

**Programmatic Environmental Assessment of the Program for Decreasing or
Eliminating Predation of Pre-weaned Hawaiian Monk Seal Pups by Galapagos
Sharks in the Northwestern Hawaiian Islands
Pacific Islands Fisheries Science Center (PIFSC),
Protected Species Division (PRD)
Hawaiian Monk Seal Research Program (HMSRP)
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Executive Summary

The purpose of this Programmatic Environmental Assessment (PEA) is for the National Marine Fisheries Service (NMFS) to consider the potential environmental impacts of research activities conducted by the Protected Species Division (PSD) at the Pacific Islands Fisheries Science Center (PIFSC). This PEA fulfills the requirements of the National Environmental Policy Act (NEPA) and the National Oceanic and Atmospheric Administration's (NOAA) Administrative Order NAO 216-6 to analyze the environmental impacts of a proposed federal action as the basis of informed decision making.

The scope of the proposed research involves research activities to reduce predation by Galapagos sharks on Hawaiian monk seal pre-weaned pups by undertaking several different approaches. Most of the research would be conducted at French Frigate Shoals (FFS), although other sites would be considered if Galapagos shark predation on pre-weaned pups is documented. The activities analyzed in this PEA include monitoring Galapagos shark activities adjacent to seal pupping areas, mimicking human presence by broadcasting small boat sounds and maintaining unoccupied boats at anchor, deploying magnetic and electromagnetic devices to decrease Galapagos shark presence near pre-weaned monk seal pups, and removing up to 40 Galapagos sharks over at least a 2-year period using a suite of fishing methods. Fishing methods under the current program (no action alternative) include handline, trolling, harpooning, drumline, and bottomset. All such fishing would be highly restricted, occurring in shallow waters and using a limited number of hooks. Under the proposed action, any of the activities of the current program could be conducted, plus fishing could be expanded to occur in deeper waters (up to 10 fm), further from pupping sites, and using more hooks, possibly with 40 sharks being removed in a single year. This expanded fishing operation would only be available as a shark predation mitigation measure if certain conditions were met, as detailed in this PEA.

This analysis presents information on the anticipated effects to the physical environment resulting from the proposed activities, as well as potential effects to the biological environment, including marine mammals, sea turtles, Galapagos sharks, other fishes, seabirds, and corals. With mitigation measures in place to prevent seal and turtle entanglements or hookings, no significant impacts would occur.

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1 Purpose and Need

1.1 Need for Action

1.1.1 Introduction and Summary of the Proposed Action

The Protected Species Division, Pacific Islands Fisheries Science Center (PIFSC), National Marine Fisheries Service (NMFS, proposes to expand the current program for decreasing or eliminating shark predation on Hawaiian monk seal (*Monachus schauinslandi*) pre-weaned pups in the Northwestern Hawaiian Islands (NWHI) (Figure 1), with a focus on pup/Galapagos shark (*Carcharhinus galapagensis*) interactions within French Frigate Shoals (FFS) (Figure 2).

The Hawaiian monk seal is on a path to extinction that cannot be altered without human intervention. This document presents a set of strategies to decrease or eliminate predation by Galapagos sharks on pre-weaned pups that has been occurring within the FFS atoll, especially at Trig islet, and recently expanding to the Gins and other islets within the atoll. With an aging monk seal population and little recruitment of younger animals into the breeding age cohort, loss of even one pup contributes to the current rate of decline of the FFS population and decreases its long-term reproductive potential.

The total abundance of Hawaiian monk seals in the NWHI has declined by 75% since the late 1950s. The causes of decline have varied over time and from place to place, but since the early 1990s the decline has been driven, in large part, by low rates of juvenile survival. Archipelago-wide many of these young animals have failed to thrive due to malnutrition, and only about one of every five live to reach maturity. The age structure of the population is therefore biased toward continually aging individuals, with little recruitment into the breeding population. The total population estimate throughout the Hawaiian Archipelago as of 2008 is 1,146 seals, with 100 to 150 in the Main Hawaiian Islands. Estimated abundance is declining by 4.1% annually (approximately 50 seals per year). At present rates, the Hawaiian monk seal species will decrease to less than 1,000 individuals within 5 years and be, for all purposes, extinct within 50 years (Harting et al., *in prep.*). FFS, the atoll with the largest pupping population, has been experiencing a 75% decline in beach counts and 35% decline in pup births since 1989 (decreasing from 120 pups in 1990 to 41 pups in 2008) (Figure 3). On top of decreasing births, 12% to 21% of the pups continue to be lost to shark predation (for every year since 2000)(NMFS 2008) (Figure 4).

History teaches us that the monk seal will continue to face new and unforeseen challenges in the future, including loss of habitat in the NWHI, such as occurred with the disappearance of Whaleskate Islet in FFS in 1998 to 1999 and the finding that islet sizes at FFS were at least 50% smaller in 2004 than in 1963 (Antonelis et al. 2006). Climate change and associated rising waters may also contribute greatly to loss of habitat. But after two decades of poor survival of juvenile seals and precipitous drops in overall numbers and numbers of pups, it is clear that this problem must be addressed immediately.

A recent and troubling trend is the loss of pre-weaned pups to Galapagos shark (*Carcharhinus galapagensis*) predation in FFS since the late 1990s. Losses peaked in 1997 through 1999, with 19 to 31 mortalities recorded each year; the trend then stabilized at 8 to 12 losses each year since 2000, equal to 12% to 21% of the annual cohort born at the atoll (Harting et al. *in prep.*).

Reducing shark predation on seal pups is one of four key activities highlighted in the new Recovery Plan for the Hawaiian Monk Seal, published by NOAA in compliance with the Endangered Species Act (ESA) in the summer of 2007. The primary activities identified in the Recovery Plan pertinent to this action (NMFS 2007) are:

- **Continue monitoring shark activity and predation events.**
- **Remove problem sharks.**
- **Develop general criteria (and site-specific plans) for shark removal.**
- **Refine methods for shark removal.**
- **Maintain needed permits for shark removal and/or other intervention.**
- **Be prepared for rapid response to predation events.**
- **Have trained staff and gear for intervention.**
- **Characterize trends in shark abundance, movement patterns, and predation losses throughout the NMHI in relation to these interventions and conduct shark behavior research.**

This Programmatic Environmental Assessment (PEA) focuses on strategies to reduce shark attacks on pre-weaned pups, especially within FFS, but also on any other pupping sites within the NWHI if such attacks begin occurring. The existing and proposed shark deterrent and removal program addresses the actions identified in the 2007 Recovery Plan through:

- **Continuing monitoring,**
- **Continuing to remove of problem sharks with traditional fishing methods, but expanding take of sharks through bottomset fishing in deeper waters if certain conditions are met,**
- **Developing criteria for shark removal, especially with the expanded bottomset fishing in deeper waters,**
- **Preparing this PEA for long term ease and timeliness in receiving and maintaining annual permits,**
- **Preparing this PEA for facilitating rapid response to predation event, and**
- **Continuing and expanding the HMSRP research and cooperation with other researchers regarding shark population dynamics, monk seal losses and shark predatory behavior.**

The current program implemented by the Hawaiian Monk Seal Research Program (HMSRP) of PIFSC involves monitoring seal populations in the NWHI, monitoring Galapagos shark populations with FFS, limited removal of sharks known or suspected to prey on pre-weaned pups (based on behavior exhibited within shallow waters near beaches where pups are present or just presence within such shallow waters), and deterrents to shark presence, such as human presence, proxies for human presence, limited fishing for sharks and electromagnetic mechanisms. To date, this program has been covered annually under permits from the NMFS Office of Protected Resources (OPR), the U.S. Fish and Wildlife Service Hawaiian Islands National Wildlife Refuge (hereafter referred to as the Refuge), and the Papahānaumokuākea Marine National Monument (referred to as the

Monument). Permits must be requested every year for the work planned for the next season. This PEA covers all aspects of the current program shark removal and deterrent program.

Based on scientific information, past experience, monitoring results, and advice from shark and Hawaiian monk seal specialists, the HMSRP proposes to continue the current program and increase the tools available for shark control and deterrence in the NWHI by increasing fishing pressure on Galapagos sharks using effective fishing methods to decrease the overall predation threat. Increased fishing pressure was applied to Galapagos shark populations by non-governmental entities in 1999, and in 2000, an apparent decrease in losses of seal pups at FFS occurred. This expanded fishing has not been attempted since. Therefore, this PEA also covers the impacts associated with the proposed action of an expanded fishing effort. If the HMSRP determines that the proposed action is appropriate for meeting program objectives, then HMRSP will include this action within the application for a permit at that time.

The current and proposed actions are further described in detail in Sections 2.2.1 and 2.2.2.

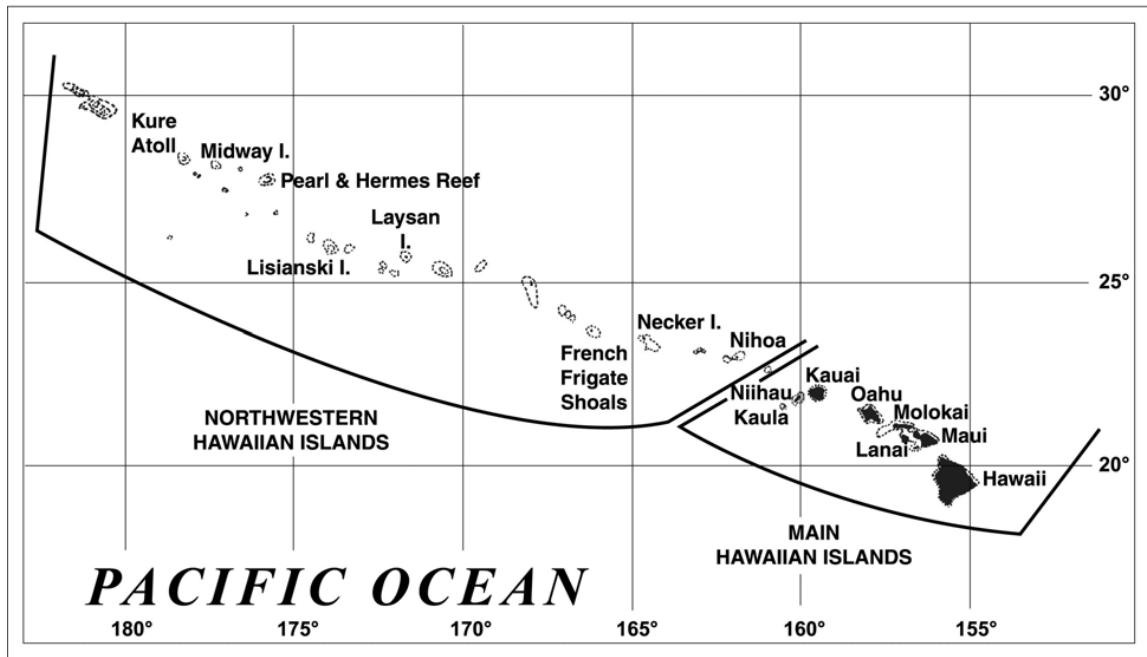


Figure 1. Northwestern Hawaiian Islands and Main Hawaiian Islands.

