, subsistence harvest by shipwrecked crews, activities by feather/guano gatherers, and in recent decades, casual visits by ships' crews) affected or disturbed monk seals remains unknown (Ragen, 1992).

In general, monk seals in the NWHI avoid beaches for breeding where people have often disturbed them. A "critical intolerance of humans" is a characteristic of monk seals (Kenyon, 1972). The most significant documented consequence of disturbance is the decrease in population size and beach counts at human-disturbed sites during the later half of the 1900s (Kenyon, 1972; Gerrodette and Gilmartin, 1990). If sufficiently disturbed, monk seals have been observed to abandon haul-out sites, and females have abandoned preferred pupping habitat to move to suboptimal habitats. The NWHI, where the major breeding colonies of monk seals occur, is remote and currently relatively free from human disturbance. However, intentional unauthorized landings of boat crews have been documented in the NWHI, specifically at Kure Atoll (Shiinoki, 2000 unpublished report; NMFS, unpublished data) and at FFS (FWS, unpublished data).

Since the 1990s, sightings of monk seals in the MHI have increased (Baker and Johanos, 2004), resulting in increased human interactions. For example, a resident threw coconuts at a resting seal, and dogs have bitten monk seals on the beach. Unlike those situations, disturbance is typically unintentional and not malicious, although it is frequent for the few seals that use MHI beaches in high traffic areas. While monk seals in general are solitary and skittish, public safety considerations need to be addressed regarding possible injury to humans (i.e., bites) in the event of an interaction. While Hawaiian monk seals tend to distribute themselves in more remote areas of the MHI where human disturbance is less likely (Baker and Johanos, 2004), individual seals have become habituated to human presence and frequent beaches and other areas heavily used by humans. This situation presents a number of challenges, and it is often difficult to convey to the public that monk seals are sensitive to disturbance, especially when some individual animals seem content to share the beach with many people.

Seals pupping on popular beaches in the MHI are a major management concern. In the past, some beaches were closed when a pupping occurred, creating animosity among NOAA, state representatives, hotel owners and beach goers. Recent efforts have been undertaken to coordinate with resort hotels and their guests to protect the monk seal mothers and their pups, while minimizing negative impacts to vacationers, in many cases by providing a stimulating conservation experience to the public. Around the clock volunteer monitoring provided protection of seals and communication with public beach goers.

Table I.G.3. The following are data of all known monk seals births in the MHI in recent years. It is important to note that very little is known about the population on Niihau. However, based on the occurrence of unknown, untagged, juvenile seals seen on Kauai, it is likely pupping occurs on Niihau annually. (Source: Moreland, NMFS).

Year	Niihau	Kauai	Oahu	Molokai	Maui	Kahoolawe	Hawaii	Total
2000	2	4	0	1	0	0	0	7
2001	5	3	0	2	0	1	1	12
2002	-	1	0	2	0	0	1	4
2003	-	2	1	4	1	1	2	11
2004	1	3	1	5	0	0	1	11
2005	-	3	1	4	0	1	1	10
2006	-	4	2	5	0	0	1	12

While vessel-based interactions, or the use of motorized or non-motorized vessels (e.g., outboard or inboard boats, kayaks, canoes, underwater scooters) are more frequently observed to strike dolphins and whales in Hawaii, vessel strikes have injured monk seals in the past (NMFS, unpublished data). Although there is no published evidence that monk seals were struck by vessels, one seal was found in 1986 with a broken jaw and presumed propeller cuts on his ventrum. Operations were conducted to treat the jaw, and the animal was sent to Sea Life Park Hawaii permanently. Another seal was found off Kona with an injured back and broken vertebrae. He also was sent to permanently reside at Sea Life Park Hawaii. The cause of this second injury could have been from a vessel strike, but that wasn't as clear as it was for the first seal. This type of interaction has a higher possibility of occurring in the MHI as more seals inhabit this area over time.

Since 1980, MMRP personnel have worked in collaboration with FWS, the U.S. Navy, the State of Hawaii, and the USCG to minimize disturbance to monk seals at their haul-out sites in the NWHI. Human activity on beaches used by monk seals was significantly reduced after the closure of the USCG facilities at FFS (1979) and Kure (1992), and the U.S. Navy facility on Midway (1997).

The ownership of Midway Islands was transferred from the Navy to the FWS in 1996, and it is now managed as the Midway Atoll National Wildlife Refuge. From 1997 to 2001, a privately owned business was granted a concession to develop and manage a limited eco-tourism and public-use program at Midway in the form of charter boat and shore fishing, diving, spearfishing, and wildlife observations. The number of visitors allowed on the atoll at any one time was limited to reduce impacts to wildlife. In 2002, the contractor stopped the visitor program. The Midway monk seal population began to increase in the early 1990s after the atoll was transferred to the FWS and while the eco-tourism venture was in the early stages of operation (Gilmartin et al., 1999). However, concerns exist regarding the potential long-term impacts to monk seals in the development of Midway as a visitor destination.

Because human disturbance can be a detriment to monk seals, it is MMRP protocol to conduct research activities as discreetly as possible and to record all disturbances that they cause. Working under federal permits, MMRP staff handles monk seals in the wild as part of the population assessment and research programs. Activities include tagging, instrumentation, and sampling tissues for health assessment, disentangling, transport for captive maintenance, translocation and die-off assessment. Between 1980 and 1999, the MMRP has handled seals 4,800 times as part of its research activities (Baker and Johanos, 2002). Of the 4,800 handling events, three seals have died during research handling: two deaths were attributed to capture stress and one seal died while under sedation for blood sampling. Statistical analysis of handled animals versus controls found no difference in subsequent survival, migration to another atoll or physical condition, suggesting that the research handling protocols are appropriate and do not harm monk seals (Baker and Johanos, 2002). Littnan et al. (2004), analyzed diving data from individual juvenile seals with and without seal-mounted video recorders (CRITTERCAMs) attached and found no evidence that the instruments altered diving. Research disturbance could theoretically cause within-atoll movements or the redistribution of seals, which are both changes that could lead to serious problems, but this has not been examined. Some handled seals remain wary of humans for many months after handling, but the negative impact, if any, of this behavior is unknown. Monk seals have been removed from the wild, and rehabilitated or translocated between locations by NMFS staff as part of management efforts to facilitate species recovery. The subsequent survival of those animals, compared to controls did not indicate that the treatment was a detriment.

3. Moderate Threats

a. Biotoxins

Biotoxins have not been confirmed as a cause of mortality, and this is considered a relatively less serious threat. Ciguatoxin is a biotoxin produced by a benthic dinoflagellate, *Gambierdiscus toxicus,* that is common in coral reefs. Herbivorous fish consume the algae and concentrate the ciguatoxin, thus passing the toxin up the food chain so that it may eventually affect mammals consuming the fish (Gollop and Pon, 1992). In 1978, at least 50 monk seals died on Laysan Island, and high levels of ciguatoxin and maitotoxin, a similar neurotoxin, were detected by bioassay in the livers of two seals examined (Gilmartin et al., 1980). To determine whether ciguatoxin affected a model phocid species, ciguatoxin at natural levels in moray eels was fed to two northern elephant seals (DeLong and Gilmartin, 1979). One seal was fed eel slurry at 9% of seal's body weight in two feedings in one day; the second was given a lower dose of eel slurry fed over 4 days to total 2.5% of seal's weight. The first seal died within two hours of its second feeding, and the second died about four days after its last feeding, following signs of myoneural involvement. Thus, ciguatoxin can cause mortality in phocids, but its role in mortality of Hawaiian monk seals is unclear due to the lack of assays for testing tissues of dead seals for toxic doses, and the lack of epidemiological data on the distribution of toxin in monk seal prey.

Domoic acid is a biotoxin produced by the diatom *Pseudonizchtia australis* that is known to affect pinnipeds and has caused mortality of California sea lions (*Zalophus californianus*) in the eastern Pacific (Scholin et al., 2000). Although not identified to date in the prey of monk seals, blooms of *Pseudonizchtia* spp. have occurred around the Hawaiian Islands (Scharek et al., 1999). Blooms of algae which could contain harmful species have been identified by satellite remote sensing in Hawaiian monk seal habitat.

Conservation Efforts - Biotoxins mitigation

While the MMRP has initiated investigations into the presence of ciguatoxin levels in monk seal prey species and in samples taken from juvenile seals in 2001 throughout their range, this work has not been comprehensive or complete due, in part, to the lack of a reliable assay for ciguatoxin. PIFSC recently published a Contingency Plan for the Hawaiian Monk Seal Unusual Mortality Events (Yochem et al., 2004). In this plan, biotoxins were described as having the potential to pose a serious risk for Hawaiian monk seals. Of the 15 Marine Mammal Unusual Mortality Events (UMEs) occurring in other marine mammals species since 1992, infectious diseases and biotoxins were the most common diagnoses (five cases each). In the "Pre-event Planning for a Rapid Response" section, procedures are in place for the on-site coordinator to call on scientific advisors from the Hawaiian Monk Seal Recovery Team, the Marine Mammal Commission, or the list of attendees at the 11-12 September 2000 Hawaiian Monk Seal Health Studies Workshop. Additional advisors may be consulted depending on the size and nature of the event (e.g., the NOAA Marine Biotoxins Program, 843-762-8500). Pre-identified risks to Hawaiian monk seals include naturally occurring biotoxins such as ciguatera. The NOAA Marine Biotoxins Program has a Flow Diagram for Suspected Marine Biotoxin Incidents. According to the plan, this flow diagram will be used to guide response to a suspected harmful algal bloom. Specimen collection protocols were also described in the Plan for specific biotoxins, and there were clearly defined Specimen Collection Protocols for Biotoxins. In addition, FWS assayed fish collected from Tern Island before seawall construction for the presence of ciguatoxin and will do follow-up sampling in fall 2006.

b. Vessel groundings

Monk seals may be injured or killed by vessel groundings that result in the release of hazardous materials, including oil or fuel spills, rotting bait, lost gear that creates entanglement hazards, and as a result of human disturbance resulting from a grounding incident (Gulko, 2002; Work, 1999). These events are typically episodic and affect only a limited area when they occur. To date, no seal mortalities have been attributed to vessel groundings.

Vessel groundings that result in damage to coral reef fauna may adversely affect monk seal habitat. In addition, trauma to reefs associated with vessel groundings have been implicated in ciguatera outbreaks, and the possibility exists that seals may be affected through the bioaccumulation of ciguatera in the prey (Gilmartin et al., 1980; Gulko, 2002). Vessel grounding has also been implicated in promoting the growth of cyanobacteria in remote oceanic areas (Gulko, 2002). Cyanobacteria that may bioaccumulate in the marine system have the potential to affect monk seals.

Information regarding vessel-grounding events in the NWHI is very incomplete. Over 50 shipwrecks have been documented on the reefs and islands of the NWHI, but only the relatively recent shipwrecks have been investigated (Table I.G.4).

Vessel groundings may also be a threat to monk seals in the MHI. Over 16,000 commercial and recreational vessels are registered in the State of Hawaii (Gulko, 2002). When the transient commercial and recreational vessels are considered, over 18,500 ships use the nearshore waters of the MHI annually. Of all the vessel groundings between 1993 and 2000, 59% involve small recreational boats and 28% were fishing vessels (Gulko, 2002).

Table I.G.4. Reported vessel groundings in the NWHI between 1969 and 2004 (Gulko, 2002; E. Flint, pers. comm.; J. Henderson, pers. comm.)			
Year	Vessel Type	NWHI location	Removed
1970	Fishing	Laysan	No
Late 1970s	Fishing	Kure	No
1976	Yacht	Pearl & Hermes	Yes
1980	Fishing	FFS	Yes
1980	Cargo	FFS	Yes
1981	Fishing	FFS	No
1989	Yacht	Pearl & Hermes	No
1992	Fishing	Kure	No
1998	Fishing	Kure	No
2000	Fishing	Pearl & Hermes	Yes

c. Contaminants

A number of contaminants originating from human occupation of the NWHI have been identified in monk seal habitat. The effects, however, of these compounds on monk seal health, reproduction and survival are unknown. Many of the toxins found in the NWHI result from the past use of this area for military purposes. Levels observed in Hawaiian monk seals are not elevated when compared with other North Pacific pinnipeds.

The levels of organochlorines (OC) were investigated from 46 Hawaiian monk seals at FFS (Willcox , 1999) and identified in blood and blubber at various levels. Blubber and blood samples collected from female and male monk seals of various ages were analyzed for selected OCs, including DDTs and PCBs. In that study, adult male monk seals had higher PCB concentrations in blubber than reproductive females or juvenile animals. Adult males had significantly higher concentrations of polychlorinated biphenyls (PCBs) than females or juveniles, possibly influenced by different foraging waters and prey selection. The lower concentrations in females are most likely the results of OC transfer during gestation and lactation. Additional blood and blubber samples from monk seals collected from four NWHI sub-populations over five years were analyzed for dioxin-like PCB congeners and other selected OCs. Higher PCB and DDT concentrations were found in seals from Midway compared to seals from the other three sub-populations (Aguirre, 2000; Ylitalo et al., in prep.). The predominant OCs measured in monk seal tissues were the moderately chlorinated PCB congeners (e.g., PCBs 153, 138). These congeners were manufactured in relatively large proportions in technical PCB formulations, and many are recalcitrant to metabolism (McFarland and Clarke, 1989). The dioxin-like PCBs detected in the monk seal samples were primarily of mono-*ortho* (e.g., 118 and 105) and di-*ortho* substituted (e.g., 180) PCB congeners. In contrast, the most toxic dioxin-like PCBs, the non-*ortho*-substituted congeners (PCBs 77, 126, 169), were not detected in any of the blood or blubber samples analyzed. In all contaminant studies of the wild monk seals to date, the OC levels were comparable to or lower than those reported in blubber of various pinnipeds from the Northeastern Pacific (Lee et al., 1996; Krahn et al., 1997; Calambodikis et al., 2001; Kajiwara et al., 2001). Conclusions from this study confirm that Hawaiian monk seals are exposed to OCs, the biological effects of which remain unclear. However, the findings of Hawaiian monk seal toxicological studies suggest that levels of anthropogenic contaminants are not elevated when compared to other North Pacific pinnipeds. There was no dichlorodiphenyltrichloroethane (DDT) found in the blood samples.

Oil/fuel spills may pose a significant threat to monk seals, especially in the MHI where there was a 200% increase in the number of oil spills from 1980 - 1990 (Pfund, 1992). In August 1998, a Tesoro Hawaii Corporation tanker offloading operation resulted in a spill of about 5,000 gallons of bunker fuel off of Barber's Point, Oahu. The waters and shoreline of Kauai were affected, and up to five monk seals were subsequently reported in the area and may have been oiled. As there were no physical exams conducted on the animals observed, no conclusion about the effects of the oil on the monk seals could be made (Natural Resources Trustees, 2000).

Conservation Efforts - Contaminants mitigation

When the facilities at Midway and Tern Island (FFS) were transferred to the FWS, the Navy and USCG took steps to clean up contaminants that had been previously released. A similar clean-up occurred when the Kure Atoll USCG station was dismantled. During the Base Realignment and Closure process for Midway Islands Naval Air Facility, the Navy spent approximately $90 million to remediate environmental contamination caused by previous naval activities, and removed structures not wanted by the FWS. However, PCB contamination left in a landfill on Sand Island (Midway Atoll) is adjacent to monk seal habitat, and will require ongoing monitoring, and may require future remedial action by the Navy. A previously used USCG dump contaminated with PCBs was discovered at Tern Island, and initial clean-up actions were undertaken by the USCG in 2001. Unfortunately, this initial USCG clean-up did not completely remove PCB contaminated soil in compliance with EPA cleanup criteria. Costs for this additional cleanup are estimated at $2.4 million, and funding for the work has not been secured by the USCG to complete this PCB cleanup effort at Tern Island.

The numerous cooperating federal and state agencies and non-government organizations (NGO) have drafted the Area Contingency Plan for oil spill response within the Hawaiian monk seal range, including the NWHI. The Hawaiian Monk Seal Unusual Mortality Plan includes the specific action plan approved for oiled Hawaiian monk seals.

H. Other Conservation Efforts

a. Population enhancement

In 1981, NMFS initiated a temporary "captive maintenance project" designed to restore the then-depleted Kure Atoll monk seal population. This project became known as the "Head-Start" program, and its objective was to improve pup survival at Kure Atoll, specifically to enhance survival of young females and increase their subsequent recruitment into the adult female population. From 1981 - 1991, 32 weaned female pups at Kure were captured and temporarily held in a shoreline enclosure, with the intent to protect them from the presumed threat of sharks and aggressive males through their first summer. After release, 26 (81%) females survived to the end of their first year of life (Lavigne, 1999). These data suggest that the Head-Start Program was a success. However, of 33 males that weaned during the same period but not held in the enclosure, 27 (82%) survived to the end of their first year, suggesting that the placement in the enclosure did not affect their survival. Rather, it may be that beach disturbance of seals by USCG personnel at Kure was reduced due to the presence of MMRP staff during the breeding seasons beginning in 1981 (Gilmartin, pers. comm.). USCG staff also removed an undetermined number of tiger sharks at Kure Atoll. The cumulative effect of these actions may have facilitated the increased survival of both females and males during the period of the headstart experiment.

During the 1990s, the survival of all immature seals at FFS plummeted and has not yet recovered (see Figure I.C.8), resulting in a severe loss of reproductive potential in the sub-population (Ragen and Lavigne, 1999). In an attempt to mitigate this loss, rehabilitation efforts were increased, and releases were shifted to Midway Atoll. In 1991-1992, 24 immature females, selected because they were underweight and/or ill and judged likely to perish without intervention, were collected and rehabilitated either on Midway or Oahu. Of those seals, 18 survived captivity and were subsequently released at Midway during 1992-1993. Many of these seals were released prematurely for want of a facility to allow the completion of the rehabilitation effort. For undetermined reasons, 16 of the 18 either died or disappeared, and translocations during 1993-1995 were redirected back to Kure.

During 1984-1991 and 1993-1995, 49 undersized (axillary girth under 90 cm) weaned female pups and juvenile female seals were taken from FFS to Oahu, where they were held in captivity for 8-10 months to increase their body mass. At the end of the captive period, the animals were screened for disease, transported to the shoreline enclosure at Kure, and subsequently released. An additional 5 healthy pups were transferred directly from FFS, for a total of 54 introduced to Kure. First-year survival for 47 of these females (pooled into a single group) was approximately 66% (Lavigne, 1999). This was the first attempt to rehabilitate and release seals older than pups. In 1993, 14 seals were rehabilitated and released, with 8 more in 1994. The rehabilitation/translocation program stopped in 1995, when 10 of 12 captive females contracted an eye condition of unknown origin, leading to blindness, which made them unfit for release in the wild.

A total of 104 immature monk seal pups (mostly female) have been collected and either "head-started" or provided with captive care. Of these, 68 were successfully released into the wild, 22 died during managed care, and 14 were judged to be unsuitable for release and were placed into public aquaria and oceanaria for research. By 1987, some of the 1981 "head-started" females began giving birth (Gilmartin et al., 1993). In 2000, of the 42 identified adult females at Kure Atoll, 25 (60%) had received care or were progeny of monk seals that had received care through past management efforts: 13 from the Head-Start Program; 9 rehabilitated from FFS; 2 translocated from FFS; and 1 translocated from Oahu (roughly 20% of the total sub-population) (Kinan and Kashinsky, 2002). By 2001, total beach counts at Kure Atoll averaged 53 seals (including pups). Nine of the ten identified parturient females (90%) had received care were progeny of monk seals that had received care through past management efforts (Haase and Harting, 2001).

b. Education and outreach

Monk seals appear to be growing in number and expanding their range in the MHI (Baker and Johanos, 2004). While the majority of seals occur in isolated areas, a few monk seals are now observed on popular public beaches, frequenting popular dive spots that tourists use and getting hooked in nearshore fishing activities. Despite legislative protection, the prohibition on interaction (take) in the ESA and MMPA are not well understood by the public. Enforcement is neither consistent nor simple, but rather difficult.

The growth of monk seal populations in the MHI has brought and will continue to bring an increasingly large number of people in contact with monk seals. Closer proximity to the seals can be seen as an opportunity to build a constituency for the species. Inevitably, it will also mean an increase in conflict between people and monk seals. An education and outreach program should attempt to minimize these conflicts, while increasing the public understanding of monk seal conservation, thus enhancing the recovery potential and conservation of the monk seal. The education and outreach program should focus on both residents and visitors, ensuring the greatest possibility for peaceful coexistence between seals and the people.

From the early 1980s through the mid 1990s, education and outreach for monk seal conservation purposes were conducted primarily on an *ad hoc* basis by two NMFS agencies. Recently, PIRO assumed its current role as the lead federal agency for monk seal conservation education and outreach. The MMRP has continued to provide valuable assistance in such efforts. The two NMFS agencies have worked in collaboration with a variety of state and county agencies and non-government entities. NMFS staff also gives frequent public presentations on Hawaiian monk seals at a variety of venues.

In the early 1980s, PIRO produced a vinyl "Do not approach monk seals" sign in collaboration with Earth Trust. Those signs were used at seal haul-out and pupping sites throughout the MHI. The sign was revised in 2000, and produced and distributed in a collaborative effort between PIRO and the Hawaii Coastal Zone Management Program. In 2005, new signs were produced by PIRO and the State of Hawaii DLNR.

In 1983, a brochure was published and distributed by PIRO in cooperation with the Seal Rescue Fund and the Center for Environmental Education. The six-fold, full color brochure featured sections on biology and behavior, threats and issues, protective measures, and guidelines for human behavior near monk seals. The brochure's cover art, depicting a seal on a beach with a "friendly" masked booby, was also produced as a separate poster. The brochure and poster were popular items among conservation groups involved in education and outreach in the early 1980s. It appears that a lack of continued funding restricted continued production and distribution of these products.

From the 1980s through the present, NMFS produced "in-house" several other education and outreach products. The products included viewing guidelines, flyers, and games. They were used frequently during school visits and public events, such as children's fairs and conservation-oriented activities. These efforts were relatively successful considering the very limited amount of resources allocated for these purposes. In 1999, PIRO produced a brochure presenting Hawaii marine mammal and sea turtle viewing guidelines in collaboration with the State of Hawaii DLNR, HIHWNMS and the NMFS Office for Law Enforcement, featuring federal and state laws protecting marine mammals and sea turtles, responsible viewing guidelines and contact information for the various agencies involved. In 2000, personnel from several agencies and organizations including the Hawaii Coastal Zone Management Program, State of Hawaii DLNR, Kauai County Police Department, Kauai County Parks and Recreation Department, PIFSC, PIRO, Hawaii Wildlife Fund, Kauai Monk Seal Watch Program, HIHWNMS, and the FWS pooled their energy and resources to produce a full color poster depicting a sleeping monk seal lying on a beach. The poster included the Hawaiian name for monk seal and the English translation, and background information on monk seals and measures the public can take to avoid disturbing the seals. The phrase "Let sleeping seals lie" was prominently displayed below the seal, and below that, a monk seal "hotline" telephone number was provided with a request for the public to report monk seal disturbances or harassment.

Internet web sites have also been developed and used recently to promote public understanding and support for monk seal conservation. The PIFSC and the NOAA Fisheries Division of Permits, Conservation, and Education currently have web pages devoted to monk seal conservation education. A few not-for-profit organizations also have informative web sites, such as the Kauai Monk Seal Watch Program. As more people go online, the value of web-based education and outreach products should continue to increase.

Non-government organizations have taken the lead on many education and outreach projects. On the island of Kauai, a volunteer group, the Kauai Monk Seal Watch Program, has provided educational information to hotels to help minimize negative human-seal interactions and to promote positive monk seal viewing opportunities. The information has been compiled and copied onto sheets that are included in "hotel compendiums," binders full of visitor information provided in the guestrooms of many hotels and resorts on Kauai. The Kauai Monk Seal Watch Program has also developed an educational program, which provides presentations in schools and educates the numerous interested onlookers that typically gather at readily accessible seal haul-out sites. The Hawaii Wildlife Fund is another non-government organization that has been active in monk seal-oriented education and outreach efforts on the islands of Kauai, Maui, and Hawaii.

Currently, the low density and wide distribution of monk seals in the MHI present a difficult target for education and outreach activities. Nonetheless, instituting a program to deal with human-seal conflict as well as the development of a constituency for monk seals in the MHI, is best done when densities are low and before conflicts emerge at a large scale. NMFS is well situated to provide a coordinating role in efforts to establish a comprehensive program in this area. Since 2005, great strides have been taken by NMFS in the development of greater community volunteer capacity, but this an ongoing effort that will require the training and maintaining of volunteers, continuing education, adaptive management and capacity building in remote areas.

PIRO is committed to the development of outreach and education networks. A Marine Mammal Response Network Coordinator was hired in the fall of 2005 to oversee a regional Hawaiian monk seal response network as well as Hawaiian monk seal and cetacean stranding. In April 2006, a full-time Outreach and Education Coordinator was hired by PIRO to organize volunteer groups and create educational programs/materials related to issues primarily concerning sea turtles and marine mammals including the Hawaiian monk seal. While increased funding by the federal and state governments is needed, funding alone is unlikely to solve the key issues of coordination, collaboration and trust. A Kauai monk seal Response Coordinator was hired by DLNR through funding from PIRO. PIRO purchased and distributed Hawaiian monk seal protection/alert signage, equipment for pupping events and haulouts, and produced a Hawaiian monk seal Public Service Announcement that was aired early in 2006. Also, PIRO supports part-time network coordination on Maui and the Big Island of Hawaii. Finally, PIRO initiated a semi-annual Hawaiian monk seal count throughout the MHI, the purpose of which was to strengthen the volunteer network and to gather information on the locations of monk seals in the MHI. The first count was held in April 2007.

In addition, PIRO and PIFSC have worked closely together to reach a diverse audience for monk seal sightings data for the purpose of monitoring Hawaiian monk seal. Target audiences have been school groups who have been trained and engaged in seal protection zone response. PIRO and DLNR have also purchased and distributed Hawaiian monk seal response network T-shirts to identify volunteers and promote a sense of ownership, empowerment, and teamwork. The March 2006 Hawaiian monk seal management meeting identified a variety of human impacts on the Hawaiian monk seals in the MHI that require outreach and education in the public's response toward the animals, and the correction of numerous misconceptions about the species' origin and natural behavior. From this meeting a few key points were identified as needing immediate outreach and education attention :

- Reach out to the fishing communities to discuss related issues and misperceptions. This meeting could involve fisherman, scientists, and response network personnel.
- Target fishing activities such as tournaments, etc., as well as using fishing television and radio shows for monk seal outreach.
- Partner with community residents and Native Hawaiian cultural experts to debunk the misperception that monk seals were introduced to the MHI, by using "testimonials" in which they share their knowledge.
- Conduct outreach regarding "translocations," explaining the government rationale based on individual animal and population needs and impacts.
- Develop a plan for target audience messaging regarding habituated and conditioned animals.

Concurrent to this is the extensive effort from the agency, stakeholders and NGOs to deliver messages about the Hawaiian monk seals. There is the need for an outreach inventory of the work that is occurring, the messages that are being presented, and the audiences that are being targeted. In addition, there is the need for the development of an evaluative process for monk seal pre- and post monitoring events, especially in regards to the knowledge gained, the response from the targeted audiences and the resulting impact for monk seals.
Education and outreach activities, while extensive, have been *ad hoc* and lacked overall coordination. Coordination and exchange of lessons learned will improve the efficacy of education and outreach programs. Discussion of conservation goals with all relevant stakeholders will help focus activities and improve the success of interventions taken. In addition, programs to evaluate the effectiveness of these education efforts are needed.

II RECOVERY STRATEGY

Since the publication of the last Recovery Plan for Hawaiian monk seals two decades ago, much has been done to eliminate many of the most direct and obvious causes of decline for the species. Extensive efforts have been made to protect important habitat, reduce disturbance on key breeding beaches and islands, reduce the impact of entanglement, reduce extraordinary mortality caused by male aggression and by shark predation, and understand how active intervention can improve the survivorship of pups. Significant progress was made to prevent direct and indirect interactions with commercial fisheries in the NWHI. These efforts have undoubtedly contributed positively to the present state of the Hawaiian monk seal, and some have almost certainly been crucial in preventing the population status from being much worse than it is now. Many of these efforts are still on-going and must be continued in the foreseeable future if the population is to persist, and hopefully recover.

In addition, intensive research under difficult conditions has provided high quality data on the status, breeding success, and survivorship of monk seals, and on the impact of various remediation efforts. These data are sufficient to provide the basis for informed population modeling that helps investigate how proposed actions will improve the potential for recovery of this species.

Unfortunately, as described in the previous sections of this Recovery Plan, actions to date have not been sufficient to result in a recovering population. In fact, because of the continuing decline, the status of the Hawaiian monk seal remains extremely critical. Things would undoubtedly have been worse but for the actions taken over the last 20 years, but the irony of conservation is that sometimes initial success has only slowed a process of decline and further actions are required to reverse the decline. Even so, slowing the decline is a significant achievement as it provides us more time to try new approaches and apply new techniques in our efforts to recover the species.

While recommendations made in this Recovery Program are many and detailed, there are four key actions required to alter the trajectory of the Hawaiian monk seal population, and to move the species towards recovery:

1. Improve the survivorship of females of all ages, particularly juveniles and yearlings, in sub-populations of the NWHI. The persistently poor recruitment of females into the breeding populations at many locations has resulted in a top-heavy demographic pyramid, with a near-term future of fewer breeding females. These sub-populations will most likely either accelerate their current declines, or move from growth or stasis into decline in the years to come. In the medium and long term, the only thing that will change these sub-population trajectories is improved survivorship of females. To do this requires these actions:

    a. Maintaining and enhancing existing protection and conservation of habitat and prey base (including assessing interactions between monk seal foraging and commercial/recreational bottomfish fisheries)
    b. Targeting research to better understand the factors that result in poor juvenile survival

c. Intervening where appropriate to ensure higher survival of juvenile and adult females
d. Continuing actions to protect females from individual and multiple male aggression and to prevent excessive shark predation

2. Maintain or expand existing field efforts. The extensive field presence that has been maintained during the breeding season in the NWHI is critical not just to the research efforts, but also to the active management and conservation of Hawaiian monk seal sub-populations in these areas.

3. Ensure the natural recovery of the Hawaiian monk seal in the MHI. This must include better coordination of activities between and among all parties interested in and affected by the increased population of monk seals in the MHI. State and federal agencies, private and public sector entities, both for profit and non-profit, will all be required to expand and coordinate their efforts.

4. Reduce the probability of the inadvertent introduction of infectious diseases into the Hawaiian monk seal population. Disease is a difficult threat to evaluate because the epidemiology and pathogenesis of most infectious agents in marine mammals are poorly understood and difficult to manage, particularly where terrestrial and aquatic systems converge. While the probability of any particular disease being introduced into the Hawaiian monk seal population is low, disease in seal populations can and has been devastating.

III RECOVERY CRITERIA FOR THE HAWAIIAN MONK SEAL

Recovery criteria can only be proposed on the basis of the best available information and expert opinion at this time. Eventually, as more data become available, it is anticipated that formal population viability analysis (PVA) and more detailed knowledge of mechanisms responsible for the population decline will be used to revise these criteria as appropriate. Biologically it is evident that the survival of this species is precarious. The present total population of the species is small and declining. The population is already so small as to be in the range where there is concern about long-term maintenance of genetic diversity. Thus, it is quite likely that this species will remain endangered for the foreseeable future.

The PIFSC MMRP has developed a detailed metapopulation model of the population, with provisions for representing many kinds of management interventions. This model, which has served usefully for evaluating a number of management proposals, is described from that perspective in Appendix B of this Recovery Plan. The existing metapopulation model constitutes a good start on a model that eventually can be used as a PVA for identifying concrete criteria that reliably satisfy the proposed underlying standard of 1% probability of extinction within 100 years. The existing monk seal model treats process uncertainty and parameter uncertainty, probabilistically for some, but not all, factors. Other uncertain factors in the existing implementation of the model are handled instead as user-specified assumptions. For eventual use as a PVA, the metapopulation model should be developed further for treating all uncertain factors in terms of propagated process uncertainty and statistically based parameter uncertainty.

A. Recovery Goals

The goal of this revised recovery plan is to assure the long-term viability of the Hawaiian monk seal in the wild, allowing initially for reclassification to threatened status and, ultimately, removal from the List of Endangered and Threatened Wildlife.

B. Downlisting Criteria

The Hawaiian monk seal will be considered for reclassification to threatened if all of the following criteria are met.

Biological Criteria

1. Aggregate numbers exceed 2,900 total individuals in the NWHI;
2. At least 5 of the 6 main sub-populations in the NWHI are above 100 individuals, and the MHI population is above 500;
3. Survivorship of females in each subpopulation in the NWHI and MHI is high enough that, in conjunction with the birth rates in each subpopulation, the calculated population growth rate for each subpopulation is not negative.

Threat-based Criteria

Factor A. Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

Criteria: Measures are in place to manage human factors affecting food limitations, habitat loss and contaminants in the NWHIs. Management measures are also in place to a) minimize human disturbance of monk seals that haul-out on beaches in the MHI, and b) protect major monk seal haul-out habitat in the MHI.

Hawaiian monk seal juvenile survival has declined most dramatically with significantly smaller pup and juvenile sizes, consistent signs of food limitation. In recent years, low juvenile survival, in part due to food limitation, has been evident at all NWHI subpopulations. Targeted research is urgently needed to explicitly link survival to prey abundance, foraging behavior, diet and juvenile condition. There continues to be a critical need for strategic foraging ecology research program linked to monk seal demography. Because most of the monk seal population occurs in the NWHI, this crucial threat continues to be of highest concern.

Recent loss of terrestrial habitat remains an issue of concern in the NWHI, especially since all of the observed NWHI habitat use by monk seals in the NWHI falls within 200 km of islands and atolls. In addition, monk seals are known to forage on benthic areas in the NWHI to at least 500 m in depth. Thus, the habitat and range extend a significant distance from the occupied islands and involve relatively deep benthic areas. In June 2006, the PMNM (71 FR 51134, August 29, 2006) was established. The boundary of the PMNM includes approximately 140,000 square miles of emergent and submerged lands and waters of the NWHI, providing protection for the Hawaiian monk seals' marine habitat via fishing prohibitions and regulations. As stated earlier, the PMNM provides the highest form of national, marine environmental protection for the Hawaiian monk seals' NWHI marine habitat. However, whether this protection is sufficient to manage food limitation is unclear.

Most beaches in the MHI that likely are used by Hawaiian monk seals historically are now used to varying degrees by people for recreational purposes. Reoccupation of the MHI by Hawaiian monk seals will depend in large part on the effectiveness of efforts to (1) protect seals from people and animals using popular recreational beaches in the MHI and (2) ensure that monk seals are able to use beaches where human access is more limited.

Factor B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Criteria:

1. Procedures, including data collection and analyses, are in place to evaluate and ensure that scientific research on Hawaiian monk seals, including their observation, handling, and instrumentation, will not cause significant adverse impacts on monk seal survival, behavior, or population growth.

2. Procedures are in place to ensure that any proposed NWHI operations that may increase seal disturbance or threaten survival will be reviewed and carefully scrutinized, and that all applicable laws protecting monk seals and their habitat have been used and enforced.
3. Management and permitting measures are in place to ensure that people, including scientists and research teams, visiting the Midway Islands or any other atoll in NWHI do not disturb monk seals or restrict their haul-out habitat in ways that could adversely affect monk seal survival, behavior, or population growth.

Based on the best available and most current information, the overutilization for commercial, recreational, scientific or educational purposes is determined to not be a current or potential threat to the recovery of the Hawaiian monk seal. Any proposed NWHI operations that may increase seal disturbance or threaten survival, such as nearshore ship traffic, beach use, noise, or unnecessary research will continue to be scrutinized carefully to ensure that the recovery of the monk seal population is not hampered by the activity. To accomplish this, all applicable laws protecting monk seals and their habitat will continue to be enforced. An example of such NWHI activities is the future recreational and visitor activities at the Midway Islands, the impacts of which will be monitored and addressed as they relate to the recovery of Hawaiian monk seals.

Research to date has found no detectable effects of handling and instrumentation on Hawaiian monk seal survival or movement away from the NWHI subpopulation where they were tagged, but the potential for cumulative impacts are possible especially for monk seals that are handled multiple times during their lifetime. Steps are currently taken and will continue to ensure that monk seal observation, handling, and instrumentation have negligible impacts on animals and population growth.

Factor C. Disease or Predation

Criteria:

1. Credible measures for minimizing the probability of introduction of diseases to any of the NWHI subpopulations, or the spread of diseases from the MHI to the NWHI, or importation of diseases that are not yet present in Hawaii are in place.
2. Contingency plans are in place to respond to a disease outbreak or introduction should this occur.
3. Research measures are in place to monitor population size, vital rates, and possible disease outbreaks or disease introductions, in all the subpopulations.
4. Management measures are in place to minimize shark predation and are demonstrably effective at maintaining predation sources at low enough levels to be consistent with continued meeting of the birth rate and survivorship criterion.

The concern about the presence of diseases in monk seal populations is serious based on past mortality events in the NWHI. Recent MHI monk seal deaths have heightened concern about monk seal exposure to diseases that they have not previously encountered, such as leptospirosis, toxoplasmosis, and West Nile virus. Infectious diseases in Hawaiian monk seals could result from: contact with terrestrial domestic, feral and wild animals, humans or their fomites; stress causing activation of sub-clinical previously undetected disease; and exposure of monk seals to marine mammals infected with an agent, or exposure to infected vectors such as mosquitoes. The lack of antibodies in monk seals to these diseases makes them extremely vulnerable to potential infection. While the frequency of disease outbreaks may be rare, their potentially devastating effects, should they spread throughout the population, makes infectious diseases a serious threat.

There has been a significant increase in shark predation on monk seal pups, and shark-related injuries and mortalities of pre-weaned pups at French Frigate Shoals (NWHI) have been conspicuously higher that at other sites. Sharks are known to injure and kill Hawaiian monk seals, and monk seal remains have been found in the stomachs of tiger sharks and Galapagos sharks. This remains a crucial threat and an ongoing source of mortality for Hawaiian monk seals in the NWHI.

Factor D. Inadequacy of Existing Regulatory Mechanisms

Criteria: Measures are in place to manage fishery interactions and are demonstrably effective at reducing these threats and maintaining fishery-related sources of mortality or stress at decreasing or low levels that are consistent with continued meeting of the birth rate and survivorship criterion.

The principle, direct fishery interaction threat currently facing monk seals are MHI recreational fisheries, particularly gillnets and shore-cast gear, which are managed by the State of Hawaii and known to cause monk seal mortalities. Two monk seals drowned in recreational gillnets on Oahu within the past year. Gillnets will still be used in other areas, and enforcement of the new regulations will be important to ensure that the threat is actually reduced. There is a continuing need for intervention for Hawaiian monk seals in the MHI to remove embedded hooks from recreational fishing; however this effort does not remedy the interaction problem itself. More management measures and enforcement of those measures are needed to ensure that this serious threat is reduced.

Factor E. Other Natural or Manmade Factors Affecting Its Continued Existence

Criteria:

1. Management measures are in place to control male aggression, entanglement, biotoxins, and other sources of human-caused mortality or stress. These measures are demonstrably effective at maintaining these threats at low enough levels to be consistent with continued meeting of the birth rate and survivorship criterion.
2. The causes of the anthropogenic threats to the species are clearly identified and are well-enough understood to be controlled or mitigated, and any newly identified threats are controlled adequately before downlisting.

Other sources of natural or manmade factors, including male aggression, entanglement and biotoxins, should be reduced prior to downlisiting. The primary cause of adult female mortality affecting the recovery potential in the monk seal population during the 1980s and early 1990s was injury and often death of female monk seals caused by multiple male aggression, or "mobbing" attacks. While this trend tends to be episodic, it is usually limited in geographic area at any given time. The methods for mitigating it have been successful, but this is still considered a serious threat to Hawaiian monk seals.