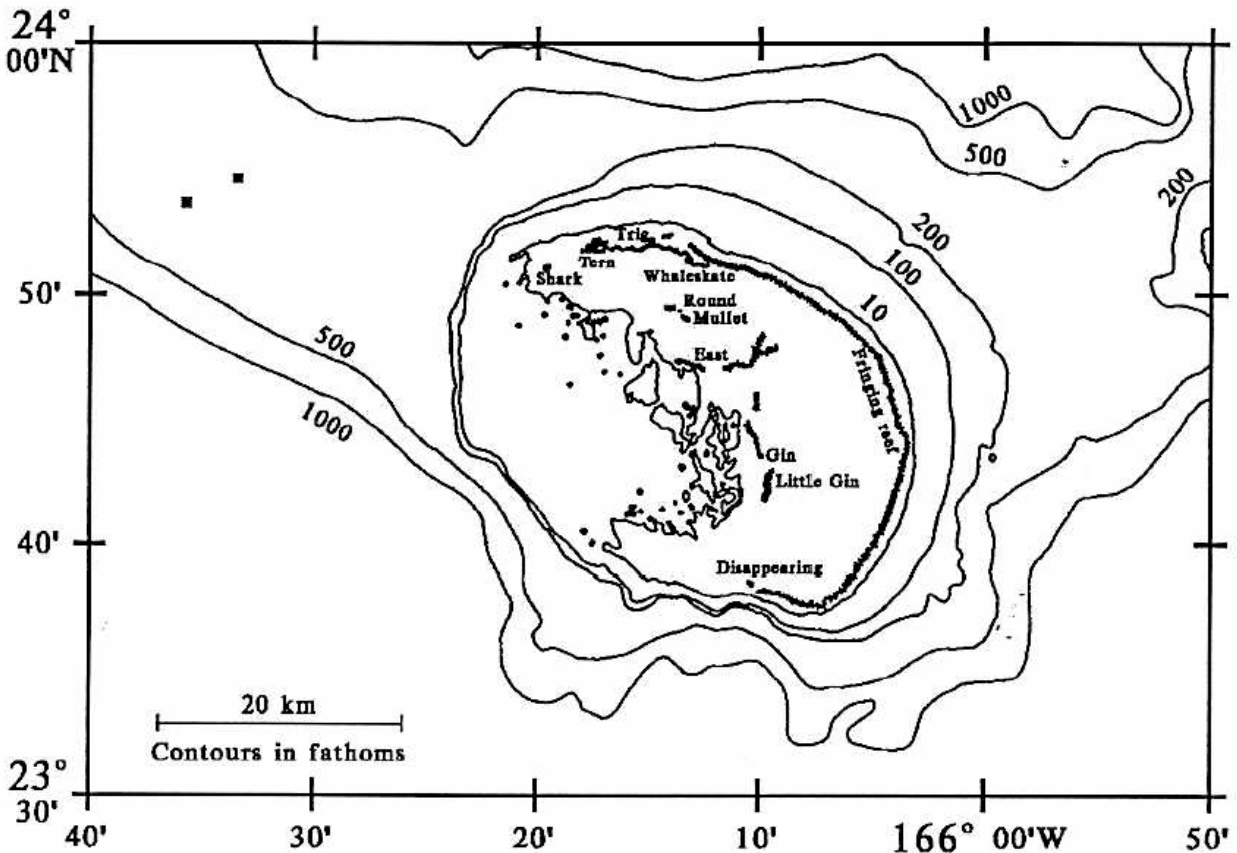


Figure 2. French Frigate Shoals Atoll.

1.1.2 Context for Hawaiian Monk Seal Conservation

Monk seals have great significance on regional, national, and even global scales. The genus *Monachus* comprises the Hawaiian monk seal (*Monachus schauinslandi*), the Caribbean monk seal (*Monachus tropicalis*) and the Mediterranean monk seal (*Monachus monachus*), all thought to be among the oldest of all existing seal genera on an evolutionary time scale. The Caribbean species was hunted to extinction for meat, skins, blubber, and museum and zoo specimens. The last wild Caribbean monk seal seen in 1952, and the species was declared extinct in 2008 (Fed. Reg. June 9, 2008, pp 32521–32526). The Mediterranean monk seal population numbers in the low hundreds and has been reduced to scattered and isolated small groups from North Africa to Greece. This species is the victim of political circumstances in that the remnant small groups reside in the waters of several countries that have failed to achieve a comprehensive and effective recovery program. The outlook for long-term persistence of the Mediterranean monk seal is bleak (NMFS 2007a).

The Hawaiian monk seal, then, may be the best – and perhaps only – chance of saving the genus *Monachus*. Despite the species' low and declining numbers, circumstances in Hawaii may potentially support the recovery of the species because:

- **the population has not been segmented into isolated fragments among which dispersal cannot occur, such as in the Mediterranean monk seal;**

- **its core habitat in the NWHI is highly protected by the designated Monument mission and objectives;**
- **the species is capable of recovering naturally in the main Hawaiian Islands (MHI), if conflicts with human use and land use can be resolved; and**
- **the Hawaiian monk seal occurs entirely within the United States, eliminating the political impediments to recovery involved with the necessity of intergovernmental cooperation. However, this means that the United States government bears total responsibility for the continued existence of the species (NMFS 2007a).**

In 2006, President George W. Bush created the Northwestern Hawaiian Islands Marine National Monument (later re-named the Papahānaumokuākea Marine National Monument), the largest marine protected area in the world. This single act added great force to recovery efforts by further protecting a major portion of the Hawaiian monk seal habitat and bringing world-wide attention to the seals' plight. Adding further momentum, the Hawaiian monk seal has rediscovered the suitable habitat existing in the MHI, lost due to human disturbance and human-caused mortality during the period from Polynesian settlement through European contact. The MHI may provide limited refuge from extinction as humans seek a beneficial co-existence with monk seals there, especially if monk seals continue to use areas isolated from human use. However, the NWHI provide the necessary habitat and conditions in which the largest proportion of the population can survive, and, with the population in a negative trajectory, every monk seal must be protected whenever and however possible for the species to recover.

1.1.3 The Decline and Specific Threats to Survival of the Hawaiian Monk Seal Population in the NWHI

The Hawaiian monk seal population in the NWHI is declining at almost 4% per year (NMFS 2007), primarily due to reduced juvenile survival. Survival rates, particularly of pups and juveniles, must increase for the species to recover. A primary goal of the HMSRP is to increase juvenile survival, including survival of pre-weaned pups, to levels sufficient to slow the rate of population decrease to ultimately assist in reversing the current downward trajectory of the population. Hawaiian monk seal pups are generally born between May and September, based on historical data. This section summarizes information about temporal and spatial variability in juvenile monk seal survival, and, importantly, predictability of survival rates.

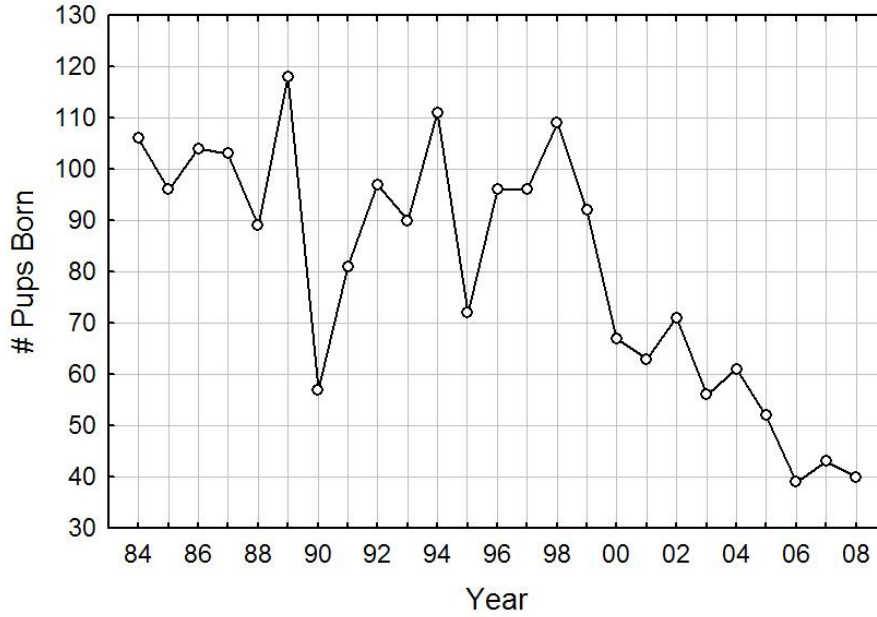


Figure 3. Number of monk seal pups born per year at all FFS sites, 1984-2008.

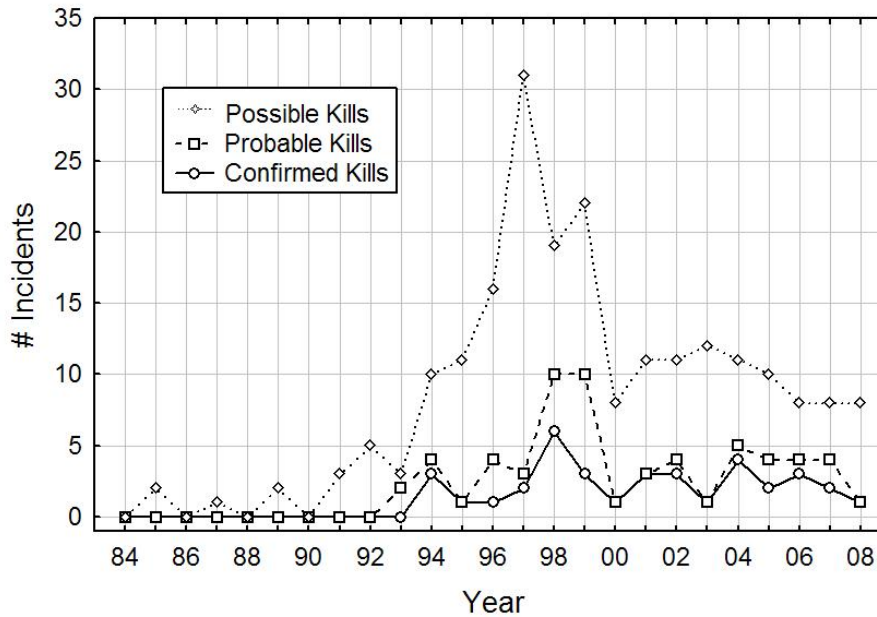


Figure 4. Number of predation mortalities (confirmed and inferred) at all FFS sites 1984-2008.

Individual subpopulations of monk seals show similar patterns in age-specific survival across the NWHI. Juvenile, subadult, and adult survival rates do vary significantly over time though general patterns are apparent (NMFS 2007). Survival during the 5- to 6-week nursing period tends to be quite high (>90%) at all NWHI subpopulations except at FFS because of maternal attendance, protection and provisioning and few other threats to survival at this stage of life (Johanos et al. 1994). After weaning, juvenile survival rate is relatively low to age 2 years, intermediate to age 4

years, and then relatively high for mature seals (until approximately age 17), after which a decline is observed as seals approach old age.