Marine debris and derelict fishing gear have been well documented to entangle monk seals, and monk seals have one of the highest documented entanglement rates of any pinniped species. Marine debris and derelict fishing gear are chronic forms of pollution that continue to affect the NWHI. This remains a crucial threat especially since the number of monk seals found entangled has not changed nor has there been a reduction in the accumulation rates of marine debris in NWHI.

Biotoxins such as ciguatera can cause mortality in phocids, but its role in mortality of monk seals was implicated and not confirmed, remaining unclear due to the lack of assays for testing tissues and the lack of epidemiological data on the distribution of toxin in monk seal prey. This continues to be a moderate threat with possible localized impacts, but is not considered to be a serious or immediate cause of concern.

C. Interim Delisting Criteria

The population will be considered "recovered" if the downlisting criteria continue to be met for 20 consecutive years, corresponding to the expected persistence time of a regime phase and without new crucial or serious threats being identified. There must be assurance that all management systems and monitoring plans that are addressed in the downlisting criteria will continue to be implemented after delisting.

IV RECOVERY PROGRAM ACTIONS

Recovery Narrative and Recommended Actions

The status of the Hawaiian monk seal is extremely serious. In the two decades since the first Hawaiian Monk Seal Recovery Plan was written, a concerted effort has been made to save the monk seal. The U. S. Government, the State of Hawaii, NGOs, private sector entities, and countless individuals in local communities across Hawaii have worked to recover the species. These efforts have not been sufficient to prevent a continued decline in the species. Although, without these efforts, the situation would undoubtedly be much worse. Some actions taken have clearly improved conditions locally (e.g. introductions of young females to Kure, removal of aggressive males from Laysan). A small population of monk seals in the MHI where the population appears to be increasing provides hope. As this recovery plan makes clear, actions to date have not resulted in a recovering population.

Reducing the rate of decline, however, does provide us more time to try new approaches and apply new techniques in our efforts to recover Hawaiian monk seals. In the following section of the Plan, those actions that are still necessary to initiate, and eventually achieve, the recovery of the species are examined. In the following discussion, recommendations are grouped in 14 categories.

Within any given category, individual recommendations may have greater urgency, or priority, and so each recommendation is given a ranking as follows:

Priority 1 – An action that must be taken to prevent extinction or to prevent the species from declining irreversibly

Priority 2 – An action that must be taken to prevent a significant decline in species population numbers or habitat quality or to prevent some other significant negative impact short of extinction

Priority 3 – All other actions necessary to provide for full recovery of the species.

Recommendations are also classified by the type of action needed:

(P) includes actions necessary for protection;
(I) are interventions, and;
(R) indicates research needs.

In the accompanying Implementation Schedule (part V of this document), an estimated cost for each recommendation is listed, and an initial timeframe over which the actions should be affected. A brief summary of issues related to each set of recommendations is provided below.

A. Recommended short-term actions:

1. *Investigate and mitigate factors affecting food limitation*

Demographic and other trends that have been observed to varying degrees at several of the NWHI monk seal sub-populations indicate that prey availability may currently play a primary role in regulating population growth. A great deal has been learned from past and ongoing foraging ecology research. However, targeted research is urgently needed to explicitly link survival to prey abundance, foraging behavior, diet and condition of juveniles. Thus, there is a need for a strategic foraging ecology research program that is explicitly linked to demography. This program should state clearly how results will further our understanding of monk seal survival and how such research might facilitate monk seal recovery. The program should encourage timely incorporation of sample results into population models to evaluate how demographic consequences of variation in foraging behavior, diet, and prey availability lead to management actions. Research on the effects of food limitation on monk seal demography should include studies on diet and foraging behavior (including time budgets, diving, and movement characteristics) and energetics, stratified by representative sub-populations, age, and sex classes, and the development of condition indices that would help compare island populations experiencing different survival and natality, and methods of monitoring prey abundance. This program should contain: 1) an implementation schedule that describes and justifies study design and sample sizes required for food habits, instrumentation, and energetic research; and 2) a conceptual model of foraging behavior linked to energetics, condition indices, prey abundance and demography of the monk seal population. Data on these, especially on prey abundance, may provide us with some predictive power relative to survival of young and may enable us to address food limitation in a factual manner rather than by implication [1.1].

1.1 Define diet by age, sex, location, season (variety of methods) and characterize feeding areas quantitatively (e.g. with CRITTERCAM, video technology) [1, R]

Declines in the monk seal beach count abundance index (especially at FFS), and cessation of previously steady increases at some sites (PHR, Midway, Kure) may indicate food limitation, particularly as these changes in abundance are often preceded by or are concurrent with reduced juvenile survival. To assess the causes of this reduced juvenile survival and to have an independent measure of monk seal prey abundance, data are needed on the details of their foraging behavior [1.2, 1.5].

1.2. Assess and monitor prey abundance; study prey selection; research must continue in order to have an independent measure of monk seal prey abundance [1, R]

In at least two populations (FFS, Lisianski), relatively low age-specific reproductive rates (including delayed maturity) have also been observed. These observations need to be further studied relative to prey abundance [1.3] through continued research using fatty acid analyses and continued collection and analysis of spew and scat samples.

1.3. Determine whether prey abundance is limiting population growth [1, R]

Though less quantitative data are available, there are indications that relatively poor body condition in various age classes is associated with declining populations, perhaps suggesting some form of food limitation. In such cases, the conflict among prey selection, prey abundance and prey availability needs careful consideration. At the present time, none of these can be quantified in any meaningful way for monk seals as individuals/ages/ sexes/ island populations, but this research is needed [1.3].

The marine spatial habitat used by monk seals is poorly understood. Considerable information is available from recent satellite tracking studies, but detailed analyses of those data have just begun. Studies of spatial use patterns are also relevant to testing hypotheses about the impacts of temporal changes in oceanographic conditions on prey abundance foraging success and survival [1.3, 1.4, 1.5, 1.6, and 1.7]. The extent to which food limitation is negatively affecting the demography of monk seals is poorly understood, and this lack of understanding remains an impediment to understanding recovery potential. Certainly, foraging success is closely tied to overall population status and fitness. Therefore, continued research is needed to understand the complex links between foraging, prey availability, and demography [1.4]. Further, foraging success may also be influenced by changes in the prey species composition of the atoll communities. Such changes may have fostered competition with other top predators within these communities [1.5]. Studies need to continue in these areas to document the ties between oceanographic changes, prey species responses and foraging ecology of monk seals [1.3, 1.6].

If translocation is a mechanism used in captive care, this research into oceanographic conditions is invaluable to relocate a monk seal to a site with the highest probability of survival. With improved knowledge and ability to predict ocean productivity, better management decisions can be made regarding the translocations with the highest survival probability [1.7]. If food limitation appears to be reducing pup/juvenile survival at one breeding location, consideration should be given to relocating young female seals prior to the age or season that this crisis may cause their loss [1.7]. Translocating and fattening underweight seals have been effective means of increasing survival of young individuals and augmenting the female population at the recipient site.

1.4. Evaluate demographic consequences in relationship to complex linkages between prey availability and foraging behavior [1, R]
1.5. Investigate competition with other top predators and commercial and recreational fisheries in the NWHI and MHI [1, R]
1.6. Investigate effects of oceanographic variability on prey abundance, availability and foraging success [2, R]
1.7. Enhance survival by translocating juvenile female seals to areas of higher survival probability [2, I]

In order to preserve the future reproductive potential for recovery, one of the highest priorities being pursued by NMFS is the development of a captive care program to nutritionally supplement juvenile female seals [1.8]. The goal of the program will be to increase the survival of female seals during the critical juvenile life stages that are now experiencing low survival. This will likely be a combined effort of NMFS and animal care organizations. A Hawaiian

Monk Seal Captive Care Workshop on the development of a 10-year captive care plan was held in June 2007. The purpose of the Workshop was to develop the framework for a NMFS ten-year plan to salvage and preserve the reproductive potential of juvenile female seals as a priority action to mitigate the population decline and improve the potential for recovery. The scope of this workshop was to organize discussions of a diverse range of potential capture mechanisms that are related to interventions, such as translocation, nutritional support, treatment, rehabilitation, the use of anti-parasitic drugs, etc. Capture mechanisms resulting from this workshop may be further developed in subsequent discussions for inclusion in a final NOAA ten-year plan. Without such efforts, the loss of young females will significantly decrease the recovery potential of the species, as there will not be enough females in the population.

1.8. Rehabilitate malnourished juvenile seals when and where food limitation is apparent to salvage their reproductive potential [1, I]

2. *Prevent entanglements of monk seals*

Hawaiian monk seals suffer one of the highest entanglement rates of any seal or sea lion reported to date. There is clearly a need to reduce monk seal injuries and deaths related to entanglements in marine debris [2.1]. The incidence of entangled monk seals at breeding sites of the NWHI has been well documented, and field staff has actively worked to disentangle seals [2.2]. Historically, monk seals have become entangled in net, line (including monofilament nylon line), net/line combinations, straps, rings (including rings/cones from hagfish traps), and other random items such as lifejackets, buckets (portion of rims), and plastic crates (Henderson, 1990). Proportionally, pups (including newly weaned pups) are at greater risk of becoming entangled than other size classes (Henderson, 1990, 2001) and debris removal effort should focus on areas with high densities of pups and juveniles [2.2.1, 2.2.1.1, 2.2.1.2]. Between 1982 and 2003, 261 monk seals were found entangled, of which 179 were released, 66 escaped unaided, 8 died (Table I.G.2.), and 8 were not released and their fate is unknown.

2.1. Continue programs that facilitate the disentanglement of animals [1, I]
2.2. Continue removing potentially hazardous debris [1, I]
  - 2.2.1. Continue focused clean-up effort on high entanglement risk zones in the water [1, I]
    - 2.2.1.1. Monitor marine debris accumulation rates and identify areas of greatest potential risk [1, I]
    - 2.2.1.2. Remove debris from beaches [2, I]

The number of annual entanglements has varied during the 20 year history of the program, with a documented high of 25 incidents in 1999 which represented 1.7% of the total population (Henderson, 2001). Despite annual efforts by MMRP staff to remove entanglement hazards from beaches, entanglement rates continued to increase until large scale management efforts to remove marine debris from the critical aquatic habitats of the monk seal was initiated in 1999. The long range solution is a decrease in the amount of debris entering the ocean and strategies to address this have been the subject of other meetings and laws [2.3., 2.3.1, 2.3.2].

2.3. Reduce the amount of debris [3, I/R]

2.3.1. Work with partners to support integration of source markers into fishing gear [2, I]
2.3.2. Implement education and marine debris reduction programs targeting identified sources [3, I]

3. *Reduce shark predation on monk seals*

Sharks are known to kill and injure Hawaiian monk seals (Hiruki, 1993a; Ragen and Lavigne, 1999). Monk seal remains have been found in the stomachs of tiger sharks (*Galeocerdo cuvier*, Taylor and Naftel, 1978; De Crosta, 1984) and Galapagos sharks (*Carcharhinus galapagensis*) have been observed preying on pre-weaned pups (NMFS unpublished data). An evaluation of shark-caused injuries and scars has indicated that pups and juveniles are more commonly injured than subadults and adults, and FFS had a higher rate of shark-related injuries than Laysan or Lisianski Islands (Bertilsson-Friedman, 2002). More needs to be understood about shark abundance, prey preferences, and seasonal movement patterns [3.1, 3.3].

3.1 Continue monitoring shark activity and predation events [1, R]

In the mid-1990s, Galapagos shark predation on pre-weaned pups escalated dramatically at FFS. Over two decades of monk seal studies indicate that Galapagos shark predation on pre-weaned pups is an unusual behavior occurring primarily at FFS and mostly at one site (Trig Islet) within the atoll. Currently, Galapagos shark predation on pre-weaned pups has not been documented at sites other than FFS. The problem should continue to be monitored. Sharks attacking pups should be removed as quickly as possible [3.2]. Site-specific removal plans and methods should be developed, permits maintained to effect removals, gear ready, and personnel trained and ready to conduct the work [3.2.1.-3.2.5.]. Efforts must continue to move monk seals to safer sites after weaning in order to protect them from shark predation [3.3].

3.2 Remove problem sharks [1, I]
- 3.2.1. Develop general criteria (and site-specific plans) for shark removal [1, P/I]
- 3.2.2. Refine methods for shark removal [1, P/I]
- 3.2.3. Maintain needed permits for shark removal and/or other intervention [1, I]
- 3.2.4. Be prepared for rapid response to predation events [1, I]
- 3.2.5. Have trained staff and gear for intervention [1, I]

3.3. Continue moving seals to safe sites after weaning if necessary to protect from predation [1, I]
3.4 Characterize trends in shark abundance, movement patterns, and predation losses throughout the NWHI in relation to these interventions and conduct shark behavior research [1, R]

4. *Minimize exposure and spread of infectious disease*

Increased use of the MHI by monk seals increases the risk of exposure to infectious diseases (such as leptospirosis and toxoplasmosis) that are present in humans and domestic animals, as well as other animals living in association with them. Action must be taken to reduce the exposure risk [4.1]. Some form of education, animal entry quarantine and screening examination must be conducted to ensure these new diseases are not introduced into Hawaii [4.1.1]. Infectious diseases in Hawaiian monk seals could result from: contact with terrestrial domestic, feral and wild animals or their fomites, contact with humans or their fomites; stress-causing activation of sub-clinical previously undetected disease; exposure of monk seals to marine mammals infected with an agent; and exposure to infected vectors such as mosquitoes. Recent relaxation of quarantine restrictions on the MHI is of concern and makes effective management all the more critical.

Some effort must be applied to observing and sampling for potential disease problems in the monk seal population at the MHI as well as Necker and Nihoa, as these are the places where interaction between MHI and NWHI seals is most likely [4.1.2, 4.1.4]. Observed ill monk seals, wherever sighted, should be examined and sampled for a broad spectrum of possible disease if a diagnosis is not readily made, treated appropriately, and monitored for recovery [4.1.3]. The cornerstone of disease surveillance should place emphasis on timely and complete necropsies as well as the appropriate specific follow up testing. For certain known potential disease outbreaks (e.g. leptospirosis, morbillivirus), contingency response plans must be developed (MMC 2000) and the necessary human and material resources identified to initiate an appropriate response [4.1.3.]. To facilitate a correct response, prior research into suitable vaccines may be necessary [4.1.6.]. Gastrointestinal parasite load reduction through worming should be evaluated in a well-controlled study as a possible means of easing the stress on young seals and possibly increasing survival [4.1.7]. Recently in the MHI, several monk seals have pupped near fresh water streams, which pose a potential threat for water-borne diseases. Several of the pups have died. NMFS should investigate management actions to prevent mother-pup pairs from coming in contact with contaminated streams [4.1.8]. Finally, there have been several instances of northern elephant seals possibly from California and discovered in Hawaii. Because of concern for disease transmission, NMFS should plan for and take the appropriate management actions if northern elephant seals are found in Hawaii [4.1.9].

4.1 Reduce exposure of seals to diseases [1, P]

- 4.1.1 Reduce the risk of exposure to exotic diseases in the Hawaiian Archipelago through quarantine, vector control, and education programs [1, P]
- 4.1.2 Increase surveillance on Necker and Nihoa Islands, as these are the places where interaction between MHI and NWHI seals is most likely [2, R]
- 4.1.3 Further develop protocols for improving early detection of diseases in seals by opportunistic sampling for diseases [1, R]
- 4.1.4 Continue to examine sick animals in the NWHI and MHI to determine cause(s) of disease and to treat them appropriately [1, I]
- 4.1.5 Develop and implement contingency management plans for known high-risk diseases [1, R/I]
- 4.1.6 Evaluate the use of vaccines for monk seals to high-risk diseases (e.g. morbillivirus, WNV, leptospira vaccines) [2, R]
- 4.1.7 Investigate whether controlled research on deworming could be conducted (on other species or on monk seals) in order to improve juvenile survival by reduction of parasite stress, including the potential negative impacts if not conducted properly [2, R]

4.1.8 Investigate management actions to prevent mother-pup pairs from coming in contact with contaminated streams [2, I]

4.1.9 Plan for and take appropriate management actions if northern elephant seals from California are found in the Hawaiian Archipelago [3, I]

Some diseases that may already be in the monk seal population (evidenced by serological titers) and others not yet known in monk seals may affect survival of individuals and/or reproductive success of females. Further investigation into possible current or future links between infectious disease and survival or reproductive failure should be studied [4.2.].

4.2 When data is sufficient, determine the associations between reproductive failure, survival, and infectious diseases [2, R]

NMFS should maintain staff and contact personnel to continue current disease monitoring programs [4.3].

4.3 Maintain current disease monitoring programs (1,P)

5. *Conserve Hawaiian monk seal habitat*

The habitat of Hawaiian monk seals encompasses areas within 200 km of their resident islands (Abernathy, 1999; Stewart, 2004a), and within this region, they are known to forage on benthic areas from near shore to over 500 m in depth (Parrish et al., 2002). Thus, the areas used in everyday life extend significant distances out from the occupied islands and involve relatively deep benthic areas, some of which include deep-water coral beds (Parrish et al., 2002). All NWHI terrestrial and marine habitats identified as important to monk seals should continue to be protected at least at the current level, and additional protection afforded as possible [5.1, 5.1.1, 5.1.2]. Existing data indicate differences in the habitats used among the various sex and age groups, and also among the various island sub-populations, and these preferences and their importance should be defined [5.2, 5.2.1, 5.2.2].

In general, the recent use of satellite-linked dive and location recording instruments and the use of underwater video have just begun to give insight into how complicated it is to identify habitat that is critical to the recovery of monk seal populations. Scat and spew analyses show that monk seal diet is diverse and varies greatly among individuals. As more data are collected on individuals, it may be possible to generalize about the relative importance of specific habitat types within foraging ranges [5.1]. Further, it seems likely that prey availability among the various sub-populations might dictate different habitat definitions in different areas.

5.1 Maintain current habitat protection or ensure if status or jurisdiction changes, protection is not diminished [1, P]

5.1.1 PMNM must maintain Proclamation provisions and should monitor human activity in the PMNM through the use of observers, video recorders, and/or vessel tracking devices [2, P]

5.1.2 Maintain current ESA Critical Habitat designations with possible expansion as new data are collected [2, P]

5.2 Define terrestrial habitat use by sex, age and sub-population [3, R]

5.2.1 Complete analysis of terrestrial habitat selection by pregnant and lactating females [3, R]
5.2.2 Examine relationship between pupping habitat type and juvenile survival [3, R]

The terrestrial habitat that monk seals occupy for pupping and resting have been well documented. It also has been established that monk seals are particularly vulnerable to activities of people and their pets in these areas. Most of these disturbances have been removed from present monk seal NWHI habitat and no longer pose threats. Diligence is needed, however, to ensure that this habitat is preserved, and not only where beaches are currently used but also those that might be available for re-colonization. Strong consideration should be given to evaluating the loss of habitat due to erosion and other factors (e.g. sea level rise) that have contributed to the loss of critical habitat for parturition at FFS (Antonelis et al., in press) and possibly other sites in the NWHI. Predicted increases in sea level this century and beyond may severely reduce the amount of habitat for seals to rest, breed and rear their pups in the NWHI (Baker et al., 2006). Feasibility of restoration should be evaluated as soon as possible (e.g. Whaleskate Island, East I, Tern I, at FFS) to rebuild habitat essential for the reproduction of monk seals and other protected species (e.g. turtles and sea birds) at several alternate sites that may lead to rebuilding preferred, stable pupping habitat (i.e. accessibility, long shoreline, stable beach) that can be permitted by the FWS [5.3]. Other sites within the Hawaiian monk seal range may serve as sites for population enhancement studies (e.g. Johnston Atoll) if appropriate [5.3.1]. Also, in order to understand the risks and potential for mitigation of terrestrial habitat loss, high resolution elevation and bathymetry data for the NWHI should be collected using Light Detection and Ranging (LIDAR), and wave, wind, tide level, and current data should also be obtained. Following that, shoreline evolution should be modeled under higher sea level scenarios and strategies devised for active mitigation of hazards [5.3.2].