The causes of these patterns and declines are numerous and complex, and are thoroughly reviewed in the species' Recovery Plan (NMFS 2007). A crucial threat that is contributing to the high rate of population decline in the NWHI is apparent food limitation, especially for younger animals (Craig and Ragen 1999; Yochem et al. 2004). Survival of juveniles recently weaned through age 3 has declined most dramatically, with smaller body sizes of juveniles consistent with signs of starvation. This condition may be due to competition with other apex predators such as some shark species, other monk seals, less efficient foraging skills of young seals, and changes in ocean productivity reducing the availability of prey. This situation contrasts with the MHI, where pups tend to wean much larger than in the NWHI, and thin animals are rarely observed.

Among the six primary breeding sites in the NWHI, French Frigate Shoals (FFS) (Figure 2) has experienced the most precipitous decline, with beach counts, as well as number of pups born generally falling from 1989 through 2008 (Baker 2008) (Figure 3). Although FFS was once the most populous site, with over 400 individuals in the late 1980s, the estimated abundance in 2006 was only 246 seals (NMFS, unpublished data). The primary factor in the FFS subpopulation's decline has been poor juvenile survival exacerbated by lower reproductive rates due to lower numbers of breeding females and young females entering the breeding cohort, as at other sites. However, at FFS malnutrition as well as shark predation is responsible for poor juvenile survivorship, with the latter greatly affecting pre-weaned pup survival.

Since about 1997, a marked increase in Galapagos shark predation on pre-weaned monk seal pups born at FFS has occurred (Hawn 2000; Hayes 2002; NMFS 2003, NMFS 2004, NMFS 2005). For example, at Trig and Whaleskate Islets within FFS, the number of predation mortalities from sharks (including both confirmed and inferred losses, Appendix 1) peaked in 1997 through 1999 (Figure 5). During this period, 19 to 31 pups, representing 38-69% of the cohort, suffered predation each year by Galapagos sharks (confirmed and inferred losses). Additional individual pups were maimed by shark bites, including amputation of body parts, potentially reducing diving and foraging ability, as well as reproductive potential, as maimed animals presumably have a lower potential to mate. Overall, from 1996 through 2006, pre-weaned pup survival was lower at FFS than at other breeding sites in all years but one.

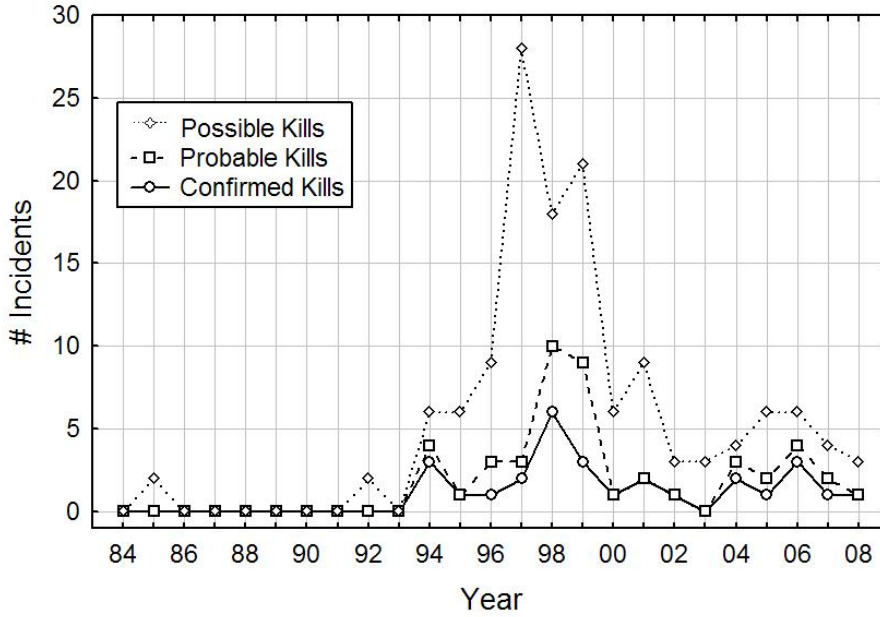


Figure 5. Shark mortalities (confirmed and inferred) at Trig Islet 1984-2008.

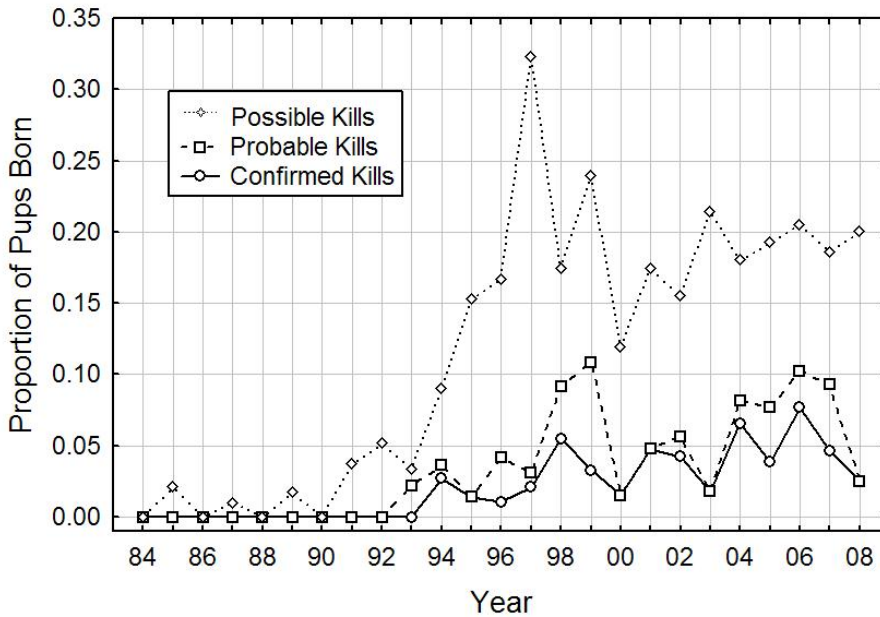


Figure 6. Proportion of pups born at FFS attacked by sharks (confirmed and inferred) 1984-2008.

Subsequent to this peak of losses in 1997 through 1999, pre-weaned pup mortalities from Galapagos sharks declined, though to a level of loss that is unsustainable for this severely declining subpopulation of this critically endangered species. From 2000 through 2008, the number of pre-weaned pup losses (confirmed and inferred) at FFS atoll-wide was relatively stable at eight to twelve pups per year. However, with fewer pups being born at FFS in recent years (41 in 2008 compared to more than 100 in the late 1980s), the lower numbers of pups lost to predation exacted

an increasingly heavy toll on smaller cohorts (Figure 6). From 1997 through 2008, 200 of 801 pups born at FFS were involved in shark incidents (Becker *per comm.* February 2009).

In 2007, at least 8 of the 43 pre-weaned pups born at FFS were lost due to shark predation and one severely-bitten pup was expected to die post-season due to extent of its wounds. In 2008, 12 pre-weaned pups died or disappeared (30%) out of 41 births in FFS, with eight of the losses due to sharks (confirmed or inferred). The disappearances of three of these pups were categorized as unknown because they were born late in the season after routine data collection had ceased, though shark-predation cannot be ruled out. Shark incidents (confirmed and inferred) affected 25% of the pups born in 2008 on Trig Islet (NMFS 2008). Shark depredations were catastrophic on the two Gins Islets in 2008, with four losses to sharks out of 6 births, with an additional non-lethal but multiple bite wound attack on a pup (Farry et al. 2009 *in prep*). One pup disappeared after the regular season; its cause of death was categorized as unknown (see description above). This level of mortality cannot be sustained at FFS, where the total population and annual pup production are projected to continue declining for the foreseeable future due to a consistently unbalanced age structure (Ragen and Lavigne 1999, Harting 2002).

A standing hypothesis developed by experts familiar with this predator-prey system at FFS is that a small number of Galapagos sharks are involved in pre-weaned pup predation. This hypothesis is currently being tested by researchers from the Hawaii Institute of Marine Biology (HIMB) using an acoustic tagging study at FFS (Antonelis et al. 2006, NMFS 2008, NMFS 2009 *in prep*). Based on tagging and other distinguishing features of individual sharks, a minimum of 14 identified Galapagos sharks were observed patrolling or pursuing pre-weaned pups at Trig Islet in 1998. One of the previously sighted and tagged Galapagos sharks from 1998 was again sighted around Trig islet during the pupping season and was identified with the killing of a pre-weaned pup that year (Harting et al. *in prep*).



Figure 7. Adult female Hawaiian monk seal (seal on left) turns to protect her pup against attack by Galapagos sharks

Based on the losses occurring in 1997 through 1999, HMSRP personnel attempted to haze predatory Galapagos sharks away from pupping and pups in FFS, especially Trig Islet, in 1998 through 2001. This management strategy proved unsuccessful in decreasing predation on pre-weaned pups and may have precipitated increased wariness by sharks toward humans (Harting et al. *in prep.*). This wariness may have contributed to a decrease in day predation and an increase in night predation (when observation of attacks is not possible) effectively maintaining the overall number of shark incidents relatively at a constant level though the observed, confirmed attacks are rare (Figure 3). Selective fishing to remove predatory Galapagos sharks was initiated in 2000 and continued each year thereafter until 2007, with a total of 12 Galapagos sharks removed during from 2000-2006 by HMRSP staff. The experimental removals were based on the assumption that only a limited number of sharks were involved, specifically those that had discovered the high density of mother-pup pairs at Trig Island after Whaleskate islet had disappeared and also the numerous pup carcasses at beaches, resulting from male aggression in 1997-1998. In addition, in July and October 1999, over 50 Galapagos sharks were removed from FFS by commercial fishers, partially operating in the deep lagoonal area of the atoll. This 1999 removal was associated with the greatest drop in pre-weaned pup losses to shark predation to date (Vader 2003, Harting et al. *in prep.*) (Figure 5).

1.1.4 Recovery

The Hawaiian Monk Seal Recovery Plan lists several criteria for reclassification of the monk seal population from “endangered” to “threatened”. The population will be considered for reclassification if:

- **aggregate numbers exceed 2,900 total individuals in the NWHI**
- **at least five of the six main subpopulation in the NWHI are above 100 individuals and the MHI population is above 500; and**
- **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.**

With the rapidly declining population in the NWHI due to all factors, especially food limitation for juvenile pups and shark depredation on pre-weaned pups, and the limited acceptance of monk seals by humans in inhabited areas in the MHI (competition for use of popular beaches), every pup born is critical for population recovery.

1.1.5 Uncertainty, Risk and Benefits

The National Marine Fisheries Service is actively working toward these recovery goals, recognizing that this effort is complex and difficult, in the face of informational gaps regarding Galapagos shark life history and behavior and monk seal response to management actions. The potential for monk seal population recovery is not certain, and will require long-term and sometimes expensive persistence and well-developed, multi-faceted tools and efforts. Direct intervention to improve juvenile survival is one such overarching tool, with many tools in the management ‘toolbox’. The HMSRP seeks to develop the components of the recovery program based on 20 years of experience, empirical studies, and the input and recommendations of various experts. Methods for increasing pup and juvenile survival are currently under further development and study to identify which tools are most effective under different conditions. Therefore, the HMSRP is not only taking immediate action to reduce pup losses, but also conducting carefully-designed studies to test efficacy of the management and research actions.

In addition, HIMB is conducting acoustic tagging studies of sharks in FFS to monitor their movement across the atoll and especially near pupping sites during the peak birth months. This data may also be useful in further substantiating that sharks preying on pre-weaned pups are a limited subset of the Galapagos shark population. This study is critical for HMSRP to characterize the Galapagos shark population in terms of its involvement in predation of monk seals and also to direct management actions to mitigate this predation appropriately. The results of this study will likely not be available until at least 2010, at which time HMSRP methodologies may be reevaluated.

The HMSRP is also translocating weaned pups from areas in the NWHI where pups are at increased risk for starvation and/or shark predation to areas with less risk; has conducted captive care programs both in the NWHI and MHI for fattening yearlings to get them past that first critical year before release back into the NWHI, and has conducted studies and medical interventions on seals found ill in the NWHI (NMFS 2007b).

One of the primary challenges to the shark predation mitigation program is the limited data available for Galapagos sharks. A global assessment of Galapagos sharks in 2003 (IUCN,

www.iucnredlist.org) listed them as “Near Threatened”(population trend unknown), but this was precautionary due to some localized extirpations that had occurred. Almost no data exist regarding population structure, age at maturity, fishing mortality, population trends, life history parameters, growth, and productivity. The primary information is by Weatherbee et al. (1996). Galapagos sharks are also frequently misidentified and confused with dusky shark (*Carcharhinus obscurus*) and silky shark (*Carcharhinus falciformisi*) in the published literature, confounding the paucity of data on the species. Shark experts participating in the shark predation mitigation workshop in November 2008 decided that they were confident that Galapagos sharks in the NWHI (NMFS 2009 *in prep.*):

- **Are primarily resident and did not travel far from where they were tagged,**
- **They were generally uncommon within the lagoon (shallow water) inside the FFS atoll,**
- **The behavior patterns of individual Galapagos sharks were highly variable over time**

The primary Galapagos shark population estimate at FFS of 703 individuals was conducted using bottomset fishing methods (approximately 32 hooks) by DeCrosta (1984). Galapagos sharks in the Hawaiian Archipelago are typically found in deeper waters (NMFS 2008) and experts have suggested that some Galapagos sharks frequenting the shallow waters of pupping beaches at FFS may be exhibiting distinctive and atypical behavior. Movement patterns of FFS Galapagos sharks have not been extensively studied yet and their dispersal across the NWHI Archipelago is not known. Thus, the FFS Galapagos shark population may or may not behave, feed and travel in patterns typical for the species. HIMB preliminary studies using acoustic tagging indicate that Galapagos sharks are likely more abundant outside the barrier reef in deeper waters and are site-attached. Four Galapagos sharks caught and tagged at Trig Islets subsequently visited pupping sites (at least one of four possible pupping sites) on numerous occasions, spending a significant amount of time in shallow waters (Weatherbee & Lowe 2003). However, all four sharks also spent a fraction of their time outside the atoll and individual movement histories were highly variability. Only one of 13 Galapagos sharks tagged outside the FFS atoll was found to subsequently enter the atoll. A tagging program conducted in Oahu produced similar findings, with only two of 25 sharks detected in shallow waters for a limited duration of time.

When and where Galapagos sharks and monk seal pups come into contact most frequently is unknown, though likely not far from pupping beaches based on known pup behavior. Pre-weaned pup behavior and movements were extensively examined by Boness (1999) at East Islet at FFS. Boness (1999) found that monk seal pups and their mothers spent nearly a fourth of their time in the water (females: 22.3%±8.32%; pups: 24.1%±6.86%), making about 5 trips from land to water per day (based on 12-hour daytime observation). For most trips, the movements of females and pups were coordinated (97.1% of the time). Rare separations between females and their pups occurred when: 1) pups or females wandering too far from their partner; 2) young pups being washed away by a high surf (only 3 pups all within the first week of life, see Appendix 1); 3) females ‘weaning’ their pups before the pups reached weaning age (weaning age averaging approximately 41 days). Females and their pups were significantly farther apart when in the water (1.3m±3.46m) than when on land (0.2m±2.57m). Greater variance in female-pup distances occurred for animals in the water than on land (SE 11.98m versus 6.62m respectively). A recent re-examination of this data indicated

that average mother-pup distances did not significantly differ across the first 5 weeks of life for 30 pairs, increasing thereafter as the pup approached weaning (Gobush *per comm* February 2009).

1.2 Program Goal and Objectives

The goal of this component of the Hawaiian monk seal research program is to reduce or eliminate losses of pre-weaned pups to shark predation in the NWHI. If reached, this goal will contribute to 1) reducing the rate of population decline and 2) increasing the potential for population recovery by raising the probability that more seals reach breeding age.

The primary objective to meet this goal is to:

Decrease total losses of pre-weaned pups to shark predation to 0 to 2 per year or 5% of the annual cohort, whichever is less. Shark incidents on pre-weaned pups average zero cases per year for other monk seal subpopulations in the NWHI, HMSRP believes that a maximum loss of 2 pups or 5% of the annual cohort, whichever is less, is reasonable given the expected asymptotic nature of extinguishing pup predation at FFS by Galapagos sharks.

In support of meeting the primary objective, the program has the secondary objectives to:

- **Apply various shark deterrents and fishing methods, using structured protocols, for effectively decreasing losses of pre-weaned pups to sharks.**
- **Cooperate with other stakeholders for sharing information, conducting studies, and implementing actions that contribute to meeting the primary objective and the program goal.**
- **Create a suite of available methods and tools that can be used in multiple strategies and combinations, thereby fostering flexibility and ability to respond rapidly to a dynamic system and changing needs. In this way adaptive management can proceed.**

1.3 Scope of Analysis

1.3.1 Temporal Scope and Actions Included

This PEA provides the detailed descriptions of existing and proposed HMSRP programs for continuing and possibly expanding efforts to reduce or eliminate predation by Galapagos sharks on pre-weaned Hawaiian monk seal pups. It includes HMSRP actions that are ongoing under previous or existing permits granted by the Monument as well as actions proposed by HMSRP for meeting the stated goal and objectives. The PEA evaluates all the tools that have been used or are being used by the program. These methods may be used individually or in various combinations based on conditions and needs. The PEA also evaluates a proposed increase of the number of sharks removed, if certain conditions are met, and the methods to accomplish this, in order to reduce shark predation on pre-weaned pups.

This PEA has no termination date; it is intended to provide the basis for long-term continuation and potential expansion of existing mitigation and research activities, as well as to provide the foundation to evaluate the effectiveness of actions intended to maintain and improve survival of pre-weaned pups. As long as individual projects are conducted as described in Chapter 2 and the actual impacts associated with implementation remain within the range of impacts as identified in

Chapter 3, this document remains current. Per NOAA policy, any Finding of No Significant Impact (FONSI) resulting from this PEA will be reviewed for consistency and appropriateness at least every 5 years.

1.3.2 Permit Requirements

Any action conducted within the land and waters of the Monument must be conducted under a permit issued by the Monument, based on National Environmental Policy Act (NEPA) analysis and documentation. The intent of this PEA is to provide sufficient analysis of informed decision making by NMFS PIFSC, and to provide the foundation for any permits issued by the Monument. The Monument can adopt the PEA in whole or in part for its own NEPA compliance in issuing permits (40 CFR 1506.3).

This PEA will also provide compliance with NEPA for considering grants to Joint Institute for Marine and Atmospheric Research (JIMAR) to assist in conducting the work within this program.

1.3.3 NEPA Compliance for Implementation of Actions within the Program

Any individual projects implemented within the described program and documented to be consistent with this PEA and its associated decision can be implemented pending appropriate permit approvals and associated compliance with NEPA. However, any site-specific and/or project-specific actions that would be added to the program and not specifically covered under this PEA or other NEPA documents, and that would potentially have environmental considerations (adverse impacts) not evaluated in this PEA, will need additional appropriate NEPA analysis in a supplement to this PEA (40 CFR 1502.9) or a new NEPA analysis. Any supplement to this PEA or new NEPA documentation shall not affect the analysis or decisions in this original PEA nor any other proposed project consistent with this PEA unless specifically stated in the supplement or NEPA document.

Any site-specific or project-specific actions that are not covered in this PEA or another NEPA document and that would not have any additional environmental considerations can be addressed in the research project implementation plan and protocol for the specific project. Possible examples include computer modeling and data analysis.

A categorical exclusion memorandum per NAO216-6 Section 5.05(b) would not be appropriate for any short-term or long-term projects or activities not consistent with this PEA because NAO216-6 Section 5.05c states: “The preparation of an EA or EIS will be required for actions that would otherwise be excluded if they involve a geographic area with unique characteristics, are the subject of public controversy based on potential environmental consequences, have uncertain environmental impacts or unique or unknown risks, establish a precedent or decision in principle about future proposals, may result in cumulatively significant impacts, or may have any adverse effects upon endangered or threatened species or their habitats.”

This program, as currently implemented and as proposed, has many activities conducted within the geographically unique Monument, both on land and in the near offshore area. In addition, some of the efforts are experimental in nature, but necessary to at least try to recover the reproductive potential of the Hawaiian monk seal subpopulations in the NWHI, with a variety of known and uncertain risks. The Hawaiian monk seal is highly endangered, with fewer than 1,200 individual animals remaining, and the population is continuing to decrease for reasons that are known, as well as speculated based on scientific evidence. Therefore, a categorical exclusion would not be appropriate for any activities conducted within the current and/or proposed program.

1.3.4 Spatial Scope and Species Included

This PEA does not include conducting research and management activities outside of the known historic range of the Hawaiian monk seal, including Wake Island and other islands within the Remote Pacific Islands Complex (except for Johnston Atoll), or outside the US EEZ (200 nm) in international waters. It also does not include any waters under the jurisdiction of the Department of Defense, including the Pacific Missile Range Facility (PMRF) on Kauai, Kaula Rock, and Marine Corps Base Hawaii on Oahu.

This PEA includes conducting research and management activities within waters and lands under the jurisdiction of the co-trustees of the Monument.

1.4 Scope of Alternatives Considered in Detail

This PEA covers only actions for enhancing pre-weaned Hawaiian monk seal pup survival by limiting or eliminating the potential for shark predation. As limited removal of predatory sharks in selected areas is included in the current program for enhancing juvenile survival, these actions are included and expanded within the scope of the proposed expanded shark predation mitigation. Therefore the existing and expanded program for controlling predatory sharks is also included within the scope of this PEA.