5.3 Restore terrestrial habitat where feasible
5.3.1 Investigate rebuilding pupping habitat and evaluate possible colonization of Johnston Atoll [2, R]
5.3.2 Collect high resolution elevation and bathymetry data for the NWHI using Light Detection and Ranging (LIDAR), and wave, wind, and tide level; model shoreline evolution under higher sea level scenarios and devise strategies for active mitigation of hazards [2, R]

Recolonization of the MHI is currently underway. Coastal development creates very different possibilities and problems. A recent Marine Mammal Commission-sponsored workshop and a Hawaiian monk seal program review discuss the ramifications of this occurrence (Marine Mammal Commission 2002, 2003). These reports outline possible actions and policies that might be considered, and indicates that while this will be positive for the enhancement of the monk seal population, it opens serious management dilemmas. Improved effort should be made to strengthen cooperative work with the local organizations and state agencies to minimize the threat of MHI coastal development, thereby ensuring that Hawaiian monk seals will not be disturbed or displaced from preferred habitats [5.4, 5.4.1, 5.4.2].

Some projects continue to occur as a result of previous military or other activities in the NWHI. At FFS, a contaminant removal project by the USCG (see Contaminants) began in

October 2001. To date, some soils contaminated with PCB have been removed and approximately $1 million has been spent on the project, however, additional USCG funding is required to complete the job (Barclay, pers. comm.) [5.4.3].

The U.S. Navy sea wall at Tern Island, FFS, is aging and deteriorating, and is a serious entrapment hazard to Hawaiian monk seals. The FWS has received a congressional appropriation for a significant portion of the necessary funds, however, full funding is still lacking. This seawall restoration project was initiated in 2004 [5.4.3]. The sections of old seawall that posed the greatest seal entrapment risk were replaced with a rock revetment seawall. However, totally replacing the old seawall will require additional funding [5.4.3].

The conservation of habitat presumes that the habitat is not directly impacted by new releases of pollutants and contaminants. To aide in the protection of the habitat from this risk, contingency plans for disaster response (oil/chemical/hazardous materials spills) should contain monk-seal specific provisions [5.4.4]. Since 2004, Hawaiian monk seal marine and terrestrial habitat (and protection) is managed (or co-managed, or protection enforced) by several federal agencies (NMFS, FWS, National Ocean Service (NOS), USCG) and the State of Hawaii.

- 5.4 Mitigate indirect anthropogenic impacts on monk seal NWHI and MHI habitat [2, I]
  - 5.4.1 Strengthen cooperative efforts with agencies and organizations responsible for managing beach areas where local groups or colonies of monk seals may become established in the MHI to ensure that measures are in place to avoid disturbance or displacement of seals that haul out to rest, pup, or molt [1, I]
  - 5.4.2 Engage state, county and business officials to minimize the loss of monk seal habitat due to development [2, I]
  - 5.4.3 Complete removal of contaminants [3, I] and repair sea wall at Tern Island [3, I]
  - 5.4.4 Maintain current contingency plan to deal with environmental disasters [2, I]

6. *Reduce Hawaiian monk seal interactions with fisheries*

The principle direct fishery interaction threat currently facing monk seals are MHI recreational fisheries, particularly the nearshore *ulua* fishery and nearshore gillnets. In recent years, NMFS has been and continues to be increasingly successful in identifying and de-hooking seals with embedded hooks around the MHI [6.1, 6.1.5]. However this effort does not remedy the interaction problem itself. Gillnets pose a hazard to seals and have resulted in mortality. The State of Hawaii has recently implemented new regulations that will further limit and regulate gillnet use, which should help to reduce this threat. However, gillnets will still be used in some areas, and enforcement of the new regulations will be important to ensure the threat is actually reduced.

Interactions between monk seals and the Hawaii-based pelagic longline fishery no longer appear to be a problem. The implementation of 50-75 nmi closed areas around the Hawaiian Islands Archipelago in 1991 has provided a safety buffer between monk seals and pelagic longlines. Further, the elevation of observer coverage over the past three years from less than 5% to greater than 20% in the deep-set fishery and 100% in the shallow-set fishery has not resulted in any reported interactions with this fishery.

Hooks embedded in seals have previously been identified as those from the federally managed bottomfish fishery. However, no recent interactions with the bottomfish are known to have occurred and the bottomfish fishery is not considered to have direct interactions with seals. All commercial and recreational fishery interactions should be identified and mitigated [6.1.1], and procedures and technology to mitigate interactions should be pursued [6.1.2].

Ocean aquaculture is ongoing and expanding off the island of Hawaii, focused primarily on *kahala* (also called *kampache*) as well as threadfin or *moi*. In addition, there is interest in the culture of bigeye and yellowfin tunas for export to sashimi markets. Like *moi* production, these tunas would be grown in pens deployed in Hawaii's nearshore coastal waters. NMFS, NOS and the State of Hawaii have been working with the existing aquaculture operators to monitor any interactions with protected species. To date, only a limited number of interactions have occurred, and the potential danger of expanded aquaculture operations to monk seals remains unknown [6.1.3].

New fishery developments that may have an impact on monk seals are the increase in the deployment of private FADs (PFADs) in the MHI that are primarily off the island of Hawaii, and marine aquaculture. FADs are a tethered raft under which tunas and other pelagic fish aggregate, and are widely used throughout the world in association with fishing for pelagic fish. PFAD deployment has risen markedly off Hawaii Island over recent years, even though little information is known about this fishery in association with these PFADs and if they represent a threat to monk seals [6.1.4].

6.1 Reduce direct fisheries interactions
- 6.1.1 Identify and mitigate the level of direct interaction between commercial and recreational fisheries [1, R/I]
- 6.1.2 Identify procedures and technology to mitigate interactions [1, R]
- 6.1.3 Identify and mitigate the potential interactions with marine aquaculture [2, R/I]
- 6.1.4 Identify and mitigate Hawaiian monk seal interactions with fish aggregating devices (FADs) [3, R/I]
- 6.1.5 Mitigate mortality by removing hooks from seals [1,I]

The level of indirect interactions (ecological competition) between Hawaii's fisheries and monk seals remain poorly understood [6.2.2]. In many cases, seals and fisheries exploit similar species. However, no study of ecological competition between fisheries and seals has looked at a seal population as small as that of the monk seal living in small island ecosystems. Recent studies indicate that monk seals forage within and adjacent to the atolls and islands where they haul out, and infrequently at locations at sea several hundred kilometers from the atolls. A number of fisheries have operated within the monk seal foraging range.

Fisheries, including the lobster fishery and bottomfish fishery are known to take prey items of the monk seal. The lobster fishery in the NWHI is closed and will remain closed as a result of the Presidential Proclamation declaring the PMNM. NMFS has attempted to investigate the extent to which monk seals are dependent on the NWHI lobster stock. However, as discussed above, the investigation is being conducted at a time when the lobster resource is depleted, and therefore possibly less represented in the present diet than if the study had been conducted previously. Recent results from fatty acid studies do indicate the possibility of indirect interactions that need investigating.

The bottomfish fishery in the NWHI will permanently close in June 2011 as a result of the Presidential Proclamation establishing the PMNM. In June 2000, NMFS closed the lobster fishery due to uncertainty in the model assumptions used to estimate allowable harvests and reduces lobster stocks. Per the PMNM proclamation and implementing regulations, this fishery will remain closed. NMFS intends to continue to reduce indirect interactions with fisheries by maintaining full measures as well as the protective intent of the Proclamation that established the PMNM [6.2.1]. NMFS also plans to use diet analysis, foraging studies, nutritional status monitoring, and monitoring of ecosystem productivity to evaluate possible competition with fisheries [6.2.2].

6.2 Reduce indirect interactions [2, R/P]
- 6.2.1 Maintain full measures and protective intent of the Proclamation establishing the PMNM [2, P]
- 6.2.2 Use diet analysis, foraging studies, nutritional status monitoring, and monitoring of ecosystem productivity to evaluate possible competition with fisheries [3, R]

Further complicating the issue of possible ecological competition between fisheries and seals is that seals in the NWHI, where fishing effort and extraction is low, are the animals experiencing food limitation, low survival, and starvation. While in the MHI, where fishing effort and extraction is high, seals are apparently foraging very successfully and pups are recorded with high weaning weights and high survival.

7. *Reduce male aggression toward pups/immature seals and adult females*

Single and multiple male aggressions that severely injure or kill adult females and immature seals have been recorded since the 1970s (e.g., Johnson and Johnson 1981; Alcorn, 1984; Johanos and Austin, 1988; Hiruki et al., 1993b). Although evidence of male aggression has been observed at all major breeding sites, the intensity of the problem varies by location and year. Observing monk seals for injuries typical of male attacks is a critical field team task [7.1]. Certain individual males are more prone to this behavior and have been observed in repeated incidents [7.1.1].

Single male aggression attacks are usually directed towards weaned pups of either sex and can result in injury or drowning. This aggression has been an ongoing concern at both Lisianski Island and FFS. At FFS, three individual adult males were observed repeatedly attacking and killing pups: one male was euthanized in 1991 (Craig et al., 1994), and two males were captured and relocated to Johnston Atoll in 1998 (Craig et al., 2000). Removal of aggressive males has successfully reduced seal losses to this trauma. This corrective action must be continued to improve female survival [7.1.2].

During multiple male aggression, a group of males attempt to mate with a single seal. Attacks are usually directed towards adult females or immature seals of either sex, and can result in severe injury or death. Multiple male aggression has been observed most frequently at Laysan and Lisianski Islands, and has also been seen at a number of other sites. The behavior has been associated with (but is not limited to) sub-populations with unusual, male-biased sex ratios (Johanos et al., 1999). This aggression has been linked to increased mortality of adult females and immature seals, and presents a threat to recovery. The Laysan Island adult sex ratio was adjusted and is currently slightly female-biased after the physical removal of 37 subordinate males from the Laysan Island population during several management efforts between 1984 and 1994 (Becker et al., 1994, Becker et al., 1996; Johanos et al., 1999). There has been a documented reduction in deaths due to male aggression following the final relocation effort (Johanos et al., 1999). Therefore future incidents must be dealt with similarly in order to reduce adult female deaths due to male attacks [7.1.2.]. The males that were removed from Laysan Island were either brought into permanent captivity or translocated to either Johnston Atoll or the MHI. None of the males that were relocated to Johnston Atoll or the MHI are known to have returned to the NWHI (NMFS, unpublished data).

In 1987, MMRP conducted a workshop and developed a plan to address the problem of multiple male aggression (Gilmartin and Alcorn, 1987). The MMRP has since refined a decision tree to aid in deciding whether to remove individual adult males that are injuring or killing other seals [7.1.2.]. This decision document should be reviewed and revised as necessary with any new relevant information.

7.1 Continue monitoring populations/tracking injuries, disappearances, and deaths [1, R/I]

7.1.1 Identify aggressive males [1, R]

7.1.2 Remove aggressive males, translocate if possible, or euthanize; periodically review criteria for removing aggressive males [1, I]

Where apparent, male-inflicted injuries may be observed, but documentation of the cause(s) and identity of males involved are uncertain. The field effort should be augmented as needed to better document the problem and individuals involved [7.2.].

7.2 Monitor populations with unknown injuries (to determine cause) by extending/increasing field effort, if necessary, to identify cause[s] [1, I]

In some field situations where seals may be injured and where a veterinarian may be available on site, attempts to treat injured seals may be possible. However, the risk of handling and treatment must be weighed against the possible benefit of the treatment [7.3.].

7.3 Treat injuries, where and when feasible [1, I]

8. *Reduce the likelihood and impact of human disturbance*

The most significant consequence of disturbance is the documented decrease in population size at human-disturbed sites during the 1960s and 1970s (Kenyon, 1972; Gerrodette and Gilmartin, 1990). While the number of people in the NWHI has decreased since the reduction of military and USCG activities in addition to the cessation of commercial flights to Midway, terrestrial and marine research projects have increased during the last two decades. Efforts must be made to ensure that all users of the NWHI (including and especially research and management staff of the various state and federal agencies) are aware of the impacts of disturbing monk seals on breeding beaches and in nearshore waters [8.1.]. Similarly, in the MHI where the seal population is increasing (Baker and Johanos 2004), and people are usually unfamiliar with the "take" prohibitions provided by the ESA as well as the MMPA, and the disturbance issues and/or the normal behavior of monk seals. Appropriate public educational materials and distributional media must be identified to inform beach users of the serious plight of monk seals, the potential impacts of disturbance to the seals, and the possibility of injury to humans.

8.1 Reduce inadvertent disturbance of monk seals by having adequate island coordinators and staff to implement outreach campaigns and volunteer groups to reduce human-seal interactions [1, I]

While the effort to protect monk seal mothers and pups on the populated beaches of the MHI is now better managed at the moment and is viewed as a valuable experience for visitors, such undertakings are resource exhaustive in staff time, personnel contracts, equipment, and materials. These efforts are not possible without the help of a large cadre of volunteers. Other management options need to be investigated for several reasons. These efforts are resource exhaustive, especially in regards to: the time and effort required of staff and volunteers; the logistical problems (e.g. unreliable night security); the sustainability of such labor intensive endeavors; the recent successful puppings in the MHI; and the potential for multiple pupping events on popular beaches. It may not be possible to adequately protect mother-pup pairs in all situations. At the PIRO-sponsored Hawaiian monk seal management meeting in March 2006, discussions centered on the options for such pupping events in high human-use areas. One action item that was suggested for further investigation was the translocation of mother-pup pairs prior to the weaning process or the deterrence of pregnant monk seals prior to pupping [8.2]. A team of local specialists is collaborating with field experts and researchers to gather useful information and guidance on such undertakings. The decision-making process and the potential use of an ESA enhancement permit will be pursued if it is believed that translocation is necessary and feasible. However, it would only be undertaken with a significant number of considerations and/or caveats, the foremost of which being safety for the mother/pup pair and handlers.

In order to more thoroughly address the concern of disturbing mother-pup pairs, a broader initiative is needed to promote the development of monk seal colonies in relatively remote areas while discouraging colony development in areas of high human use. A plan must be developed to consider the following: the effectiveness of moving seals of different ages and sexes; the procedures that should be used to ensure the well-being and safety of seals and people involved in moving the seals; steps to monitor the movement, behavior, and survival of seals after being moved; optimal locations to which seals might be moved; and related research needs [8.3]. With regard to identifying possible seal relocation sites, factors that should be considered include the extent to which new locations are protected, their distance from foraging grounds, and their isolation from potential sources of disease and infection. The plan should also identify criteria for measuring the success of failure of such translocation efforts, including sample sizes, effects on seal distribution, etc. Efforts to move seals undoubtedly will require the support and approval of numerous parties, including the owners of beaches to which seals are moved. The preparation of such a plan would help to lay the groundwork necessary for making decisions quickly when cases calling for the relocation of seals arise.

In addition, an important measure currently taken to prevent human disturbance of seals hauling out on popular recreational beaches involves posting temporary seal protection zones around hauled-out seals. Although this effort appears to be important and helpful, studies should be undertaken to document and assess procedures and factors that influence the effectiveness of this approach (e.g., the size of areas around seals, the presence of seal monitors at the site, the types of information that increase compliance with protection boundaries, etc.) [8.4]. The results of such a study would provide a basis for evaluating how effective sea protection zones are and for refining procedures on when and how to establish such zones.

8.2 Investigate feasibility of translocating mother-pup pairs or deterring pregnant females from high public-use areas to remote locations, and if feasible, consider the use of an ESA enhancement permit to authorize this activity when adequate protection for the pair cannot be provided by other means [2, I]

8.3 Develop a monk seal pupping and haul-out intervention plan to determine if, when, where, and how monk seals might be moved to reduce risks of potential adverse interactions between seals and people in the MHI [2, I].

8.4 Document and assess procedures for protecting seals that haul-out on recreational beaches [2, I].

All activities proposed to take place in the NWHI within monk seal habitat should be reviewed for compliance with the ESA and the MMPA and their prohibitions against the take of marine mammals, in particular, giving increased attention to the potential to disturb monk seals. Defined under the ESA "take" is "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." "Take" as defined in the MMPA includes "to harass, hunt, capture, kill or collect, or attempt to harass, hunt, capture, kill or collect." Appropriate mitigation measures include training on human behavior when near seals and how to report any observed problems or threats to the species. At NWHI sites where there is a high potential for beach disturbance (e.g. Midway during the contracted tour operations of the late 1990s), NMFS should work with action agencies to ensure an enforcement and/or research staff presence to deter disturbance and monitor possible seal behavioral changes [8.5, 8.6].

8.5 Continue permitting requirement and training process for all NWHI travel to minimize reduction of human disturbance at breeding sites [2, P]

8.6 Maintain a research and/or enforcement presence at sites where necessary to prevent human disturbance [2, P]

On several occasions during the last two decades, various developments that could threaten the monk seal population have been proposed or discussed for possible construction and operation in the NWHI. The HMSRT has opposed these developments and has recommended that the NMFS and FWS not authorize them. Any proposed NWHI operations that may increase seal disturbance or threaten survival such as nearshore ship traffic, beach use, noise, unnecessary research or in any other way that negatively affects the marine or terrestrial habitat of the monk seal should all be scrutinized carefully to ensure that the recovery of the monk seal population is not hampered by the activity [8.7]. To accomplish this, all applicable laws protecting monk seals and their habitat should be used and enforced.

8.7 Evaluate and minimize adverse effects of future development or increased use of the NWHI with respect to impact on monk seals [2, P]; no facility should be constructed in the NWHI without a review by NOAA to ensure compliance with the MMPA and ESA

Research to date has found no detectable negative effects of handling and instrumentation on Hawaiian monk seal survival or movement away from the NWHI subpopulation where they were tagged. However, other problems are possible. Additional research needs to be done to investigate the possible influence of handling and instrumentation on other behaviors, especially changes in hauling patterns and possible pupping sites [8.8.]. The latter is a documented problem related to disturbances that led to high pup mortality due to beach disturbance of seals at Kure and Midway.

8.8 Determine if handling associated with the application and removal of telemetry and data-logging devices alters the behavior or hauling site preferences of seals [3, R]

9. *Investigate and develop response to biotoxin impacts*

At a 1999 Hawaiian monk seal health and disease workshop (MMC, 2000), one of the highest priority recommendations was the development of a general UME plan and specific contingency plans for response to possible disease outbreaks and biotoxin poisonings in the monk seal population [9.1]. Lethal exposure of monk seals to biotoxins apparently is rare; however, it might be possible to rescue some animals if exposure can be detected early enough and facilities for holding animals can be made available. Possible steps must be considered for detecting, capturing, and rehabilitating monk seals affected by biotoxins.

9.1 Develop contingency plan to manage a biotoxin dieoff in monk seals, considering possible steps to detect, capture, and rehabilitate monk seals that are affected by biotoxins [2, P]

Ciguatera was implicated but not confirmed as the cause of the 1978 die-off of seals at Laysan Island (Gilmartin et al., 1980). No potential cases of ciguatera have been identified since that time. In 1978, at least 50 seals died on Laysan Island, and high levels of ciguatoxin and maitotoxin, a similar neurotoxin, were detected by bioassay in the livers of two seals examined (Gilmartin et al. 1980). Ciguatoxin can cause mortality in phocids, but its role in mortality of monk seals is unclear due to the lack of assays for testing tissues of dead seals for toxic doses, and the lack of epidemiological data on the distribution of toxin in monk seal prey. The effects of ciguatoxin on Hawaiian monk seals are unclear [9.2, 9.3].

9.2 Develop an appropriate and sensitive assay for biotoxins and metabolites in tissue of monk seals and prey species [2, R]

9.3 Investigate biotoxin dose-response effects on monk seals through opportunistic sampling and retrospective studies [3, R]

Domoic acid is a biotoxin produced by the diatom *Pseudonizchtia australis* that is known to affect pinnipeds and has caused mortality of California sea lions (*Zalophus californianus*) in the eastern Pacific (Scholin et al., 2000). Although not identified to date in the prey of monk seals, blooms of *Pseudonizchtia* spp. have occurred around the Hawaiian Islands [9.4].