This program has been conducted at various levels since 1997 when predation of pre-weaned pups was heightened to a level of concern requiring action. The current program has been evaluated in several Environmental Assessments in support of Monument permit applications and consultations per the Endangered Species Act:

- **Environmental Assessment for the Proposed Experimental Shark Removal to Enhance Preweaned Monk Seal Pup Survival at Trig Island, French Frigate Shoals, Hawaiian Islands National Wildlife Refuge, May 2002 (NMFS)**
- **Supplemental Memorandum to Environmental Assessment for the Proposed Experimental Shark Removal to Enhance Preweaned Monk Seal Pup Survival at Trig Island, French Frigate Shoals, Hawaiian Islands National Wildlife Refuge, May 31, 2006 (NMFS, adding bottomset fishing)**
- **Environmental Assessment for Issuance of a Permit to the National Marine Fisheries Service Pacific Islands Fisheries Science Center Protected Species Division for Conducting Shark Deterrent Activities in the Papahānaumokuākea Marine National Monument, May 2008 (Monument)**
- **Previously, a formal Section 7 consultation was completed on the effects of the presence of PIFSC personnel in monk seal and green sea turtle habitat throughout the Hawaiian Archipelago, and permit 848-1695 was issued for scientific research and enhancement of the Hawaiian monk seal.**
- **Endangered Species Act consultation regarding HMSRP proposal to remove Galapagos sharks using bottomset gear and drumlines at previously identified locations or locations suspected of having the greatest likelihood of catching predatory sharks, such as reef channels surrounding Trig Islet, channels between Tern and Trig Islets, and nearshore waters surrounding Round Island, with perhaps some sites in the Gins Islets. No more than 10 Galapagos sharks**

would be removed in 2007. The NMFS concluded that the proposed fishing would not adversely impact Hawaiian monk seal or green sea turtles, and would benefit Hawaiian monk seals.

NMFS received the following permits from the Monument for activities related to the shark predation program:

- **Shark deterrent deployment at FFS 2008, permit number PMNM-2008-045, which covered deployment of electromagnetic Shark Shields, magnets attached to foam floats, recordings of boat and outboard engine noise broadcast from underwater speakers, and a permanently anchored small boat.**
- **Shark removal at FFS 2007, permit number PMNM-2007-025, which covered monitoring of shark activity and shark removal by various fishing methods, including hand line, harpooning, bottomset, and drumline.**

This PEA includes the following types of actions:

- **Applying various shark deterrents, including human activity, proxy for human activities, and electromagnetic devices near or on pupping beaches (Sec. 2.2.1);**
- **Removing a limited number of Galapagos sharks within shallow waters near pupping beaches, including various fishing methods (Sec 2.2.1);**
- **Removing up to 40 Galapagos sharks in up to 10 fm of water using bottomset fishing (Sec 2.2.2).**

1.5 Scope of Decisions to be Made

The Responsible Program Manager (RPM; the Director of the PIFSC) will use this PEA to make the following decisions:

1. Might the current and proposed management and research activities as described have significant impacts requiring analysis in an Environmental Impact Statement?
2. Should the PIFSC continue to conduct existing management and research program for minimizing or eliminating Galapagos shark predation on pre-weaned Hawaiian monk seals in the NWHI in support of Endangered Species Act (ESA) recovery requirements?
3. Should the PIFSC continue to conduct existing management and research for minimizing or eliminating Galapagos shark predation on pre-weaned Hawaiian monk seals in the NWHI and include an expansion of fishing effort to reduce the potential for shark predation?

This PEA, therefore, will be used as the basis for PIFSC decisions regarding the components of the program that will be submitted by application for necessary permits from the Monument for the monk seal and shark work evaluated in this PEA. Galapagos sharks are not regulated under either the Marine Mammal Protection Act or ESA, but under the Monument permit. Therefore, this PEA will also provide the basis for the decision the Monument must make regarding a permit requested by the program and this PEA may be adopted, in whole or in part, by the Monument for use in their decision making.

1.6 Adaptive Management Approach

This PEA uses the ‘adaptive management’ approach that allows implementation of actions in light of uncertainty and risk to improve management, with monitoring to allow informed and rapid response to necessary changes for meeting objectives. Every policy choice is essentially an experiment that requires monitoring and adaptation in response to impacts and level of effectiveness. Candidate actions for application under an adaptive management system must be assumed to have some level of efficacy and/or low impacts before being considered. Adaptive management approaches are dependent on quality protocols, experimental design, and adequate monitoring and evaluation. Protocols, design and monitoring and evaluation are all integrated into the current program and the proposed expansion of fishing because of the high risk to monk seal recovery of using methods that have not been adequately effective for too long a period of time (NMFS 2008).

The RPM can, therefore, select the no action alternative now, or in combination with the expanded fishing now or in the future. The current program provides various actions within the available ‘toolbox’ for use by the HMSRP as needed and appropriate, individually or in any combination. The expanded fishing as described in Alternative 2 is also evaluated, and, if selected, can also be used individually or in combination with other actions in Alternative 1, if the HMSRP determines that the identified conditions in Alternative 2 are met. The HMSRP can then determine which actions to include in any application for a permit from the Monument in any given year, and, of course, the Monument can decide which actions to permit, with conditions, if necessary. Therefore, no additional NEPA analysis and documentation will be required for any combination of actions requested in an application for a permit and permitted by the Monument if the actions include those evaluated in this PEA and associated impacts remain consistent with the conditions and impacts evaluated in this PEA at that time.

For any action outside the scope of this PEA that would have additional or different environmental impacts, either a supplement to this PEA or a new NEPA evaluation and document would be required.

1.7 HMSRP Actions Not Included within Scope of PEA

The HMSRP also conducts other actions in support of Hawaiian monk seal recovery that are not included within the scope of this PEA. The program includes monitoring monk seal population abundance, assessment, and dynamics; foraging studies; disentangling seals from marine debris; conducting disease and health assessments; and conducting limited translocation of weaned juveniles to areas within the NWHI, especially from Trig Islet to Tern Islet within FFS and FFS to Nihoa, with historical lower probability of shark attack. In the past, the HMSRP has also translocated weaned juveniles with evidence of starvation to care facilities in Oahu for a year before releasing them back into the NWHI (NMFS 2007b). These actions are not included within the scope of this PEA.

NEPA documentation is currently underway for evaluation of a program for emergency translocation of mother/pre-weaned pup and pregnant females in the MHI. This is not included in the scope of this PEA. Another NEPA document is currently being prepared for translocation of weaned pups within the NWHI and is therefore not within the scope of this PEA.

1.8 Consistency with Monument Mission and Necessary Findings for Permit Approval

In June 2006, President George W. Bush created the Northwestern Hawaiian Islands National Monument by Presidential Proclamation under authority granted the president by the Antiquities Act of 1906. Jurisdictional authority for managing the Monument is shared by the Secretary of Commerce, acting through NOAA, and the Secretary of Interior, acting through USFWS. Per the Proclamation, actions taken within the Monument must be permitted by the Monument prior to implementation, based on the impacts evaluated by the action entity and consideration of ten factors identified in the Presidential Proclamation.

The mandate for the Monument is:

The Reserve shall be managed to further restoration and remediation of degraded or injured Reserve resources.

This program meets this mandate because the Hawaiian monk seal population endemic to the Hawaiian Archipelago, including the NWHI, has decreased precipitously since the 1950s, and is currently decreasing at more than 4% per year. In support of this mandate, the Monument has helped seek funding to expand the study of Galapagos sharks and its associated ecosystem at FFS and has funded and permitted research on shark tagging conducted by HIMB. In addition, the Monument has provided direct support in FY08 and FY09, which included logistical support through ship time in the NWHI. The Monument has also provided advice over time to ensure that predation studies are consistent with the mandate. The Monument has committed to facilitating the processing and issuance of necessary permits for shark removal and deterrence to protect pre-weaned pups in a timely manner (R. Kosaki PIFSC Workshop II, *pers. comm. November 2008*). Furthermore, HMSRP will attempt to provide additional population data on the Galapagos sharks at FFS if an application for a permit for expanded fishing effort is submitted in the future and permission is granted by the Monument (Section 2.2.2).

This PEA should fulfill the NEPA requirements for any decision necessary to issue a permit from the Monument at any time regarding any NMFS application that includes actions evaluated within this PEA. If the Monument feels that additional NEPA analysis is required, then this PEA can be supplemented by the Monument or NMFS.

In addition to compliance with NEPA for granting a permit for the actions described, this PEA also provides sufficient information and analysis for the HMSRP to evaluate consistency of HMSRP actions proposed to be conducted within the Monument with the identified factors prior to issuing a permit.

1.9 Alternatives Not Considered in Detail

1.9.1 Reducing or Eliminating the Program

This PEA does not consider reduction in or elimination of the existing program because NMFS is mandated by both the Endangered Species Act and the Marine Mammal Protection Act, consistent with the Hawaiian monk seal recovery plan (National Marine Fisheries Service 2007), to implement and continue actions identified in the recovery plan.

1.9.2 Control of Tiger Shark (*Galeocerdo cuvier*) Predation

Currently, after over 3,000 hours of observation from 2001 through 2004, tiger sharks have not been observed to display predatory behavior (behavior codes 3-5) toward pre-weaned monk seal pups at FFS (Appendix 1). However, tiger sharks are known to prey on older monk seals (Taylor and Naftel, 1978), so their involvement in pre-weaned pup predation cannot be ruled out. Nonetheless, the only species HMSRP observed displaying predatory behavior toward pre-weaned pups is the Galapagos shark. Tiger sharks are not included within the program for the following reasons:

- **Tagging studies have shown that tiger sharks travel widely and do not stay in one place for very long, making it extremely difficult to contain and manage the behavior and movements of this species.**
- **In the NWHI, tiger sharks appear to focus their predation on fledgling albatross chicks. An examination of tagged tiger shark data (2005 through 2008 at Tern, Trig and East islets), demonstrated that tiger shark presence was not coincident (day of and day prior for disappearances) with shark incidents (confirmed and inferred) on pre-weaned pups (Gobush, HMSRP, pers. comm. and Meyer, HIMB, pers. comm.).**
- **The potential for releasing predation pressure by tiger sharks on smaller species of shark, including the Galapagos shark, is a risk. As a result, the Galapagos shark population may increase in numbers, which in turn could potentially increase predation on pre-weaned monk seals. Taylor and Naftel (1978) examined stomach contents of captured tiger sharks at FFS and Pearl and Hermes Reef which contained remains of Galapagos sharks.**

However, if new information arises implicating tiger sharks in pre-weaned pup predation, re-evaluation of this shark predation program would occur at that time.

1.9.3 Use of Barriers with Electromagnetic Devices

Physical barriers such as netting or wire mesh to exclude sharks from nearshore areas have been discussed at several workshops as a possible means to reduce or eliminate presence of Galapagos sharks from pupping areas. Barriers would require openings to allow passage of non-elasmobranch species. Such openings could be fitted with electromagnetic devices to selectively discourage or prevent elasmobranchs from transiting through them. At this time, this action is not considered in this PEA in more detail because a number of feasibility pilot studies must be conducted before such structures could be erected at FFS, and more extensive evaluation of possible impacts is necessary. Nonetheless, HMSRP intends to pursue this option further; possible feasibility studies and other considerations are presented in Appendix 2.

1.9.4 Use of High Powered Rifles

The Monument prohibits the use of firearms, so firearms for removing sharks in shallow waters will not be considered within this PEA.

1.9.5 Use of Lights for Detering Predatory Sharks

The potential for adverse effects on green sea turtle and sea birds may be unacceptable because lights may disorient these species. The effectiveness of lights as a shark deterrent is still

questionable, and it has been found to attract sharks in some cases. Therefore, use of lights is not included within this PEA.

1.9.6 Translocating Mother/Pup Pairs

Translocating mother/pup pairs to areas of historically low shark activity has been suggested. However, the potential for separation of pups from mothers, abandonment of pups by mothers, and/or driving pups into the water must be examined before this type of action can be considered further. In addition, an increase of mother-pup density on Trig islet was associated with increased shark incidents in the past, suggesting that the impact of increasing density at receiving sites needs also to be examined before such translocations could occur within FFS (Harting *in prep*). The danger to mother and pup of attempting translocations on a larger scale likely prohibits this option as well. Therefore, no translocation of mothers and pre-weaned pups will be considered at this time.

1.9.7 Attaching Deterrent Devices or Acoustic Tags to Preweaned Pups

Although this might be considered in the future, marking pups with magnetic shark point-source deterrents and/or with acoustic tags for collecting data will not be considered in this PEA at this time. The effect on mother/pup bonds and pup health and development is not known at this time.

1.9.8 Rebuilding Whaleskate Islet and/or Creating a Manmade Reef at Trig Islet

These actions were considered by the HMSRP to reduce shark access to pre-weaned pups and provide more pupping beaches to potentially decrease pup density on Trig Islet. The feasibility of such actions is unknown. It is also unknown if breeding females would use any created beaches for pupping or if they do use them, if shark access to pre-weaned pups would be reduced. Therefore, rebuilding pupping beaches of mothers will be considered at this time.

1.9.9 Use of Killer Whale Sound

Use of auditory deterrents of higher trophic level predators that might prey on sharks, such as sounds of Orca, may not be effective because phocids such as monk seals would also be deterred and pregnant monk seals searching for safe beaches for birthing may be negatively impacted. Therefore, this deterrent will not be used in the program.

1.9.10 Use of Semiochemicals

One type of semio-chemical present in rotten shark tissue has been shown to repel sharks on a very localized scale, but not fish. However, even if this approach was found to be empirically effective in deterring sharks, the localized nature of this deterrent prohibits its wide-ranging effective use as would be needed at FFS. For example, the chemicals would be washed away by the current and the deterrent effect would only be short-term (NMFS 2008). Furthermore the impacts of these compounds on other wildlife are not known. Therefore, this deterrent will not be used in the program.

1.9.11 Relocation of Sharks

Relocating Galapagos sharks would both be difficult and dangerous to personnel, with a high likelihood of failure in terms of protecting pre-weaned pups from predation. No known translocation release point is currently available and it is not known if translocated sharks would survive. Therefore, this action will not be considered in this program.

1.10 Anticipated Use of this PEA for Future Research Program Actions

Any individual research project implemented within the described program and documented as consistent with this PEA and its associated decision can be implemented without further compliance with the National Environmental Policy Act (NEPA). However, any site-specific and/or project-specific actions that would be added to the program long-term and not specifically covered under this PEA or other PIFSC PEAs and that would potentially have environmental adverse impacts not evaluated in this PEA will need additional appropriate NEPA analysis in a supplement to this PEA (40 CFR 1502.9) or a new NEPA analysis. Any supplement to this PEA or new NEPA documentation shall not affect the analysis or decisions in this original PEA nor any other proposed project consistent with this PEA or any other PIFSC PEAs unless specifically stated in the subsequent supplement or NEPA document.

Any site-specific or project-specific actions that are not covered in this PEA or another NEPA document and that would not have any additional environmental considerations that have not already been addressed in this PEA or a previous EA, or that are purely administrative, conducted entirely within a laboratory without the use of live subjects caught in the wild for the purpose of the research, or purely technical in nature can be addressed in the research project implementation plan and protocol for the specific project. Possible examples include computer modeling and data analysis, technical support and advice, or laboratory studies using turtles that are already captive.

For any short-term project not consistent with this PEA, a categorical exclusion memorandum can be prepared if in compliance with NOA216-6(a) or (d), and having no exceptions to the use of a categorical exclusion. To determine if a categorical exclusion is appropriate for the proposed action, the following factors will be considered per NAO216-6 5.05(b)):

- 1) “a prior NEPA analysis for the same action demonstrated that the action will not have significant impacts on the quality of the human environment (considerations in determining whether the proposed action is the “same” as a prior action may include, among other things, the nature of the action, the geographic area of the action, the species affected, the season, the size of the area, etc.). In this case, a categorical exclusion may be appropriate.” Or:
- 2) “the proposed action is likely to result in significant impacts as defined in 40 CFR 1508.27.” In this case, a categorical exclusion would not be appropriate.

The appropriate categorical exclusion would either be:

“NAO216-6. 6.03.3(a): Research Programs. Programs or projects of limited size and magnitude or with only short-term effects on the environment and for which any cumulative effects are negligible. Examples include natural resource inventories and environmental monitoring programs conducted with a variety of gear (satellite and ground-based sensors, fish nets, etc.) in water, air, or land environs. Such projects may be conducted in a wide geographic area without need for an environmental document provided related environmental consequences are limited or short term.”

Or:

“NAO216-6. 6.03.3(d): Administrative or Routine Program Functions. The following NOAA functions that hold no potential for significant environmental impacts qualify for a categorical exclusion:

- **Basic and applied research grants, except as provided by Section 6.03b of this Order [trustee restoration actions per CERCLA and other laws];**
- **Environmental data and information services;**
- **Administrative services;**
- **Basic environmental services and monitoring, such as weather observations, communications, analyses, and predictions...”**

A categorical exclusion memorandum for the proposed action cannot be prepared if the one or more of the following conditions or exceptions apply:

- **“CEs may not be appropriate when the proposed action is either precedent-setting or controversial, although such a determination must be made on a case-by-case basis. (NAO216-6 4.01c).”**
- **“Exceptions for Categorical Exclusions: The preparation of an EA or EIS will be required for actions that would otherwise be excluded if they involve a geographic area with unique characteristics, are the subject of public controversy based on potential environmental consequences, have uncertain environmental impacts or unique or unknown risks, establish a precedent or decision in principle about future proposals, may result in cumulatively significant impacts, or may have any adverse effects upon endangered or threatened species or their habitats. (NAO216-6 5.05c).”**

2 Affected Environment and Alternatives

This chapter incorporates:

- the description of the affected environment,
- the description of the No Action alternative,
- description of the proposed action alternative

2.1 Affected Environment

This section is summarized entirely from the Hawaiian Monk Seal Recovery Plan (2007a), and omits the references to the literature for ease of reading. Specific references can be readily found in the “Background” section in Chapter I of the Recovery Plan.

2.1.1 Species Description

Newborn pups of both sexes are covered with black lanugo (fetal hair) and weigh approximately 31 to 37 pounds. Near weaning, following the lanugo molt, pups become silvery gray, usually darker on the dorsum. At weaning, pups will weigh 110 to 220 pounds. Weight loss in post-weaned phocid pups up to age two, including monk seals, is a normal part of their life cycle as they learn to forage effectively.

Few adults have been weighed or measured, so a complete growth curve is not available, but from the limited data, adult females weigh approximately 550 pounds and are about 7 feet long, whereas the average adult male is smaller at about 375 pounds and 6 feet long. Sexual dimorphism, with females larger than males, is normal among seals of the genus *Monarchs*.

Initial studies of genotypic variation suggest that the species currently is characterized by low genetic variability, minimal genetic differentiation among subpopulations and, perhaps, some naturally occurring 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. It is possible that the long-term evolutionary history of the species and recent human impacts are both possible sources for the extremely low genetic variation observed.

2.1.2 Summary of Island History and Monk Seal Abundance

When monk seals arrived at the Hawaiian Islands, they found an archipelago quite different from today. The earliest record of Hawaiian monk seals in the Hawaiian Islands indicated that they were present prior to European contact in about 1400 to 1760 AD. Today, monk seals are found throughout the NWHI at six main reproductive sites: French Frigate Shoals (FFS), Laysan Island, Lisianski Island, Pearl and Hermes Reef (PHR), Midway Atoll, and Kure Atoll (Fig. 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 in limited numbers throughout the Main Hawaiian Islands (MHI), where births have been documented on all of the major islands. 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.

On June 15, 2006, the NWHI Papahānaumokuākea Marine National Monument (PMNM) was established by Presidential Proclamation 8031 (71 FR 51134, August 29, 2006; 71 FR 36443, June 26, 2006) 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.**

2.1.3 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 (which eroded away in the late 1990s) and Trig, are scattered along the westerly reef of the crescent (totaling 44 acres).

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 from 1942 through 1948, and by the USCG from 1944 through 1952 on East Island, depressed that sub-population. The US Coast Guard remained on Tern Island (but not East Island) until 1979. Following the departure of the Coast Guard from FFS, a dramatic increase occurred in seals hauling out on Tern Island. In 1986, the mean count at FFS (excluding pups) was 284 (NMFS, unpublished data), approximately 6 to 8 times higher than the number had been in the late 1950s.

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 two. After 1995, the decline in weaning sizes at FFS moderated, and early survival has generally improved slightly since 1999. 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. Ecosystem-wide productivity decreased in the late 1980s and early 1990s, probably due to a decadal scale oscillation in oceanographic conditions. This appears to have resulted in declines in the abundance of coral reef fishes at FFS. 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, 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 resultant poor physical condition, have reduced survival of juvenile seals at FFS. Data from 1984 to 1994 suggest that the number of severe injuries attributable to shark predation increased substantially after 1987, especially at Trig Island within the atoll. Most FFS pups were born at Trig Island after the main pupping islet in the atoll, Whaleskate Island, gradually eroded and eventually disappeared between 1994 and 1999. Adult male aggression 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. In addition to poor survival of juveniles, the onset of reproduction is later and the mean fecundity for mature females is lower at FFS compared to Laysan Island. 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 subpopulation.

2.1.4 Laysan Island

Laysan Island, the largest land area in the NWHI, is a coral-sand island enclosing a hyper-saline lake. The island is almost 2 miles long and 1 mile wide, and partially surrounded by a fringing reef. It lies approximately 132 miles east of Lisianski Island. 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 nearly extirpated the monk seal population at Laysan. These activities were followed in 1909 to 1910 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 USFWS volunteers and seasonally by a Marine Mammal Research Program (MMRP) field camp.