9.4 Develop a collaborative link with Harmful Algal Bloom monitoring programs, for detection of potential toxic blooms [3, P]

10. *Reduce impacts from compromised and grounded vessels*

Hawaiian monk seals and their habitat are susceptible to a variety of direct and indirect impacts from grounded or compromised vessels. These impacts can result from the harm to the habitat caused by the hull's contact as well as the direct threat posed to monk seals by the release of fishing gear and oil aboard the vessel. Baited fishing gear poses the greatest direct concern to monk seals. Additional damages could be caused by salvage operations to remove a vessel and its pollutants. Across Hawaii, many contemporary place names are a result of historic vessel grounding in the area. The NWHI are no exception including, for example, French Frigate Shoals. Storms, mechanical problems, maintenance failures, and poor navigational skills may result in these situations.

Hawaiian monk seals may be injured by vessel groundings that result in the release of hazardous toxic chemicals (refrigerants, organochlorines, ammonia, sewage, acids, etc.), oil and/or fuel spills, rotting bait, lost gear that creates entanglement hazards (lines baited and unbaited, monofilament line, hooks, nets and/or traps), or the human disturbance associated with the grounding or removal of the vessel (Gulko, 2002; Work, 1999). Human impacts can vary between incidental disturbances resulting from human presence to direct subsistence harvest by stranded boat crews. Vessel groundings, which result in coral reef damage, may adversely affect monk seals' aquatic habitat. In addition, trauma to reefs associated with vessel groundings have been implicated in ciguatera outbreaks. Response to a vessel grounding must be swift to reduce potential seal injury and damage to habitat [10.1, 10.2]. A trained, equipped, funded response team with appropriate experts and necessary agency agreements should be able to respond quickly [10.2.1, 10.2.2, 10.2.3, 10.2.4, 10.2.5, 10.2.6]. Importantly, vessels operating near the NWHI must carry insurance adequate to cover removal of the vessel and associated liability in the event of grounding.

Quick agency responses are necessary when groundings or other events occur to minimize the effects on the Hawaiian monk seal and their habitat in both the NWHI and the MHI. Several agencies have response protocols, but further coordination and collaboration among the agencies will help minimize the effects during these events. Agreed upon and standardized protocols need to be in place to ensure a rapid and well-organized response, including assessment, proper collection of evidence, and continued monitoring occurs during and after an event [10.2.7, 10.2.8].

10.1 Ensure that monk seal concerns are included in all grounding response planning [3, P]
10.2 Provide rapid response, removal, and ecological assessment and monitoring of vessel groundings [2, P/I]
  10.2.1 Identify and pre-place equipment on appropriate islands to ensure a rapid response [3, P]
  10.2.2 Establish a trained, well-equipped emergency response team to evaluate and potentially treat Hawaiian monk seal during and after an event [3, P]
  10.2.3 Identify experts and develop protocols for damage assessment and habitat restoration activities [3, P]
  10.2.4 Ensure proper funding for Hawaiian monk seal and habitat monitoring post-event [2, P]
  10.2.5 Maintain contingency plan outlining how agencies work together during an event [3, P]
  10.2.6 Immediately remove debris from a grounding that might result in entanglement of monk seals [1, I]
  10.2.7 Publish response plans [3, I]
  10.2.8 Provide educational material for appropriate response plans [3, I]

Problems regarding policy, jurisdiction, response and enforcement, damage assessment and restoration, and funding mechanisms associated with vessel groundings in the Pacific Island Region were addressed at a recent workshop, which convened in Honolulu, Hawaii. Although groundings are infrequent, gaps in the current policy framework to deal with impacts associated with grounding events can create a number of ecological, legal and funding challenges.

11. *Reduce the impact of contaminants*

A number of contaminants originating from human occupation of the islands have been identified on both the NWHI and the MHI (see also Biotoxins section 9.1) and opportunistic sampling and tissue storage for possible contaminant testing should continue [11.1]. The effects, however, of these compounds on monk seal health, reproduction and survival are unknown [11.2]. Blubber and blood samples collected from female and male monk seals of various age classes on FFS in 1999 have been analyzed for selected OCs, including DDTs and PCBs (Willcox 1999). In this study, adult male monk seals had higher PCB concentrations in blubber than reproductive females or juvenile animals. The OC levels were comparable to or lower than those reported in blubber of various pinnipeds from the northeastern Pacific (Lee et al., 1996,; Krahn et al., 1997; Calambokidis et al., 2001; Kajiwara et al., 2001). Additional blood and blubber samples from monk seals collected from four NWHI sub-populations over five years have been analyzed for dioxin-like PCB congeners and other selected PCBs and OCs at the Environmental Conservation Division of NMFS, Seattle. Higher PCB and DDT concentrations were found in seals from Midway compared to seals from the other three sub-populations (Aguirre 2000; Ylitalo et al., in prep.) In the future, if a contaminant link to reproductive failure is suspected, this tissue bank will be a critical factor in resolution of the question.

11.1 Continue collection of samples from seal and prey species and banking of samples for potential contaminant monitoring [3, R]

11.2 Examine data for association between reproductive failure and exposure to contaminants and conduct a risk assessment specific for monk seals [3, R]

B. Recommendations for Essential Long-term Actions

12. *Continue population monitoring and research*

Virtually all NWHI monk seal population data are collected during field seasons that currently occur roughly from either March through July (Laysan/Lisianski) or May to July/August (FFS, PHR, Midway, Kure) each year at each island. Field camps are deployed during these months because they cover most of the breeding season and because weather conditions usually allow for predictable landing and retrieval of field crews. The objectives are to collect data throughout the NWHI on the abundance and distribution of seals, demographic parameters, body condition and behavior of seals relevant to interpreting demographic data at each site.

A primary goal of this large population monitoring effort is to identify the threats to recovery, to provide data that may be used to formulate recovery strategies for implementation, and then the subsequent field monitoring data are used to evaluate the effectiveness of the implemented recovery actions. This critically important goal drives the need for the annual field monitoring of the monk seal population, and contributes directly to some of the threat mitigation work (e.g., disentangling seals found in nets [12.1, 12.2]). Annual surveys are important for generating a data set of annual birth and death rates for comparison to the time series of oceanographic, meteorological, and productivity indices, in the hopes of discovering relationships that bear on the effects of environmental factors on the population.

The monk seal population is small, and the identification and re-sighting of individuals has proven to be a highly successful means of monitoring critically important demographic data in the population [12.21, 12.2.2]. The combination of permanent marks (i.e. tags that enable identity to be tracked from weaning to death) and easily seen seasonal marks (e.g. pelage bleaching, photographs) facilitate the collection of critical demographic data from this population. These data, collected in a standard manner at all sites and in all years, enable comparisons of population characteristics among the island locations and trends over time. Weaned-pup tagging and the maintenance of these identities through the life of these seals are critical to understanding the dynamics of the population, how it is affected by the threats, and how it responds to recovery actions.

Surveys of Hawaiian monk seals are performed at each of the major breeding locations annually, and this effort [12.1, 12.2, 12.5] must continue. Usually a series of at least eight beach counts are conducted to provide a mean beach count index that is compared to earlier years to assess the island populations' trends. More importantly, population size, age and sex composition are assessed by identifying most or all of the individuals [12.2.1]. This is accomplished during beach surveys which occur throughout the field seasons. At single island breeding sites, such as Laysan Island, field teams can typically identify the entire subpopulation long before the end of the field season. However, at large multi-island sites, such as PHR, shorter field seasons and limitations (e.g. sea and weather conditions) to traveling among the islets in small boats, preclude identification of all seals in the subpopulation. Other schemes that might allow identification of all seals using a location should be investigated [12.2.7].

In addition to seal identity, field personnel inspect each seal and record any apparent condition that could affect survival [12.2.3], such as injury, illness, entanglement, etc. Field staff also note reproductive-related observations [12.2.4], such as whether a female appears pregnant, if a pup birth or weaning has occurred since a female was previously observed, also noting the identities of the female and pup. Observers record if an exchange of pups has occurred between two lactating females. As soon as possible after weanings and within two weeks, field personnel obtain morphometrics from the pup and apply permanent tags. In some cases, field crews arrive at islands after one or more weanings have occurred. In these situations, tissue from the subject animals (obtained when flipper tagged) could be used to identify the mother of any weaned pup [12.2.4]. DNA sampling to identify individuals genetically would greatly help in assigning pups to mothers, for purposes of understanding reproductive histories of individuals, and developing age specific reproductive schedules [12.6]. The DNA library would also be helpful in maintaining continuity of identity in cases of tag loss.

Overall, this monitoring system has provided one of the most detailed data sets available on the demography of any endangered species. While it has been a disappointment that this knowledge of demographic rates cannot currently resolve the relative importance of the leading hypotheses about the mechanisms that are driving these rates, continuation of the detailed demographic monitoring will be essential to the studies that eventually will reveal causal mechanisms.

- 12.1. Continue annual monitoring in the NWHI [1, R]
- 12.2. Optimize survey techniques to observe all seals [1, R]
  - 12.2.1 Record identities of all seals using each site [1, R]
  - 12.2.2 Identify seals that may move between subpopulations [1, R]
  - 12.2.3 Record observed threats to survival [1, R]
  - 12.2.4 Record reproductive data using all current techniques [1, R]
  - 12.2.5 Adjust timing of annual field studies to optimize demographic data collected [1, R]
  - 12.2.6 Assign pups to mothers using DNA methods [2, R]
  - 12.2.7 Develop methods to integrate the demographic monitoring with management experiments, foraging studies, prey abundance surveys, and oceanographic monitoring, with an aim to eventually resolving the causal factors that are important in influencing the vital rates [1, R]

Data entry, database management, and analysis of all of the data collected are enormous tasks [12.3.]. Most of the monk seal observational data collected in the NWHI field camps are now entered into laptop computers at the field site and go through an initial editing/correction process. On return to the MMRP, these field data files are further edited and then entered into the database that includes the 20+ year full population record for the species. An urgent need is the development of an updated management manual for this database [12.3.1]. Following final correction procedures and entry of the field data to the database, laboratory staff must analyze the new data for both site-specific and NWHI-wide trends [12.3.2] in beach counts, births, mortality, fecundity, population composition, and annually publish these findings together with a summary of observed threats to survival and reproductive observations. In that report, the recent year's findings should be discussed in relation to the long-term trend for each site.

12.3 Maintain and analyze data, report findings [1, R]
- 12.3.1 Improve database accessibility and develop database management manual [1, R]
- 12.3.2 Continue annual site-specific and NWHI-wide statistical analyses [1, R]

The stochastic monk seal population model developed over the last decade has evolved to become a valuable tool in both projecting the NWHI monk seal population's future based on current available data, and in assessing future population changes in response to proposed population management strategies [12.4]. Knowledge of the MHI monk seal population is rudimentary compared to that available for the NWHI. An ambitious program to assess distribution, abundance, movements and vital rates of monk seals in the MHI should be undertaken. The MHI data should be added to the model, collectively treated as an additional site in the metapopulation [12.4.1.1]. This model should be maintained and updated with each new year's data [12.4.1.2], especially new findings that may influence the model's handling of survival, reproduction, migration, and carry capacity in projections. The recommendation to develop a PVA for the monk seal population [12.4.2.] originates from the need to establish recovery criteria for the species. Using current data, this is a method of projecting population trend with an assessment of estimated time to extinction.

Ecosystem and multi-species predator-prey models may be important tools for testing hypotheses and guiding research. There are a number of modeling approaches including bioenergetic, tropho-dynamic, inverse, ECOPATH, and simulation, each with strengths and weaknesses. Some models attempt to include trophic levels and energy fluxes whereas others seek to include only those key interactions that account for much of the variability in the response variables. Thus, it is valuable to use a variety on modeling approaches [12.4, 12.4.3]

ECOPATH/ECOSIM modeling is being used as one means to address carrying capacity of Hawaiian monk seals. The original FFS ECOPATH model has been revised with new trophic and growth parameters from the literature, and a reference biomass based on reef fish assemblages. Fish were surveyed in all the primary habitat types identified by recent NOS habitat mapping. Habitats ranged from complex shallow reefs, to deep slope sand fields. The summits and slopes of neighboring banks were also surveyed because seals routinely traveled to and foraged in these areas. MMRP is currently waiting for the results of the fatty acid analysis to use as the seals diet vectors. Once this is available the model will project the carrying capacity of seal biomass and this will be compared to the actual FFS seal population for appraisal. Currently, the model is undergoing sensitivity analysis to identify the robustness of the model compartments. Once the monk seal diet vector is included and if the projections from the model are verified, other regions of the NWHI can be incorporated and the modeling can begin the ECOSIM phase. Finally, serious consideration must be given to testing the validity of model results if it becomes apparent that additional proactive efforts (e.g., removal of predators or human competitors for food) are needed to recover the species [12.5]. To evaluate the efficacy of such actions, studies must be carefully designed hypothesis driven experiments that evaluate possible major ecological impacts, afford sufficient alternative actions for adaptive responses to unpredicted results, and are ultimately applicable to an ongoing conservation oriented management program.

12.4 Continue demographic and ecosystem modeling [1, R]
- 12.4.1 Maintain monk seal population model [1, R]
  - 12.4.1.1 Implement MHI research plan to assess distribution, abundance, movements and vital rates of monk seals in the MHI [1, R]
  - 12.4.1.2 Add annual NWHI, MHI data [1, R]
- 12.4.2 Develop a PVA for monk seals [1, R]
- 12.4.3 Develop models linking foraging, diet, physical condition of seals and demography [1, R]

12.5 Conduct hypothesis driven ecological experiments to evaluate potential options for enhancing monk seal recovery [3, R]

13. *Create a Main Hawaiian Islands Hawaiian Monk Seal Management Plan*

A comprehensive management plan to address issues of the MHI will need to be collaborative, adaptive, and implemented in such a manner that current decisions and actions will inform future decision making. While monk seal management in the NWHI is well-coordinated, in large part due to a 25-year history and few agencies involved, a similar collaborative approach in the MHI including the Department of Commerce, the Department of the Interior, the State of Hawaii, several NGO/volunteer groups, and interested individuals to manage such planning is starting to materialize.

Recent surveys indicate that there are at least 77 monk seals residing in the MHI. While this sub-population raises promising new prospects for the species' recovery, it also poses new management challenges. For example, monk seals have hauled out and given birth on populated recreational beaches, where their presence has encroached upon human activity and they are subject to harassment by people and pets. On more than one occasion, this has led to swimmers being bitten, seals chased and/or attacked by dogs. In some cases, acclimation and habituation to humans have led to interactions that are harmful to humans and ultimately the seals. Other areas of concern include interactions with the recreational fishery, as well as interactions with recreational and commercial boating.

A critical threat to monk seals in the MHI and to seals in the NWHI is the introduction of disease from domestic, feral, and wild animals. There is evidence of leptospirosis and toxoplasmosis in MHI seals, and leptospirosis has killed thousands of seals on the California coast. Disease introduction could lead to a loss of many seals and further reduce the possibility of recovery of the species. Management of this threat in the MHI, including procedures to contain a disease outbreak in the MHI, must be a high priority consideration in this management plan.

In October 2002, *The Workshop on the Management of Hawaiian Monk Seals on Beaches in the MHI* was co-sponsored by the Marine Mammal Commission, NMFS, and the Hawaii DLNR Division of Aquatic Resources. Over a three-day period, stakeholders, including representative from federal, state and city and county agencies, NGOs, and interested individuals discussed many issues of concern and importance. Comprehensive comments and suggestions were compiled in a final report. This report served as the first community-based scoping of management issues relevant to the creation of a comprehensive management approach for seals in the MHI.

PIRO sponsored a two-day MHI Hawaiian Monk Seal Management Workshop in March 2006. Representatives from PIFSC MMRP, Hawaii DLNR and DOCARE, the HIHWNMS, and other agencies were in attendance. Areas of discussion included adaptive management approaches to high profile issues such as emerging disease concerns, pups born on popular beaches, techniques and issues dealing with conditioned and/or habituated seals, pups born near contaminated streams, captive care and rehabilitation of sick or injured seals, and volunteer network development and outreach. This was the first step in the continuing development of a MHI Hawaiian Monk Seal Management Plan.

Coordinated, management planning and implementation should be directed toward the primary issues of: public education and outreach, information collection and dissemination, population assessment, recording and communication, response and intervention (permitted and non-permitted activities), research, and protection. NMFS is charged with the ultimate responsibility for this endangered species management and recovery. However, it is clear to all involved that cooperative involvement of all stakeholders, each offering their area of expertise and influence, will be necessary to create a culture of cooperation throughout the MHI. That culture will be necessary for monk seals and people to maximize the appreciation and utility of our beaches and nearshore resources. Thus, the development and implementation of this MHI monk seal management plan is critically important [13.1, 13.2].

13.1 Develop a MHI monk seal management plan that addresses all critically important assessment, disease, regulatory, intervention, coordination, and education needs [1, P/I/R]

13.2 Implement the MHI management plan [1, P/I/R]

There have been extensive efforts to use education and outreach in the MHI to both develop a local constituency for monk seals, and to mitigate conflict between people and seals. The efforts have been led by NOAA, state agencies, and by non-profit institutions across the MHI. The greatest efforts have been made on Kauai which, with the exception of the privately owned Niihau, has the largest population of Hawaiian monk seals in the MHI.

Monk seal education and outreach efforts over the past 20 years have been opportunistic and, at times, *ad hoc*. Yet despite this, the activities of groups like the Kauai Monk Seal Watch, and the Hawaii Wildlife Fund have had real impact at a local level. Various products (brochure, posters, web sites, etc.) have also been relatively successful in reaching a diverse group of people, given the limited resources available for these activities. The growing conservation and recovery needs of Hawaiian monk seals in the MHI call for a more extensive education and outreach program and efforts that are better planned and coordinated [13.3, 13.4].

The structure of increased efforts at education, outreach and constituency-building will be complex because of the large area involved, the currently low densities of seals, and the need to engage a number of different audiences that include but are not limited to: local residents, the tourism industry; tourists; commercial and recreational fishermen; Native Hawaiian communities; and other federal agencies [13.5, 13.6]. A diverse set of education and outreach activities will be essential to accomplishing the goals of protecting monk seals in the MHI. To accomplish this, agencies need to assist, support, and promote monk seal-focused community organizations, individuals, agencies, businesses, and other interested parties. Native Hawaiian cultural perspectives regarding monk seals are varied, and it would be valuable to engage the Native Hawaiian community in the research and conservation of monk seals, since their cultural concerns are important for program development.

13.3 Implement statewide, multi-media information campaign, drawing on professional expertise in public education and social marketing [1, P]

13.4 Use a performance monitoring and evaluation system to measure the effectiveness of education and outreach activities and to identify program changes to enhance effectiveness [2, P]

13.5 Target numerous audiences including fishers, marine resource managers, beach and ocean users, and the visitor industry [1, P]

13.6 Complete a focused survey about the social behaviors and relationships of monk seals to investigate the cultural concerns of the Native Hawaiian community, the general public perception of Hawaiian monk seals and the nearshore interactions with fishermen, divers, and the public to evaluate frequency, characteristics, and impacts of interactions [2, P]

The proceedings of the report from the Marine Mammal Commission's "*Workshop on the Management of Hawaiian Monk Seals on Beaches in the Main Hawaiian Islands"* (Marine Mammal Commission, 2002) offer a number of recommendations and suggested approaches to implementing education and outreach activities in the MHI. Despite the lead responsibility held by NMFS under the MMPA and the ESA, the Workshop concluded that NMFS had been severely limited by staff and funding. Federal funding for these activities has been small, and insufficient to execute even the most basic coordination or response to conflicts. As a result, and with little funding, state and local agencies, NGOs, volunteers, and local business have all stepped in to assist in both education and outreach activities, and in the management of seals hauled out on easily accessible beaches.

14. *Implement the Recovery Program for the Hawaiian monk seal*

To ensure the timely and efficient implementation of the revised Recovery Plan as well as the coordination among PIRO, PIFSC, and other agencies and non-governmental organizations, a Hawaiian Monk Seal Recovery Coordinator should be hired by NMFS PIRO [14.1.1]. In other regions, NMFS has devoted funds to hire specific recovery coordinators for highly endangered species (ex: Stellar sea lion recovery coordinator in the Alaska Regional Office, and two right whale recovery coordinators – one in the Southeast Region, and another in the Northeast Region). The status of Hawaiian monk seals warrants a well-organized recovery effort, and the addition of a coordinator will greatly enhance current conservation efforts. Ensuring implementation of the plan also requires the support of an integrated education and outreach program by NOAA Fisheries in close collaboration with other government agencies and non-government partners. Program goals should include minimizing human disturbance and other adverse impacts and maximizing public support for conservation activities [14.2]. Staffing and personnel should be maintained in order to address management concerns in the

NWHI and MHI [14.3]. NMFS should also maintain research programs in the NWHI and the MHI that are sufficient to provide the information required by managers [14.4]. Finally, it is the responsibility of NMFS to maintain a Hawaiian Monk Seal Recovery Team and to use the team to provide outside advice and review of actions needed to accomplish recovery [14.5], and to revise the Recovery Plan for the Hawaiian Monk Seal at appropriate intervals [14.6].

- 14.1 Hire a Hawaiian Monk Seal Recovery Coordinator for NMFS PIRO to ensure the timely and efficient implementation of the revised recovery plan and coordination among PIRO, PIFSC, and other agencies and non-governmental organizations [1, P]
- 14.2 Support an integrated education and outreach program by NOAA Fisheries in close collaboration with other government agencies and non-government partners. Program goals should include minimizing human disturbance and other adverse impacts and maximizing public support for conservation activities [1, P]
- 14.3 Maintain staffing needed to address management concerns in the NWHI and MHI [1, P]
- 14.4 Maintain a research program in the NWHI and the MHI sufficient to provide the information required by managers [1, P]
- 14.5 Maintain a Hawaiian Monk Seal Recovery Team and use the team to provide outside advice and review of actions needed to accomplish recovery [1, P]
- 14.6 Revise the Recovery Plan for the Hawaiian Monk Seal at appropriate intervals [1, P]

V IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated costs for the recovery program for the Hawaiian monk seal, as set forth in this recovery plan. It is a guide for meeting the recovery goals outlined in this plan. This schedule indicates action numbers, action descriptions, action priorities, duration of action, the parties responsible for actions, (either funding or carrying out), and estimated costs. Parties with authority, responsibility, or expressed interest to implement a specific recovery action are identified in the Implementation Schedule. The listing of a party in the Implementation Schedule does not require the identified party to implement the action(s) or to secure funding for implementing the action(s).

The priorities in column 2 of the Implementation Schedule are assigned as follows: Priority 1 – An action that must be taken to prevent extinction or to prevent the species from declining irreversibly; Priority 2 – An action that must be taken to prevent a significant decline in species population numbers or habitat quality or to prevent some other significant negative impact short of extinction; Priority 3 – All other actions necessary to provide for full recovery of the species.

The Implementation Schedule is structured in parallel to the Recovery Plan with 14 categories for action. The cost of actions within each category is assigned to the most detailed action for which costing can be made. Any action that incurs no additional cost is so noted in the comments section. For each action, sub-totals are given for each category as a whole in ***bold italics***.

Any given action is placed within the category which best describes the intent of that action. However, a single action may have multiple consequences. For instance, many of the actions described in Category 8 (Reduce the Likelihood and Impact of Human Disturbance) also have a strong impact on ameliorating threats identified in Category 5 (Conserve Hawaiian Monk Seal Habitat). While this is of little consequence to the overall goal of recovering Hawaiian monk seals, readers should note that because actions are linked across categories, the total cost of achieving the objectives of a single category will include the cost of actions completed in other categories. Hence, while the total cost of recovery described in the Implementation Schedule reflects the cost of recovering the species, individual actions, or the costs of completing the goals of individual categories, may be understated when categories are viewed in isolation.

Plan Action				Fiscal Year Costs ($K)					Comments
	Priority*	Resp. Agency	Action Duration	FY 1	FY 2	FY 3	FY 4	FY 5	
1) Investigate and Mitigate Factors Affecting Food Limitation									
1.1 Define diet by age, sex, location, season (variety of methods) and characterize feeding areas quantitatively (e.g., with CRITTERCAM, video technology)	(1, R)	PIFSC	ongoing	*500*	*500*	*500*	*500*	*500*	
1.2 Assess and monitor prey abundance; study prey selection; research must continue in order to have an independent measure of monk seal prey abundance	(1, R)	PIFSC	ongoing	*200*	*200*	*200*	*200*	*200*	
1.3 Determine whether prey abundance is limiting population growth	(1, R)	PIFSC	ongoing						Part of 12.2.7
1.4 Evaluate demographic consequences in relationship to complex linkages between prey availability and foraging behavior	(1, R)	PIFSC	ongoing						Part of 1.1
1.5 Investigate competition with other top predators and commercial and recreational fisheries in the NWHI and MHI	(1, R)	PIFSC/ FWS	1 year	*20*					Evaluation of CRITTERCAM deployments
1.6 Investigate effects of oceanographic variability on prey abundance and availability and on foraging success	(2, R)	PIFSC	annual						Part of 1.1 & 1.2
1.7 Enhance survival by translocating juvenile female seals to areas of higher survival probability	(2, I)	PIRO/ PIFSC	annual	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*	Implement as appropriate based on information from 1.3
1.8 Rehabilitate malnourished juvenile seals when and where food limitation is apparent to salvage their reproductive potential	(1, I)	PIFSC/ PIRO	annual	*1,200*	*1,200*	*1,200*	*1,200*	*1,200*	
TOTAL ACTION 1				***1,920***	***1,900***	***1,900***	***1,900***	***1,900***	

* (P) indicates actions necessary for protection; (I) indicates interventions; and(R) indicates research needs.

2) Prevent entanglements of monk seals									
2.1 Continue programs that facilitate the disentanglement of animals	(1, I)	PIFSC/ PIRO/ FWS	ongoing						Action conducted as part of the annual monitoring program, See 12.1
2.2.1 Continue focused clean-up effort on high entanglement risk zones in the water	(1, I)	PIFSC/ FWS	annual	*1,100*	*1,100*	*1,100*	*1,100*	*1,100*	Augment ongoing work by the Coral Reef Ecosystem Division; this total assumes ongoing funding of $500k
2.2.1.1 Monitor marine debris accumulation rates and identify areas of greatest potential risk	(1, I)	PIFSC/ FWS	annual	*100*	*100*	*100*	*100*	*100*	Augment ongoing work by the Coral Reef Ecosystem Division
2.2.1.2 Remove debris from beaches	(2, I)		ongoing						Part of 2.2.1.
2.3.1 Work with partners to support integration of source markers into fishing gear	(3, R/ I)	PIFSC/ PIRO	annual						Augment ongoing work by the Coral Reef Ecosystem Division - No Cost
2.3.2 Implement education and marine debris programs targeting identified sources	(3, I)	PIRO/ PIFSC	annual	*60*	*60*	*60*	*60*	*60*	Augment ongoing work by PIFSC and PIRO
TOTAL ACTION 2				***1,260***	***1,260***	***1,260***	***1,260***	***1,260***	
3) Reduce shark predation									
3.1 Continue monitoring shark activity and predation events	(1, R)	PIFSC	annual						Included in 12.1
3.2 Remove problem sharks	(1, I)	PIFSC/ PIRO/ FWS/ State of HI	annual	*100*	*100*	*100*	*100*	*100*	
3.2.1 Develop general criteria (and site-specific plans) for shark removal	(1, P/I)	PIFSC	ongoing						Completed on a case by case basis
3.2.2 Refine methods for shark removal	(1, P/I)		ongoing						Included in 3.2
3.2.3 Maintain needed permits for shark removal and/or other intervention	(1, I)	PIFSC/ FWS	ongoing						Included in 3.2

3.2.4 Be prepared for rapid response to predation events	(1, I)	PIFSC	annual	*50*	*50*	*50*	*50*	*50*	
3.2.5 Have trained staff and gear for intervention	(1, I)	PIFSC	ongoing						Included in 3.2
3.3 Continue moving seals after weaning if necessary to protect from predation	(1, I)	PIFSC/ PIRO	ongoing						Included in 3.2
3.4 Characterize trends in shark abundance, movement patterns, and predation losses throughout the NWHI in relation to these interventions and conduct shark behavior research	(1, R)	PIFSC	ongoing	*150*	*150*	*150*	*150*	*150*	
TOTAL ACTION 3				***300***	***300***	***300***	***300***	***300***	
4) Prevent introduction and spread of infectious decrease									
4.1.1 Reduce the risk of exposure of exotic diseases to the Hawaiian archipelago through quarantine, vector control, and education programs	(1, P)	PIFSC/ PIRO/ FWS	annual	*0*	*0*	*0*	*0*	*0*	Included in 4.3 and 13.1
4.1.2 Increase surveillance on Necker and Nihoa Islands as these are the places where interaction between MHI and NWHI seals is most likely	(2, R)	PIFSC/ FWS	annual	*75*	*75*	*75*	*75*	*75*	
4.1.3 Further develop protocols for improving early detection of diseases in seals by opportunistic sampling for diseases	(1, R)	PIFSC/ PIRO	annual	*25*	*25*	*25*	*25*	*25*	
4.1.4 Continue to examine sick animals in the NWHI and MHI to determine cause(s) of disease and treat them appropriately	(1, I)	PIFSC/ PIRO	annual	*35*	*35*	*35*	*35*	*35*	
4.1.5 Develop and implement contingency management plans for known high-risk diseases	(1, R/I)	PIFSC/ PIRO	ongoing						Included in 4.3
4.1.6 Evaluate the use of vaccines for monk seals to high-risk diseases (e.g. morbillivirus, WNV, leptospira vaccines)	(2, R)	PIFSC/ PIRO	annual (see comment)	*75*	*75*	*75*	*75*	*75*	Evaluate after 5 years of effort

4.1.7 Investigate whether controlled research on deworming could be conducted (on other species or on monk seals) in order to improve juvenile survival by reduction of parasite stress, including the potential negative impacts if not conducted properly	(2, R)	PIFSC/ PIRO	1 year	*20*					
4.1.8 Investigate management actions to prevent mother-pup pairs from coming in contact with contaminated streams	(2, I)	PIRO/ PIFSC/ FWS	ongoing	*20*	*20*	*20*	*20*	*20*	
4.1.9 Plan for and take appropriate management actions if northern elephant seals from California are found in the HI chain.	(3, I)	PIRO/ PIFSC	ongoing	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*	Cost to be determined; completed on a case by case basis
4.2 When data is sufficient, determine the associations between reproductive failure, survival and infectious diseases	(2, R)	PIFSC/ PIRO	1 year	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*	Data not currently sufficient to assess
4.3 Maintain current disease monitoring programs	(1, P)	PIFSC/ PIRO	ongoing	*355*	*355*	*355*	*355*	*355*	
TOTAL ACTION 4				***605***	***585***	***585***	***585***	***585***	
5) Conserve Hawaiian monk seal habitat									
5.1.1 PMNM must maintain proclamation provisions and should monitor human activity in the PMNM through the use of observers, video recorders, and/or vessel tracking devices	(2, P)	NOS/ FWS/ PIFSC/ PIRO/ State of HI	annual						No Cost
5.1.2 Maintain current ESA Critical Habitat designations with possible extension as new data are collected	(2, P)	PIRO	annual						No Cost
5.2 Define terrestrial habitat use by sex, age and sub-pop	(3, R)	PIFSC	annual						Part of 12.1
5.2.1 Complete analysis of terrestrial habitat selection by pregnant and lactating females	(3, R)	PIFSC	annual						See 5.2

5.2.2 Examine relationship between pupping habitat type and juvenile survival	(3, R)	PIFSC	annual						See 5.2
5.3.1 Investigate rebuilding pupping habitat and evaluate possible colonization of Johnston Atoll	(2, R)	PIFSC/ PIRO/ FWS	ongoing	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*	Action commensurate with results from feasibility study
5.3.2 Collect high resolution elevation and bathymetry data for the NWHI using Light Detection and Ranging (LIDAR), and wave, wind, and tide level; model shoreline evolution under higher sea level scenarios and devise strategies for active mitigation of hazards [2, R]	(2, R)	PIFSC	3 years	*250*	*50*	*50*			
5.4.1 Strengthen cooperative efforts with agencies and organizations responsible for managing beach areas where local groups or colonies of monk seals may become established in the MHI to ensure that measures are in place to avoid disturbance or displacement of seals that haul out to rest, pup, or molt	(1, I)	PIRO/ PIFSC/ State of HI	ongoing						Included in 8.1
5.4.2 Engage state, county and business officials to minimize loss of monk seal habitat due to development	(2, I)		ongoing						Included in 5.4.1 & 8.1
5.4.3 Complete removal of contaminants (a) and repair sea wall (b) at Tern Island	(3, I)/ (3, I)	FWS	1 year 1 year		*TBD*				Partially done, cost to complete not yet determined
5.4.4 Maintain current contingency plan to deal with environmental disasters	(2, I)	PIRO/ PIFSC/ FWS/ State of HI	annual						Included in 5.4.1 & 8.1
TOTAL – ACTION 5				***250***	***50***	***50***	***0***	***0***	
6) Reduce Hawaiian monk seal interactions with fisheries									
6.1 Reduce direct fisheries interactions			annual	*150*	*150*	*150*	*150*	*150*	
6.1.1 Identify and mitigate the level of direct interaction between commercial and recreational fisheries	(1, R / I)	PIFSC/ PIRO	annual						Part of 6.1

6.1.2 Identify procedures and technology to mitigate interactions	(1, R)	PIFSC/ PIRO	ongoing						Part of 6.1
6.1.3 Identify and mitigate the potential interactions with marine aquaculture	(2, R / I)	PIRO/ PIFSC	annual						Part of 6.1
6.1.4 Identify and mitigate Hawaiian monk seal interactions with fish aggregating devices (FADs)	(3, R / I)	PIRO	annual						Part of 6.1.
6.1.5 Mitigate mortality by removing hooks from seals	(1, I)	PIRO/ PIFSC	ongoing	*50*	*50*	*50*	*50*	*50*	
6.2 Reduce indirect fishery interactions	(2, R / I)	PIFSC/ PIRO	ongoing	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*	Based on research from action 1; action as necessary
6.2.1 Maintain full measures and protective intent of the Proclamation establishing the PMNM	(2, P)	NOS	ongoing						Measures and protections of Proclamation will result from monument process, no additional cost
6.2.2 Use diet analysis, foraging studies, nutritional status, and ecosystem monitoring to evaluate possible competition with fisheries	(3, R)	PIFSC	ongoing						See action 1
TOTAL – ACTION 6				***200***	***200***	***200***	***200***	***200***	
7) Reduce male aggression toward pups/immature seals and adult females									
7.1.1 Identify aggressive males	(1, R)	PIFSC	ongoing						See 12.1
7.1.2 Remove aggressive males, translocate if possible, or euthanize; periodically review criteria for removing aggressive males	(1, I)	PIFSC/ PIRO/ FWS	ongoing						Rely on emergency Prescott funding
7.2 Monitor populations with unknown injuries (to determine cause) by extending/increasing field effort, if necessary to identify cause(s)	(1, I)	PIFSC/ FWS	ongoing						Included in 12.1
7.3 Treat injuries, where/when feasible	(1, I)	PIFSC	ongoing						Included in 12.1
TOTAL ACTION 7 * all included in other costs									

8) Reduce the likelihood and impact of human disturbance									
8.1 Reduce inadvertent disturbance of monk seals by having adequate island coordinators and staff to implement outreach campaigns and volunteer groups to reduce human-seal interactions	(1, I)	PIRO	annual	*800*	*800*	*800*	*800*	*800*	Coverage for all possible user interactions to include main HI Island specific coordinators
8.2 Investigate feasibility of translocating mother-pup pairs or deterring pregnant females from high public use areas to remote locations, and if feasible, consider the use of an ESA enhancement permit to authorize this activity when adequate protection for the pair cannot be provided by other means	(2, I)	PIRO/ PIFSC	annual	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*	Cost to be determined; completed on a case by case basis
8.3 Develop a monk seal pupping and haul-out intervention plan to determine if, when, where, and how monk seals might be moved to reduce risks of potential adverse interactions between seals and people in the MHI	(2, I)	PIRO/ PIFSC	annual						Part of 8.1
8.4 Document and assess procedures for protecting seals that haul-out on recreational beaches	(2, I)	PIRO/ PIFSC	annual						Part of 8.1
8.5 Continue permitting requirement and training process for all NWHI travel to facilitate reduction of human disturbance at breeding sites	(2, P)	NOS/ PIFSC/ FWS	annual						Part of 8.1
8.6 Maintain a research and/or enforcement presence at sites where necessary to prevent human disturbance	(2, P)	PIRO/ PIFSC/ FWS/ OLE	annual						Part of 8.1
8.7 Evaluate and minimize adverse effects of future development or increased use of the NWHI with respect to impact on monk seals; no facility should be constructed in the NWHI without a review by NOAA to ensure compliance with the MMPA and ESA	(2, P)	PIRO/ PIFSC/ FWS/ NOS	annual						Part of 8.1

8.8 Determine if handling associated with the application and removal of telemetry and data-logging devices alters the behavior or hauling site preferences of seals	(3, R)	PIFSC	ongoing						Included in 12.1
TOTAL ACTION 8				***800***	***800***	***800***	***800***	***800***	
9) Investigate and develop response to biotoxin impacts									
9.1 Develop contingency plan to manage a biotoxin dieoff in monk seals, considering possible steps to detect, capture, and rehabilitate monk seals that are affected by biotoxins	(2,P)	PIFSC/ FWS	ongoing	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*	Cost to be determined; completed on a case by case basis
9.2 Develop an appropriate and sensitive assay for biotoxins and metabolites in tissues of monk seals and prey species	(2, R)	PIFSC	3 years	*100*	*50*	*50*			
9.3 Investigate biotoxin dose-response effects on monk seals through opportunistic sampling and retrospective studies	(3, R)	PIFSC/ FWS	annual	*125*	*50*	*50*	*50*	*50*	$100K for assay, plus annual testing and monitoring
9.4 Develop a collaborative link with Harmful Algal Bloom monitoring programs, for detection of potential toxic blooms	(3, P)	PIFSC/ FWS	annual	*25*	*25*	*25*	*25*	*25*	
TOTAL ACTION 9				***250***	***125***	***125***	***75***	***75***	
10) Reduce impacts from compromised and grounded vessels									
10.1 Ensure monk seal concerns are included in all grounding response planning	(3, P)	PIRO/ PIFSC/ FWS	annual						Part of 8.1
10.2 Provide a rapid response, removal, and ecological assessment and monitoring of vessel groundings	(2, P/I)	PIRO/ FWS	annual	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*	Cost to be determined; completed on a case by case basis and will implement as necessary

10.2.1 Identify and pre-place equipment on appropriate islands to ensure a rapid response	(3, P)	PIRO/ PIFSC/ FWS	annual	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*	Cost to be determined; completed on a case by case basis and will implement as necessary
10.2.2 Establish a trained, well-equipped emergency response team to evaluate and potentially treat HMS during an event	(3, P)	PIRO/ PIFSC/ FWS	annual						Part of 8.1
10.2.3 Identify experts and develop protocols for habitat restoration activities	(3, P)	PIFSC/ PIRO/ FWS	annual						Part of 8.1
10.2.4 Ensure proper funding for monk seal and habitat monitoring post-event	(2, P)	PIRO	annual	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*	Cost to be determined; completed on a case by case basis and will implement as necessary
10.2.5 Maintain contingency plan outlining how agencies work together during an event	(3, P)	PIRO	annual						Part of 8.1
10.2.6 Immediately remove debris from a grounding that might result in entanglement of monk seals	(1, I)	PIFSC/ FWS	annual						Part of 2.2.1
10.2.7 Publish response plans	(3, I)	PIFSC/ PIRO/ State of Hawaii	annual						Part of 8.1
10.2.8 Provide educational material for appropriate response plans	(3, I)	PIRO	annual						Part of 13.3
TOTAL ACTION 10				***0***	***0***	***0***	***0***	***0***	
11) Reduce the impact of contaminants									
11.1 Continue collection of samples from seal and prey species and banking of samples for potential contaminant monitoring	(3, R)	PIFSC/ FWS	ongoing						Part of 12.1