The abundance of monk seals at Laysan Island declined significantly after the late 1950s. While numbers 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, and while the cause was not conclusively determined, ciguatoxin was suspected. Abundance tended to increase from 1995 to 2000, and has subsequently declined. As the sex ratio was known to be biased toward males at Laysan in the late 1970s through the 1990s, some of the decline in abundance was probably due to female mortality caused by male aggression. From 1982 through 1994, 63 deaths of seals older than pups were confirmed; of those, 45 died as a result of male aggression, with 23 of those killed being adult females. During the years from 1983 to 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.

In contrast to FFS, juvenile survival has been relatively good at Laysan Island for most cohorts. Exceptions include 15% survival of the 2000 cohort from weaning to two years of age and record

low survival of one- to three-year-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.

2.1.5 Lisianski Island

Lying about 1,036 miles Northwestern of Honolulu, Lisianski Island is a low, sandy island measuring approximately 1.1 miles long and 0.6 miles wide. It lies near the north edge of Neva Shoal, a large area varying in depth up to 10 fathoms. It was the site of a number of shipwrecks during the 19th century and stranded crews from these ships often relied on easily-caught 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, sea cucumbers, sharks and monk seals. More concentrated exploitation of the island took place during the period 1904 to 1910 by Japanese feather poachers, but this activity was apparently halted by 1911. Subsequent visits to Lisianski appear to have been limited to those made by fishermen, survey parties, and scientific expeditions. Lisianski is currently only occupied during MMRP monk seal field camps.

Beach counts of monk seals 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 surviving juvenile seals. The adult sex ratio has been strongly male-biased, mostly due to a preponderance of older males. Recently, the sex ratio has been equalizing, and in 2002, the sub-population included 1.3 adult males per adult female. Multiple-male aggression has been observed at Lisianski, but only two deaths are known from this cause since 1984. Aggression by single males has accounted for the documented deaths of some weaned pups. The full impact of male aggression at Lisianski is not known.

Another factor contributing to the lack of population growth is relatively low fecundity of adult female seals. 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 tend 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.

2.1.6 Pearl and Hermes Reef (PHR)

The first land area southeast of Midway Atoll is Pearl and Hermes Reef (named after two ships that wrecked on the same day), a low coral atoll made up of as many as eight islets, five of which are permanently above water. The reef encloses an elliptical lagoon, approximately 20 miles by 11 miles. The atoll was visited in 1859 by a sealing expedition and by a vessel collecting turtles, 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. Fishing for pearl oysters ceased in 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-gallon drums, some filled with fuel. The atoll is now unoccupied except for MMRP and USFWS 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. Beach counts increased from the mid-1970s until 2000, with a 6% average annual rate of increase between 1983 and 2000. As at Kure and Midway Atolls, both beach counts and juvenile survival have tended to decline since 2000. The prime reproductive cohorts (ages 7 to 20) remain well-represented at PHR, but recent declines in juvenile survival have depleted the younger cohorts (ages 1 to 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 through 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. From these results, it is presumed that male mating success may be contributing to this pattern of genetic variation.

2.1.7 Midway Atoll

Located approximately 1,300 miles Northwestern of Honolulu, Midway Atoll consists 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 resulting 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 20th century. 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 to fewer than 250 in 1978. At that time, families were not longer allowed to accompany military personnel during deployment, causing the schools and main support operations to close.

The highest recorded beach counts of Hawaiian monk seals were made in 1957 through 1958 (mean of 56 seals), but within a decade, monk seals had essentially disappeared. Only one seal was seen during an aerial survey in March 1968. Seals were observed at Midway occasionally and only in low numbers during the 1980s, when the Navy requested USFWS 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 USFWS and the Naval Air Station.

In the early 1990s, seals began to appear in increasing numbers, mostly immigrants from PHR and Kure Atoll, and births increased. This situation continued until 1996 when the Navy officially transferred jurisdiction of the atoll to the USFWS. The USFWS immediately closed almost all of the atoll's beaches to human access to reduce the potential for monk seal disturbance. The USFWS 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 allowed on the island at any one time, a

number still allowed. The concessions never reached the planned numbers of island guests, and the contractor withdrew from the agreement in 2002. Today, the USFWS 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 of monk seals increased steadily and have declined thereafter. Similar to the Kure subpopulation, recent cohorts have experienced low juvenile survival. During 1997 through 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. This time period covered the post-Navy occupation, pre-ecotour operations and the first two years of the contractor-operated tour activities. Observations detected a high rate of migrations between Midway and the neighboring atolls of Kure and PHR, giving Midway a higher proportion of transient seals than any other NWHI site. Beach counts of monk seals 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. Increased numbers of seals immigrating to Midway and increased hauling on Sand Island were attributed to the reduction in human disturbance following the USFWS beach closures.

2.1.8 Kure Atoll

Kure Atoll, at the northwestern end of the Hawaiian Archipelago, is the world's northernmost coral atoll. About six miles 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 Northwestern of Midway and 2,177 km Northwestern 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 through 1843 and the crew of the U.S.S. Saginaw killed at least 60 seals there in 1870.

Establishment of a 20-person U.S. Coast Guard (USCG) long-range navigation (LORAN) station on Green Island at Kure in 1960 resulted in a significant and abrupt decline of the monk seal population on Green Island beaches caused by the residents and their dogs and vehicles which caused adult females to abandon prime pupping habitat. Pup survival declined first, followed by a decline in recruitment of breeding females and the development of an age structure skewed toward older animals. The sex ratio of adults also became heavily biased toward males, 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 to protect the seals. Births declined steadily from the late 1970s to the mid 1980s, and only one pup was born in 1986.

Beginning in 1981, during the spring and summer months, the NMFS Pacific Islands Science Center's 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 remaining station personnel that resulted in fewer disturbances to the seals and better pup survival. 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.

From 1983 through 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. 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 micro-satellite DNA found evidence of low genetic variation and heterozygote deficit in the seal population at Kure Atoll. These results are a possible indication that inbreeding may be occurring.

2.1.9 Necker and Nihoa Islands

Necker Island (also known as Mokumanamana), located close to the MHI, less than one mile long and extremely narrow, is a rocky 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 1,500 feet long and ranging in width from roughly 300 to 1,000 feet. 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, monk seal births have been recorded during occasional visits. This island is only visited by USFWS 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. In 2002 through 2006, combined beach census totals for Necker and Nihoa ranged from 32 to 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. 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.

2.1.10 Main Hawaiian Islands

Most of the extant Hawaiian monk seals live in the NWHI. Although no systematic surveys were conducted prior to 2000, an increasing number of sightings and births have recently occurred in the MHI. The earliest seal documented in the MHI was reportedly killed by Hawaiians in Hilo Bay on the island of Hawaii and subsequently eaten, as reported in 1912 and evidence of monk seal remains dating to between 1400 and 1760 on the island of Hawaii have been recorded. There are eight primary islands and numerous small islets and offshore rocks around these. Seals have been observed on each of the eight main islands. At least 45 seals were known to occur 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. 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. This number is based upon non-systematic sightings of tagged and naturally marked individuals, and likewise is probably well below true abundance.

While monk seals have been seen on all the main Hawaiian islands, the largest numbers likely occur on Niihau (a privately owned island where ground access for research activities is currently prohibited), and the number of sightings tends to decrease moving to the southeast along the island chain toward the islands with higher levels of development and human densities and activities. On all islands, seals tend to frequent remote areas where human presence or access is limited. MMRP personnel organize and train volunteers who cordon off and protect seals on public beaches until the seals move off.

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.

2.1.11 Critical Habitat

In 1980, NMFS completed a draft Environmental Impact Statement (DEIS) that proposed monk seal critical habitat be extended out to the 10 fathom (fm) isobath adjacent to pupping and haul-out islands in the NWHI. The following year the lobster fishery was prohibited in waters less than 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 USFWS, 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), Pearl and Hermes Reef, Lisianski Island, Laysan Island, Gardner Pinnacles, French Frigate Shoals, Necker Island and Nihoa Island (April 30, 1986, 51 FR 16047). However, concerns raised by the Marine Mammal Commission, the Hawaii Monk Seal Recovery Team 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.

2.2 Description of Alternatives

This PEA evaluates the impacts of the current program (Alternative 1, or the No Action alternative) and considers an addition to the current program to further the program goals and objectives. The addition includes increasing the fishing on Galapagos sharks in deeper waters within the FFS atoll near pupping sites. Once the actions evaluated in detail are determined to have no significant impacts by NMFS based on this PEA, the HMSRP can choose to include any actions evaluated in detail in subsequent annual applications for permit from the Monument, providing the opportunity to mix actions for any one season in any combination. For the 2009 season application, only the current program actions have been requested.

2.2.1 Alternative 1: Description of the Current Program (No Action Alternative)

Under this alternative, existing methods to decrease Galapagos shark predation on monk seal pups would continue, as adapted and modified as necessary. Procedures would continue to include monitoring Galapagos shark activity and behavior, deploying devices to deter presence of Galapagos sharks, removing Galapagos sharks by various fishing techniques, and continually evaluating fishing techniques.

2.2.1.1 Methods: Overnight camping

NMFS staff may camp overnight at islets where monk seal pups are born to collect information during crepuscular and nighttime periods. Personnel would collect information on increased shark activity and predation if possible, and monk seal behavior. During overnight observations, the shark monitoring team may use night-vision goggles or other such viewing devices to enable observations in low-light conditions (nocturnal and pre-dawn hours). Campsites would use primitive camping techniques typically used for backpacking, including carrying in food and using small, low profile tents and sleeping bags. All waste material would be removed and transported to Tern Island for appropriate disposal. Such short camps have been successfully completed at Trig Island on numerous occasions in the past without causing harm to the environment or the wildlife.

Monk seal population assessment personnel would continue to routinely visit pupping sites to detect shark predation incidences and conduct routine monk seal population monitoring. Additional trips may occur specifically for maintenance of deterrent devices, or in response to shark incidents (sightings, woundings, or other).

2.2.1.2 Methods: Shark Deterrent Devices

The types of deterrents are based on input received during two workshops addressing shark predation on Hawaiian monk seals (NMFS 2008, NMFS in prep) or from private consultations with shark biologists. We would deploy two categories of devices: human proxy deterrents and electromagnetic deterrents.

Use of human proxies is based on HMSRP observations that the ability to observe active predators near the pupping sites is limited by the predators' wariness to humans. For example, this wariness has likely caused reduced efficiency of fishing methods conducted from shore. Although 12 Galapagos sharks have been removed historically by hook-and-line fishing or harpoon (2000-2006), HMSRP fishing effort (number of hook hours) was low (ranged from 10-30 hours) and efficiency (removals per effort hours) progressively deteriorated throughout that period.

Electromagnetic devices would exploit the capability of elasmobranchs to perceive electromagnetic fields with their Ampullae of Lorenzini (Figure 8). Galapagos sharks are less likely to bite bait in the presence of large electric fields (Stoner and Kaimmer 2008), so items which create such fields may serve as repellents.