11.2 Examine data for association between reproductive failure and exposure to contaminants and conduct a risk assessment specific for monk seals	(3, R)	PIFSC	1 year	*50*						
TOTAL ACTION 11				***50***						
12) Continue population monitoring and research										
12.1 Continue annual monitoring in the NWHI	(1, R)	PIFSC/ FWS	ongoing	*1,300*	*1,300*	*1,300*	*1,300*	*1,300*		
12.2.1 Record identities of all seals using each site	(1, R)	PIFSC	ongoing							Part of 12.1
12.2.2 Identify seals that move between subpopulations	(1, R)	PIFSC	ongoing							Part of 12.1
12.2.3 Record observed threats to survival	(1, R)	PIFSC	ongoing							Part of 12.1
12.2.4 Record reproductive data using all current techniques	(1, R)	PIFSC	ongoing							Part of 12.1
12.2.5 Adjust timing of annual field studies to optimize demographic data collected	(1, R)	PIFSC	ongoing							Part of 12.1
12.2.6 Assign pups to mothers using DNA methods	(2, R)	PIFSC	1 year			*100*				Part of 12.1 Feasibility study
12.2.7 Develop methods to integrate the demographic monitoring with management experiments, foraging studies, prey abundance surveys, and oceanographic monitoring, with an aim to eventually resolving the causal factors that are important in influencing the vital rates	(1, R)	PIFSC	ongoing							Part of 12.1
12.3.1 Improve database accessibility and develop database management manual	(1, R)	PIFSC	ongoing							Part of 12.1
12.3.2 Continue annual site-specific and NWHI-wide statistical analyses	(1, R)	PIFSC	ongoing							Part of 12.1
12.4.1 Maintain monk seal population model	(1, R)	PIFSC	ongoing							Part of 12.1

12.4.1.1 Implement MHI research plan to assess distribution, abundance, movements and vital rates of monk seals in the MHI	(1, R)	PIFSC	annual	*250*	*250*	*250*	*250*	*250*	Augments MHI population monitoring program
12.4.1.2 Add annual NWHI, MHI data	(1, R)	PIFSC	ongoing						Part of 12.1 & 12.4.1
12.4.2 Develop PVA for monk seals	(1, R)	PIFSC	1 year		*50*				
12.4.3 Develop models linking foraging, diet, physical condition of seals and demography	(1, R)	PIFSC	ongoing						Part of 1.1, 8.1 & 12.1
12.5 Conduct hypothesis driven ecological experiments to evaluate potential options for enhancing monk seal recovery	(3, R)	PIFSC	ongoing						Part of 1.1, 8.1 & 12.1
TOTAL ACTION 12				***1,550***	***1,600***	***1,650***	***1,550***	***1,550***	
13) Create a Main Hawaiian Islands Hawaiian Monk Seal Management Plan									
13.1 Develop a MHI monk seal management plan that addresses all critically important assessment, disease, regulatory, intervention, coordination, and education needs	(1, P/I/R)	PIRO/ PIFSC	2 years	*50*	*50*				
13.2 Implement the MHI management plan	(1, P/I/R)	PIRO/ PIFSC							Included in other action items, particularly 8.1 and 13.3
13.3 Implement a statewide, multi-media information campaign, drawing on professional expertise in public education and social marketing.	(1, P)	PIRO/ PIFSC	ongoing	*150*	*150*	*150*	*150*	*150*	
13.4 Use a performance monitoring and evaluation system to measure the effectiveness of education and outreach activities and to identify program changes to enhance effectiveness	(2, P)	PIRO/ PIFSC							Part of 13.3

13.5 Target numerous audiences including, fishers, marine resource managers, beach and ocean users, and the visitor industry	(1, P)	PIRO/ PIFSC/ State of Hawaii							Part of 13.3
13.6 Complete a focused survey about the social behaviors and relationships of monk seals to investigate the cultural concerns of the Native Hawaiian community, the general public perception of Hawaiian monk seals and the nearshore interactions with fishermen, divers, public to evaluate frequency, characteristics, and impacts of interactions	(2, P)	PIRO/ PIFSC/ State of Hawaii							Part of 13.3
TOTAL ACTION 13				***200***	***200***	***150***	***150***	***150***	
14) Implement the Hawaiian Monk Seal Recovery Program									
14.1Hire a Hawaiian Monk Seal Recovery Coordinator for NMFS PIRO to ensure the timely and efficient implementation of the revised recovery plan and coordination among PIRO, PIFSC, and other agencies and non-governmental organizations	(1, P)	PIRO	ongoing	*150*	*150*	*150*	*150*	*150*	
14. 2 Support an integrated education and outreach program by NOAA Fisheries in close collaboration with other government agencies and non-government partners. Program goals should include minimizing human disturbance and other adverse impacts and maximizing public support for conservation activities	(1, P)	PIRO/ PIFSC/ State of Hawaii	ongoing						Part of 13.3
14.3 Maintain staffing needed to address management concerns in the NWHI and MHI	(1, P)	PIRO/ PIFSC/ State of Hawaii	annual						Part of 8.1

14.4 Maintain a research program in the NWHI and the MHI sufficient to provide the information required by managers	(1, P)	PIRO/ PIFSC/ State of Hawaii	annual						Part of 1.1 & 12.1
14.5 Maintain a Hawaiian Monk Seal Recovery Team and use the team to provide outside advice and review of actions needed to accomplish recovery	(1, P)	PIRO	annual						Part of 8.1
14.6 Revise the Recovery Plan for the Hawaiian Monk Seal at appropriate intervals	(1, P)	PIRO	ongoing	*20*	*20*	*20*	*20*	*20*	
TOTAL ACTION 14				***170***	***170***	***170***	***170***	***170***	
TOTAL ALL ACTIONS				***7,555***	***7,190***	***7,190***	***6,990***	***6,990***	

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VIII APPENDIX A. CARRYING CAPACITY INFORMATION

The concept of carrying capacity for a population rests upon the basic idea that as a population grows in size it reaches some level where the resources it depends upon become limiting and this limitation leads to changes in population vital rates. Eberhardt (1977) has suggested that one of the first rates to be influenced is juvenile survival, followed by a decrease in reproductive rates and an increase in age of maturity. Hawaiian monk seals in the French Frigate Shoals sub-population have exhibited these characteristics during the past ten years or so. Thus, changes in population vital rates of this group certainly appear to demonstrate the classic characteristics of a population having reached a level where resources were limiting population growth.

This rather classic case of density-dependent change in vital rates of a population reaching the carrying capacity of its environment has rarely been documented for pinnipeds (e.g., Fowler, 1990). This has led to the idea that perhaps there is something different about monk seals with respect to their relationship between resources and population levels. However, it is also possible that the lack of long-term information on vital rates and population abundance of other pinniped species in this regard bias our perceptions. For example, studies have revealed what appear to be classic density-dependent changes in the vital rates of harp seals (Bowen et al. 1981; Cabot et al. 1996; Sjare et al. 1996) and grey seals (W. D. Bowen unpublished data) in the Northwest Atlantic, in Antarctic fur seals (Doidge et al. 1984) and northern fur seals (Fowler 1990). Thus, additional data on a wider range of species may show, as might be expected, that pinnipeds respond to resource limitation in the same way as other mammals.

Nevertheless, there are characteristics of monk seal habitat that suggest they may respond more strongly to environmental variability than many other species of pinnipeds. In general, the sub-populations of monk seals are small today and were presumably always relatively small given the limited availability of terrestrial, and perhaps, aquatic habitat. All extant pinniped species inhabiting tropical environments occur in small sub-populations and therefore will be greatly affected by stochastic and large scale variability. There is evidence that inter-annual and long-term oceanographic variability around the Hawaiian Islands significantly affects the productivity of the reef ecosystem upon which monk seals depend. However, oceanographic changes may have stronger effects in some parts of the species range than others. Thus prey availability could change relatively quickly throughout monk seal range seriously impacting the vital rates of specific sub-populations. Monk seals also consume an extremely large number of prey species in comparison to temperate and polar seal species. This may reflect the lower abundance of individual prey species and the overall greater level of biodiversity of prey than found in temperate or polar ecosystems. By contrast, the more abundant pinniped species are usually found in highly productive areas associated with nutrient upwelling or oceanographic fronts.

Thus, the small sub-populations of the tropical seals are presumably simply a reflection of the ecosystems in which they occur and therefore subject to a highly variable prey base. Tropical systems do not possess the potential to support large populations of pinnipeds because of the lack of abundant forage fish or euphausiid populations, typical of colder water ecosystems. They may also face greater levels of competition from a more diverse group of fish predators. Given that monk seals will never be very abundant in any one location, but that they have persisted for millions of years, the re-establishment of monk seals on the main Hawaiian Islands is probably an essential element in increasing carrying capacity and thus promoting the recovery of this endangered species.

IX APPENDIX B. STOCHASTIC SIMULATION MODEL FOR THE HAWAIIAN MONK SEAL

1. Model background and description

The population as a whole has been declining for as long as there have been reliable records (about 50 years). For approximately the latter half of this time, considerable protection, including mitigation of threats, has been in place. That protection has been dramatically effective in reducing human disturbance at the 6 major NWHI sub-populations, and interventions to deal with male aggression and pup survival on some of the islands have definitely been effective. Nevertheless, the population continues to decline, albeit at a slower rate than in the earlier half of this period. The causes of the ongoing decline are poorly understood, and it is not certain whether new contemplated interventions are likely to reverse it. For this reason it is not possible, with present knowledge, to specify what particular actions need to be in place in order to control or eliminate all the various threats to the species survival. For the same reason, with present knowledge our only indicators as to whether those threats have been controlled will simply be the observation for a sustained period of sufficiently favorable demographic rates, in conjunction with a large enough population size to buffer against random natural downturns in conditions.

In the NWHI, where almost all the present population lives, the six respective main sub-populations have individually exhibited more volatility in dynamics than has the population total. Some sub-populations have undergone episodes of sustained population growth, some have undergone episodes of sustained decline, and some rookeries have manifested both substantial growth and substantial decline during the course of the roughly half century of observation. The reasons for these changes in dynamics have not been resolved unambiguously (though there are some hypotheses), and for the time being are treated as "random" in this analysis. The periods of sustained increase or decrease are fairly long, so there is no sufficient sample size of observations to reliably characterize the expected duration, or intensity, or degree of synchrony of these episodes, and there is no clear signal of the strength of density dependence in moderating declines at lower levels of local crowding.

If these dynamics really are effectively random, and compensation is in fact weak at low local population densities, it will be crucial for there to be (a) multiple independent sub-populations to provide risk spreading, and (b) an increased average population size to sustain random declines. A scenario in which a population size of 2,900 individuals would provide enough buffer against random decline that the population would have a 99% probability of persistence above a population level of 50 individuals for 100 years, consistent with our proposed standard. A population below 50 would be considered effectively extinct. Imagine that the realized overall annual population decline rates of 0.7% (post 1993), as estimated by Carretta et al. (2002), and 4.3% (1950s till 1993), characterize the growth rates associated with random environmental phases, and that each phase has an annual persistence probability corresponding to a mean persistence time of 20 years. With these assumptions, a population initialized as 2,900 individuals would have a 1% probability of declining to effective extinction within the next 100 years.

In order for the population as a whole to experience these rates, all the six major NWHI sub-populations would need to be functioning in the population. Further, this would require a substantial sustained growth in the MHI sub-population, as evidence that management measures are allowing this habitat to be utilized and that disease from close proximity to humans and domestic animals is not taking a toll.

For the time being then, an interim criterion for downlisting to threatened has been proposed with a total population size of 2,900 individuals, with each of the six major NWHI sub-populations above 100 individuals, and the MHI sub-population above 500. The NWHI segment of the population probably was at least this large 50 years ago (at which time it was probably somewhat depressed from disturbance during WWII). Soon after, the human population at Midway escalated to near 3,000; a USCG Loran Station was placed at Kure in 1960; and military flights commenced at PHR. The seal populations at these western sites plummeted during the 1960s-19070s leading to the species' endangered listing in 1976. There has been no known alteration of habitat to preclude attainment of this presumed post-WWII population level (though there are outstanding questions about effects of fisheries and about "normal" or global climate change effects on the productivity of the NWHI ecosystem).

Nevertheless, based on the present evidence that the population is still declining, for reasons that are poorly understood and therefore not amenable to mitigation with a high degree of certainty, there is no prospect that the population will attain recovery, in the near future. If and when the population does satisfy these interim recovery criteria, it is very probable that enough new information will have been learned by that time to justify revision of the recovery criteria. There is evidence from observed population growth at some sites for some periods of time that monk seal populations have the biological capacity, under favorable circumstances, to grow at a rate of around 7% annually. Thus, if the current population total of roughly 1200 individuals were to grow sustainably at this best case rate, the population could attain the population total criterion level for the NWHI in just 12 years, and the MHI, assuming it is 52 individuals, could reach the MHI criterion level in 34 years. There are no indications at present that such a period of sustained growth is about to begin, and recovery is not expected in the foreseeable future.

Future research may provide more information that would allow modeling the monk seal populations on a basis that depended more on causal mechanisms and less on stochasticity and simple monitoring of demographic rates. Future experimentation may uncover additional effective interventions. Future research may reveal causal links between monk seal population dynamics and oceanographic conditions, and the changes in oceanographic conditions may turn out to be at least partly predictable. Statistical analysis of results from continued monitoring of the population may indicate the strength of density dependence, both at high densities and at low densities, allowing modeling that is less determined by random walk processes even though it is still stochastic. All these eventualities would lead to a better understanding than what exists now, and would permit more predictive modeling and more reliable intervention. Increased understanding would probably justify revisions to the interim recovery criteria that are proposed now while still adhering to the proposed standard.

The monk seal simulation model was developed through a collaborative effort between biologists with the NMFS Pacific Islands Fisheries Science Center (Ragen, 1994-97, unpublished work) and researchers at Montana State University (Harting, 2002). The model is designed to represent the monk seal's life history as accurately as possible, and includes the capability to simulate specific natural perturbations and/or management options. It is intended as both an exploratory tool for management and research planning and as a tool to better understand the implications of recent vital rates and natural perturbations on population trends.

The model uses as inputs all of the demographic rate data on monk seals that have been collected by NMFS and other agencies and cooperators over the last 20 years. Using those data it can then simulate (for each atoll and each year) events including natural survival (with optional catastrophes), births (with optional catastrophes), specific natural perturbations (optionally: single male aggression, multiple male aggression, and shark predation), migration between islands, and management actions (captive rearing, translocation, head start of pups, and adult removals). Uncertainty in the input parameters or the method by which processes operate is considered at all stages of the simulation. The primary output of the model is the population trajectory over time, but a number of other statistics (e.g., the final age/sex structure, or the pup production in the final year) are also produced.

2. Applications of the monk seal model

The exact results of simulation models should be viewed with caution (Ralls and Taylor, 1997; Beissinger and Westphal, 1998; Reed et al., 1998; Fieberg and Ellner, 2000; Coulson et al., 2001). With this in mind, this section of the Plan describes important aspects of the simulation model and briefly demonstrates some of its capabilities. The monk seal simulation model is best suited for comparing the relative outcomes from a set of contrasting scenarios, for example a properly designed baseline scenario compared to a scenario with a specific perturbation or management action. Projections from the model will be most reliable when performed over a short time horizon (5-10 years). When the line of investigation requires longer projections, multiple simulation scenarios should be performed so that a wide range of possibilities is represented.

The model can operate with density dependence and without density dependence. If runs are performed with no density dependence, the trajectories follow the intrinsic growth rate that results from the specified life table. Atolls with a positive annual growth rate (lambda) will increase at that rate, and atolls with negative growth rates will decline to eventual extinction. The statement that the population will grow at the lambda of the lifetable applies to populations at stable age distribution. Age structure anomalies (a particular problem at FFS) can have a major effect on the actual, realized growth rate in the near-term.In the latter case, the only opportunity for rescue is via dispersal from other atolls.

Non-density dependence runs of the model clearly do not conform to reality (for example, Laysan Island increases to over 800 seals in less than 25 years), and realistic simulations require some density-dependent regulation of demographic rates. However, there are few data that can be used to characterize the type and magnitude of density dependence in monk seal populations. Thus, the simulation model provides three alternative density-dependence models and four types of density- dependent regulation (pup/juvenile survival, early reproduction, mature reproduction, and mature survival). Harting (2002) described the complexities of selecting parameters to use in the density dependence formulation. Generally, parameters are set such that population growth for the base scenario (no perturbations) conforms to recent trends. Additional discussion regarding the role of density dependence in simulation models is available in the ecological literature (e.g., Burgman et al., 1993; Mills et al., 1996).

Short-term projection using current demographic rates

One obvious application of the model is to help evaluate the implications of recent demographic rates by projecting the current population forward over a short time span with no density dependence. Because the most recent (2003) estimates of demographic rates give a lambda of less than 1.0 for all breeding sites except Laysan Island (NMFS unpublished data), and current age structures are not sufficient to compensate for the unfavorable lambdas, it is not surprising that the trajectories indicate a decline for all sites except Laysan. This simple projection provides a general baseline for comparing the results of more complex scenarios.

Use of the model for simulating natural perturbations

The model can be used to help understand the response of the monk seal population to major perturbations. Consider a generic survival catastrophe that reduces survival rates of young seals up to 50% (the effect is reduced with age) for 3 years. The annual probability that a survival catastrophe will begin is 0.25. Over a 25-year period, periodic survival catastrophes of this severity would reduce the final abundance at all atolls by a significant amount (Figure App.B.1). However, the predicted magnitude of the effect is very different at the different atolls. For example, the mean final abundance at Kure was reduced by only 5%, whereas the other atolls experienced > 20% reduction and FFS declined by 65%. An atoll's relative resilience to this perturbation is related to the initial age and sex structure: sub-populations with a greater proportion of young females are better able to withstand the impacts of survival catastrophes.

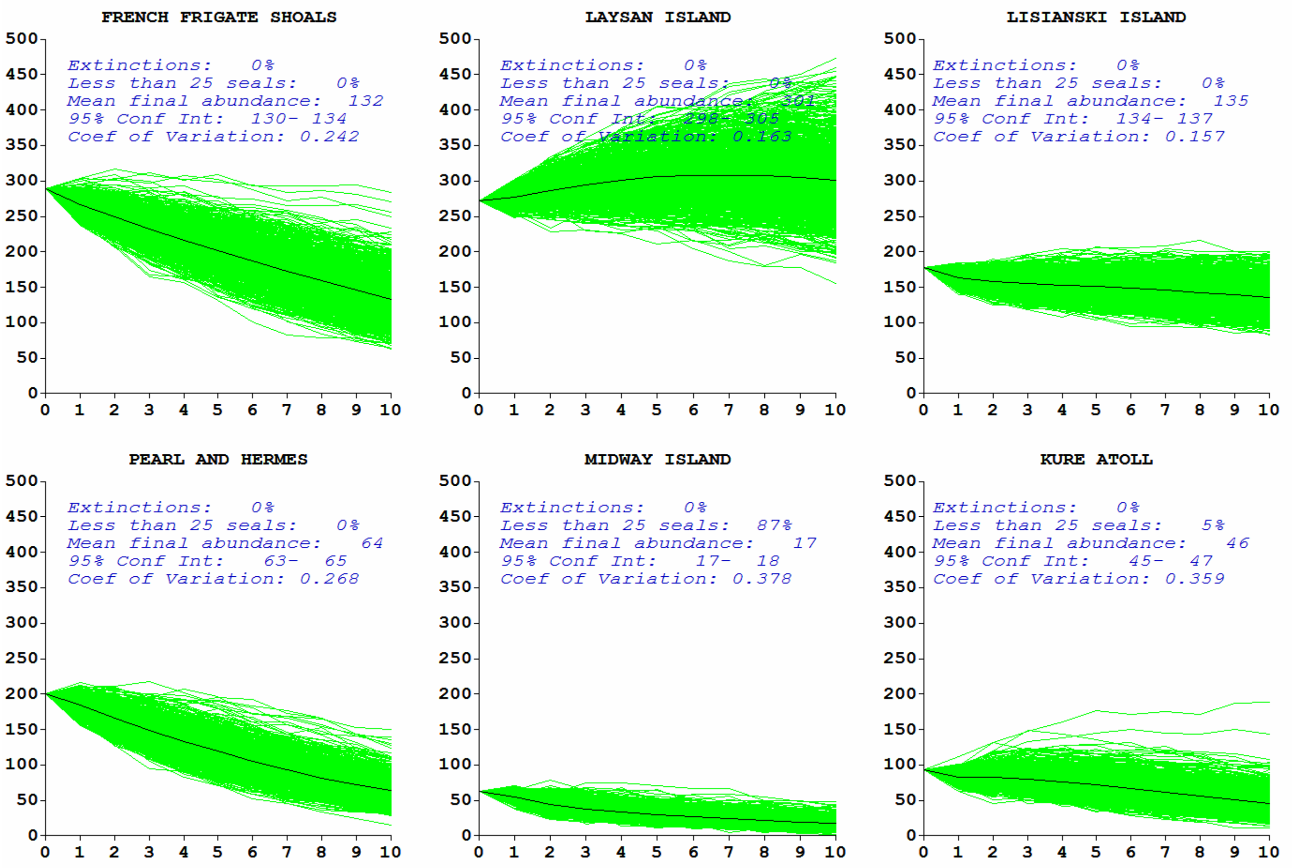


Figure App.B.1. Trajectory plot for 10-year projection using current demographic rates and initialized at current (2003) age/sex composition. Source: NMFS.

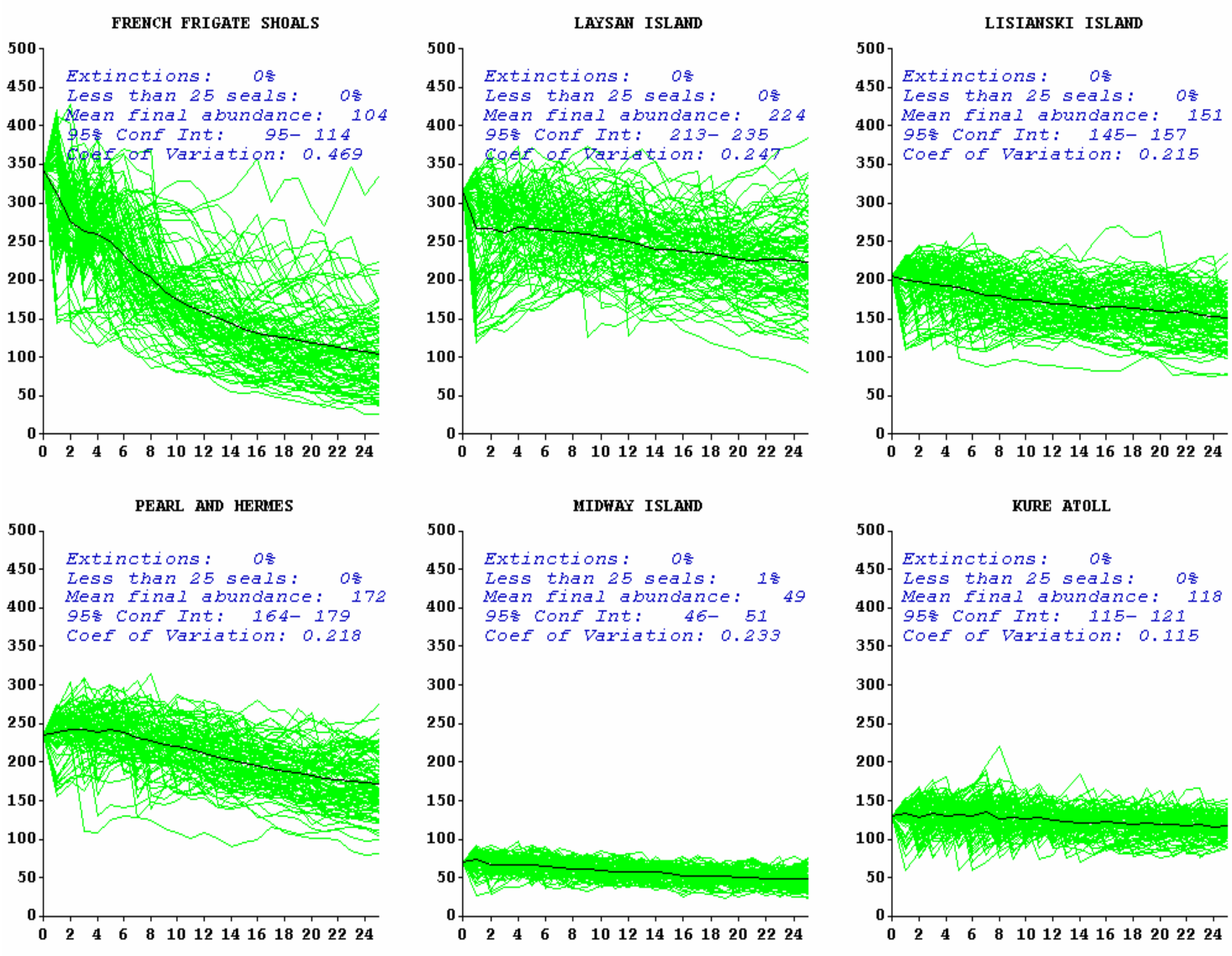


Figure App.B.2. Trajectory plot for 25-year projection with density dependence and periodic survival catastrophes (n=1000 simulations; mean value at each time step indicated by dark line). Source: NMFS.

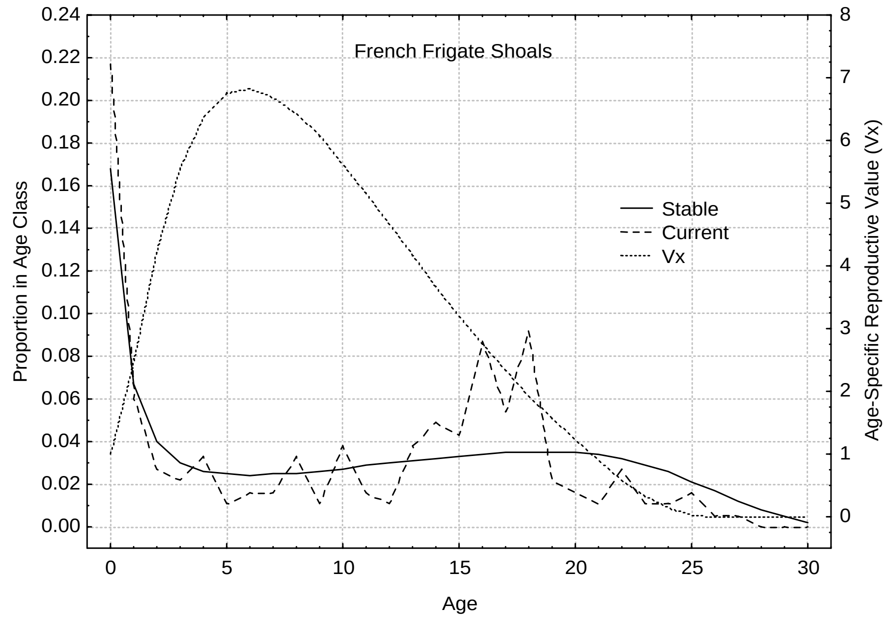
Use of the model to evaluate factors impeding recovery

The simulation model can be used to investigate the expected effects associated with the three major demographic factors constraining recovery at French Frigate Shoals: unbalanced age structure, poor juvenile survival, and low fecundity. To minimize the confounding effect of other factors, 10-yr simulations with no density-dependent regulation were run. All scenarios discussed below include 1000 simulations, with demographic stochasticity and parameter uncertainty incorporated in the simulations.

As previously noted, the current age structure at French Frigate Shoals has few pre-reproductive and early-reproductive females relative to the proportions associated with stable age distribution for the current lifetable. The result of this condition can be seen by comparing the relationship between the current age structure, the stable age structure, and the age-specific reproductive value (v_x; Figure App.B.3). The latter measure pertains to the expected future reproductive contribution of a female currently of age x. Age-specific reproductive value is a relative measure, scaled in units of "newborn value" (with a newborn seal assigned $v_x = 1.0$).

Using the estimated reproductive and survival rates for recent years, the highest age-specific reproductive values (v_x) at FFS are for ages 4-8, when each female is "worth" more than six newborns (Figure App.B.3). The observed pattern is largely attributable to low survivorship from birth to age five such that fewer than 10% of female seals which *do* survive to this age are worth considerably more than a newborn. The current age structure is deficient in those ages with the highest v_x (Figure App.B.3).

In contrast, the current age structure for Laysan Island, while unlike the stable age distribution, has an overabundance in certain age classes of both young (ages 4-7) and older (> age 17) aged females. Because the departure includes both high and low v_x ages, the implications for population recovery are less obvious than for French Frigate Shoals. However, the surfeit of young, reproductively active females (again, relative to the stable age structure) is transient and serves to boost the realized growth rate only in the short term. As the population settles toward stable age structure, the growth rate is likely to decline. At both atolls, the validity of these interpretations hinges on demographic rates remaining at approximately current levels.



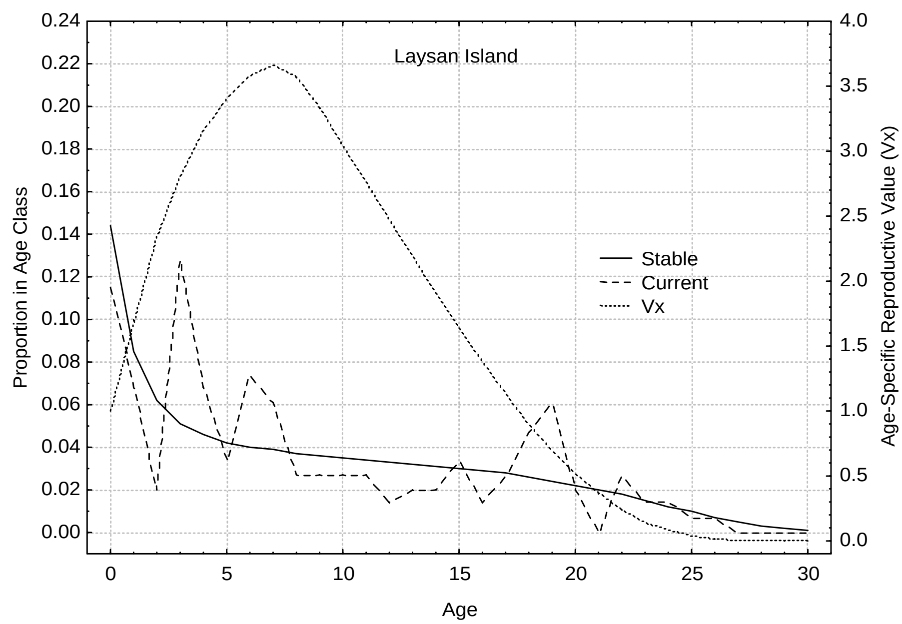


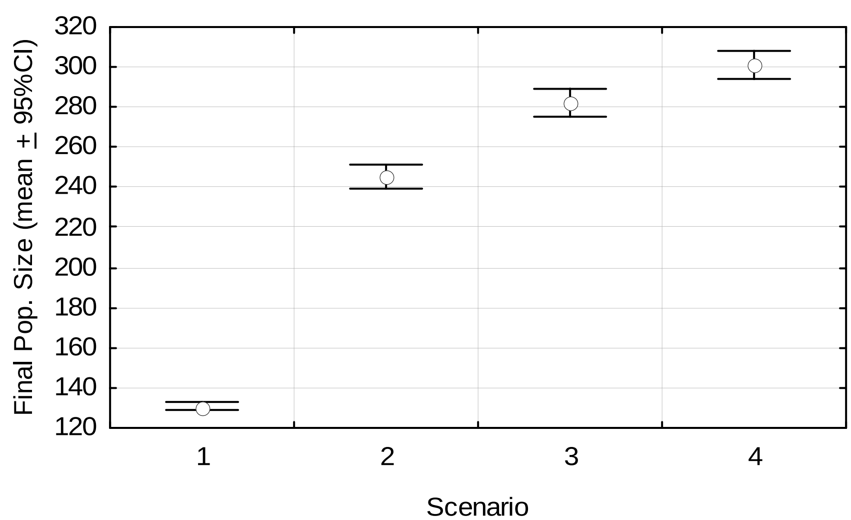
Figure App.B.3. Current age distribution, stable age distribution, and age-specific reproductive value (v_x) at French Frigate Shoals and Laysan Island (2002 values). Source: NMFS.

The next set of simulation exercises pertains to the poor juvenile survival rates at French Frigate Shoals. Changing the survival parameter that most strongly governs juvenile survival (Siler model parameter *a1*) to match the estimated value for Laysan Island raises both pup and juvenile survival at FFS. If the population is then projected using this hypothetical survival curve (ten years, with no density dependent regulation), the mean final abundance increases from 130 to 245 seals (88% increase; Figure App.B.4 Scenario 2). When coupled with higher immature survival (as in Scenario 2), projections using increased age-specific fecundity (i.e., higher asymptotic rate and no senescent decline), initialized at the observed 2003 age structure, lead to a mean final abundance of 286-303 seals (Figure App.B.4: Scenarios 3-4).

Comparisons of the mean final abundance for all four of the above scenarios (Figure App.B.4) can be summarized as follows: the influence of poor age structure, low immature survival, and low fecundity is intertwined, and improvement in any one, whether singly or in concert with the others, is likely to improve the outlook. However, juvenile survival exerts the greatest influence of the three. The influx of additional females to augment the breeding population, or improved reproduction among the females already present, will lead to only modest gains unless survival to reproductive maturity also improves. Should conditions at the atoll improve in such a way that both immature survival and fecundity are enhanced (as by an increase in prey availability), then the outlook for the atoll is substantially better than when the population is projected forward with the rates fixed at the most recent estimates.

Figure App.B.4: Mean final abundance at French Frigate Shoals from simulation scenarios testing effects of age structure, juvenile survival, and reproductive rate. (Bars indicate 95% confidence intervals for the mean). Scenario codes are:

1. Baseline scenario (current age structure and rate estimates)
2. Improved pup/juvenile survival
3. Improved immature survival + Laysan maximum fecundity
4. As in #4, but with no senescent decline in fecundity



X APPENDIX C – SURVEY OF EXISTING FEDERAL LEGAL PROTECTIONS FOR THE HAWAIIAN MONK SEAL

A variety of powerful federal laws provide protection to Hawaiian monk seals and their habitat. The monk seal is a not only a federally designated endangered species protected by the provisions of the Endangered Species Act (16 U.S.C. Section 1531 et seq.), but also a marine mammal, protected under the Marine Mammal Protection Act (16 U.S.C. Section 1361 et seq.). While in the NWHI, the seals may benefit from the Nation's highest form of marine environment protection afforded by the PMNM as established by Presidential Proclamation 8031 as authorized by section 2 of the Antiquities Act of June 8, 1906 (16 U.S.C. 431). When within certain areas of the main Hawaiian Islands, designated as a federal national marine sanctuary for the humpback whale, monk seals may also derive benefits from the National Marine Sanctuaries Act (16 U.S.C. Section 1431 et seq.) and the Hawaiian Islands Humpback Whale National Marine Sanctuary Act (Subtitle C, Public Law 102-587 as amended by Public Law 104-283, Section 2302 et seq.).

The ecosystems which form monk seal habitat derive benefit from an array of laws including the Act to Prevent Pollution from Ships (33 U.S.C. Section 1901 et seq.), the Clean Water Act (33 U.S.C. 1251 et seq.), the Clean Air Act (42 U.S.C. 7401 et seq.), the Oil Pollution Act (33 U.S.C. Section 2701 et seq., 46 U.S.C. Section 3703a.), the Resource Conservation and Recovery Act (42 U.S.C. Section 6901 et seq.), the Coastal Zone Management Act (16 U.S.C. Section 1451 et seq.), and the Comprehensive Environmental Response, Compensation and Liability Act (42 U.S.C. Section 9601 et seq.). The Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1801 et seq.) allows federal management of the nation's fisheries which are similarly a food source for the monk seal. The National Environmental Policy Act (42 U.S.C. 4321 et seq.) may also provide benefit via its requirement that actions proposed, permitted or funded by federal agencies are subject to environmental planning review prior to implementation.

Endangered Species Act

The Endangered Species Act, specifically 16 U.S.C. 1538, similarly prohibits the "take" of an endangered species. The penalty for violating this prohibition can be as high as $50,000 and a year in prison as set forth at Section 1540. A specific regulation, issued pursuant to the Endangered Species Act and published at 50 CFR 224.103 (a) , created a protective zone around humpback whales requiring vessels not to approach humpback whales, within 100 yards by vessel or 1,000 feet by aircraft, when these whales are within 200 nautical miles of the Hawaiian Islands. No such stand off zone has been established for monk seals leaving the prohibitions subject to human interpretation of an animal's behavior if the offending activity results in something less than discernable physical injury to or death of the animal.

The Endangered Species Act, at 16 U.S.C. Section 1533, also provides for the designation of habitat which is deemed to be critical to the survival of the species, giving that habitat a protected status equal to that of the individual animal. The beaches and waters around the northwest Hawaiian Islands to a depth of 20 fathoms were designated in 1988 as critical habitat for the monk seal.

Marine Mammal Protection Act

The Marine Mammal Protection Act, specifically 16 U.S.C. Section 1372, makes it unlawful to "take" a marine mammal. Take includes direct action against a seal such as harassment, hunting, capturing or killing them. Harassment includes any act of pursuit, torment or annoyance which has the potential to injure an animal or to disrupt their behavioral patterns, such as migration, breathing, nursing, breeding, feeding or sheltering. The penalty for participating in this behavior and causing this result can be as high as $20,000 and a year in prison, as set forth at Section 1375.

The Papahanaumokuakea Marine National Monument (PMNM)

On June 15, 2006, President Bush signed the Presidential Proclamation 8031 (71 FR 36443, June 26, 2006; 71 FR 36443, June 26, 2006) that created the Northwestern Hawaiian Islands Marine National Monument under the authority of the Antiquities Act (16 U.S.C. 431). The Proclamation reserves all lands and interests in lands owned or controlled by the government of the United States in the NWHI, including emergent and submerged lands and waters, out to a distance of approximately 50 nmi from the islands. The outer boundary of the Monument is approximately 100 nmi wide and extends approximately 1200 nmi around coral islands, seamounts, banks, and shoals. The area includes the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, the Midway Atoll National Wildlife Refuge/Battle of Midway National Memorial, and the Hawaiian Islands National Wildlife Refuge. The monument will be managed by the Department of the Interior's U.S. Fish and Wildlife Service and the Commerce Department's National Oceanic and Atmospheric Administration, in close coordination with the State of Hawaii.

This national monument enables nearly 140,000 square miles of the Northwestern Hawaiian Islands to receive our Nation's highest form of marine environmental protection. It honors the government's commitment to be good stewards of America's natural resources, shows what cooperative conservation can accomplish, and creates a new opportunity for ocean education and research for decades to come. The national monument will: preserve access for Native Hawaiian cultural activities; provide for carefully regulated educational and scientific activities; enhance visitation in a special area around Midway Island; prohibit unauthorized access to the monument; phase out commercial fishing over a five-year period; and ban other types of resource extraction and dumping of waste. This PMNM is the largest single area dedicated to conservation in the history of the United States and the largest protected marine area in the world.

The National Marine Sanctuaries Act

The National Marine Sanctuaries Act, specifically 16 U.S.C. 1436, prohibits behavior which results in the destruction of or injury to any sanctuary resource managed under a law or regulation for a given sanctuary. The penalty for this behavior may be as high as $100,000 and vessel forfeiture as set forth at Section 1437, as well as liability for damage and response and damage assessment costs, as set forth at Section 1443. Within the Hawaiian Islands Humpback Whale National Marine Sanctuary, humpback whales and the portion of area designated as being within the published sanctuary boundary are designated as sanctuary resources (15 CFR 922.180 et seq.). Monk seals may occupy this area designated as humpback whale habitat and a sanctuary resource, and therefore derive benefits from that resource being protected by law from injury or destruction.