Figure 8. Electromagnetic sensory perception via snout pores on Galapagos shark

The human proxy category would comprise primarily two types of stimuli: visual and auditory. Other techniques to create human proxy may also be used if the impacts are determined to be within the bounds of the effects evaluated in Chapter 3. The electromagnetic category of actions would comprise two devices: magnets and implements to artificially create electrical fields.

Additional actions for both types of techniques may be applied if the impacts are determined to be within the impacts evaluated in Chapter 3. If these techniques cause impacts beyond the scope of Chapter 3, a supplement to this PEA would be prepared.

Human proxy activities that would be conducted near pupping sites include:

- **Boat(s) anchored in nearshore water**
- **Assorted visual stimuli, such as floats and other, often deployed in association with magnetic and electro-magnetic deterrents**
- **Observation tower visible from the water**
- **Sound in the water**

A boat anchored offshore near pupping sites may serve as a passive deterrent to sharks. HMSRP personnel have observed that patrolling Galapagos sharks tend to leave the area as a boat

approached, and that Galapagos sharks tend to avoid the area near where boats are anchored. Further, in recent years most shark predation has occurred during times when no humans were present at the island, suggesting that sharks may use visual cues to detect when humans are present and adjust their predatory behaviors accordingly. Because boats are commonly used at FFS, this type of visual stimulus is an accepted part of the regular operations at FFS and does not introduce any novel environmental risks to the system. Boats may be anchored throughout FFS as needed at any one time, using a single anchor on sandy bottom (no coral areas) and routinely moved to prevent habituation by sharks to a static object. A second anchor to shore would be deployed if inclement weather is imminent. No fuel, batteries or other risk factors would be left on board the anchored boat. As with all of the deterrents, this deterrent type would be suspended if any unforeseen risk is detected.

Various types of floats, streamers and buoys may be deployed in conjunction with the magnetic and electromagnetic deterrents. These would be placed on the surface or within the water column nearshore to pupping sites in 2m to 3m of water in a staggered pattern to impede shark patrolling behavior. They would serve the dual purpose of providing an attachment point for the other devices, such as electromagnetic deterrents, while at the same time serving as additional visual deterrent stimuli. These stimuli are intended to either deter sharks directly or warn them of the presence of other stimuli that deliver an unpleasant sensation. These devices would consist of standard, over-the-counter devices, such as fishing buoys, fishing floats, water “noodles” and similar objects made from plastics or other inert materials. Observations in 2008 indicated that PVC tubing is preferable to plastic “noodles” because the latter material accumulates algae and degrades over 4 to 6 weeks time, as well as green sea turtles feed on the algae (NMFS 2008b). These devices would resemble objects already commonly found in the water or on the beaches at FFS and would not introduce any novel environmental concerns to the system. Also, all anchoring would be in sandy substrate away from coral.

The distribution strategy would be to array the floats concentrated along the shoreline in what is likely to be within the zone where sharks typically take pups, in a depth of two to three meters. Each segment of the anchoring line would be sufficiently far away from the next adjoining segment that there would be no possibility of cross contact to avoid risk of entanglement.

A 12-foot portable observation tower made from scaffolding with a 4-foot x 6-foot base, has been erected in the past. This tower was used primarily for visual monitoring. When the observation tower in place in 2000 through 2004, it was observed that shark presence decreased as time progressed, indicating that the tower itself may function as a visual deterrent. Therefore, the program may install the portable tower again to serve this purpose. The tower would primarily be erected in the daytime, but may, on occasion, be used at night for monitoring purposes.

Underwater loudspeakers with amplifiers to broadcast noise from small boats or other human-activity related sound and patterns would involve sounds within the decibel and frequency range known to deter sharks. As with the anchored boat(s), the objective is to displace predatory sharks by either giving the impression that humans are in the vicinity and/or through a negative auditory stimulus to deter their approach (Myberg 2001). These speakers would be suspended from surface floats and anchored by a chain on sandy substrate within 10m to 20m of the shoreline in 2m to 3m of water. The cables on the island would be buried and cables in the water would have little to no slack, minimizing the potential for entanglement (NMFS 2008b).

Many shark sensory biologists refer to the combination of inner ears and lateral lines as the acoustico-lateralis system. Field and laboratory experiments have demonstrated that sharks can hear sounds with frequencies ranging from about 10 Hz (cycles per second) to about 800 Hz, but are most responsive to sounds less than 375 Hertz. Therefore, transmissions would overlap the upper end of sharks frequency range (200 Hz to 800 Hz). No transmissions would be emitted in the low frequency of sharks hearing range (10 Hz to 200 Hz). The absence of transmissions in this range may be advantageous as some biologists speculate that low frequency sound may in fact attract sharks (Myberg 2001). Also, sharks are found to be attracted to sounds that are irregularly pulsed broadband frequencies below 80 Hz transmitted without a sudden increase in intensity, which mimics sounds of struggling prey. However, sounds, even attractive ones, that have sudden increases in intensity of 20 dB or more above a previous transmission can result in immediate withdrawal from a source (Myrberg 2001).

The transmission unit used in 2008 was a Lubell LL916 transmitter, having a maximum output of 180dB @ 1k Hz, and frequency range of 200 Hz to 20 kHz (NMFS 2003b), and HMSRP has no plans to increase the amplitude of transmissions.

Boat noise is unique in character in that it has two underwater domains, or operating conditions: noncavitating and cavitating noise (Gerstein 2002). With cavitation noise, tiny bubbles form and collapse and produce a broad range of frequencies above prevailing ambient conditions at frequencies up to 20,000 Hz. The frequency and power of boat noise are directly related to the speed of the vessel- the faster the propeller rotation, the more cavitation is created. Conversely, when the rotation of the propeller is reduced and a boat is traveling slowly, the turbulence is minimal, and both the frequency and power spectrum of the noise are significantly reduced. The dominant noise spectra are below 1,000 Hz. As stated above, the upper hearing threshold for sharks is 800 Hz.

On the other hand, ambient noise generally ranges from 60 to 90 decibels, over a frequency range of 1 to 20,000 Hertz, but ambient noise levels can reach 130 decibels during heavy rain or in industrial areas. The critical ratio compares the intensity of a signal at the moment it is just detectable (the masked threshold) to the intensity of the background noise. The size of the critical ratio has important significance, as high ambient levels could conceivably raise detection thresholds beyond the absolute acoustic energy emitted by many boats or proposed sound transmissions. Therefore, while our sound transmissions may occasionally be masked at distance by ambient sounds, we believe they may still prove to be a deterrent in close proximity to the speaker within the shallow confines of pupping sites.

Ultimately the sound should be audible above ambient noise levels, and the frequency should overlap that which would change the behavior of sharks (Temporary Threshold Shift; TTS; 200 to 800 Hz), but not overlap that which would cause TTS in cetaceans and pinnipeds (Section 3.2). Therefore, sounds that are proxy for human activities or that have the repulsive characteristics with the shark acoustical range and that do not attract sharks would be used or change behavior in cetaceans and pinnipeds. In 2008, observers recorded no adverse effects to any wildlife species, and, although monk seals were seen investigating active speakers on several occasions just after deployment, no further attraction or other impacts were observed (NMFS 2008b).

2.2.1.3 Methods: Electromagnetic Devices

Elasmobranchs, including sharks, have the ability to detect electric fields emitted by living organisms in the marine environment using a sensory organ called the Ampullae of Lorenzini. These are gel-filled pores homogeneously distributed around the nose and mouth of the shark. In the presence of an electric field, the electric potential at the surface of the prey differs from the electric potential of the interior of the animal, which is detectable by the shark.

Magnetic deterrents would be deployed in conjunction with in-water visual deterrents (Section 2.2.1.2). A permanent magnet with the correct specifications is hypothesized to over-stimulate the Ampullae of Lorenzini, and may therefore be used as selective shark repellent. Design of these systems is based largely on the findings of Dr. Eric Stroud of Shark Defense Inc. (<http://www.sharkdefense.com>), whose research has demonstrated a measurable repellent effect of magnets on captive sharks of multiple species. Preliminary research and consultation indicate that Grade C8 barium-ferrite permanent magnets (~15.24 cm x 10.1 cm x 1.27 cm dimensions) and neodymium-iron-boride magnets correspond closely with the detection range of the Ampullae of Lorenzini and therefore are likely to be suitable for our purposes. The fields generated by these permanent magnets decreases at the inverse cube of the distance from the magnet. Therefore, at distances of a few meters from the magnet, the field exerted is less than the Earth's magnetic field.

The probable deployment method would be water column sets (magnets suspended at 40 to 50cm separations fixed between anchor and a surface float and attached to floats used as visual deterrents). Spatial arrangement may involve double or multidimensional arrays to optimize the deterrent effect at each locale where a system is deployed. Up to 40 magnets may be deployed in the vicinity of each pupping site (NMFS 2008b).

Electromagnetic devices which generate electrical fields (such as "Shark Shields") may be deployed at areas where patrolling sharks typically approach pupping sites. The units utilize "electronic wave-form" technology invented by the Natal Shark Board of South Africa (<http://www.shark.co.za/>). The main advantage of such a system, as compared to permanent magnets, is that it is likely to have a more powerful deterrent effect near the point of deployment. A distinct advantage of the unique electronic wave-form is that it deters sharks with no potential for injury. Once the shark is out of the affected area, it no longer feels the effect of the electronic wave form. Moreover, the devices pose no risk to humans and are not expected to affect the behavior of non-elasmobranch species (<http://www.shark.so.za/>).

The Shark Shield units have an output of approximately 80 volts. In comparison, an electro-shocking device used to non-lethally collect fish for sampling uses a DC current of 3 to 7 amperes and 100 to 250 volts in fresh water. The high electrical conductivity of salt water is less resistive than living tissue and the electro-shocking current would flow around them. In addition, as water temperature is reduced from 20°C to 0°C, conductivity increases 40%. Therefore, colder water increases the electro-shocking efficiency. For application in the NWHI, the lower voltage (80 volts) and high conductivity of warm salt water (26°C to 28°C at the sea surface) supports the manufacturer's claim of minimal impact on fish.

However, such systems require battery or direct power, and at present can be deployed for only short periods of time (up to 7 hours) before the batteries require recharging at a wall outlet, which is only available at Tern Islet. NMFS personnel are currently researching suitable options for electromagnetic devices and associated power systems, including potential for custom modification

of systems for operation on a DC battery. As with permanent magnet systems, electromagnetic systems may be coupled with visual deterrents to achieve maximum repellent effect.

Deployment would be in an array across shallow waters perpendicular to the beach to take advantage of shoreline patrolling behavior and to maximize the likelihood of a shark encountering the Shark Shields. The units would be attached to surface floats anchored by chain and anchor to sandy substrates. Experience with these devices deployed in this manner in 2008 indicated that the electric shock was similar to that of a moderate electric fence. No direct observations or indirect evidence of the devices shocking any wildlife, including fish were made (NMFS 2008b).

2.2.1.4 Methods: Removal of Galapagos Sharks in Shallow Waters Near Pupping Sites

Up to 40 Galapagos sharks in shallow waters near pupping sites would be removed across a two year period from FFS (NMFS 2002). A crew of 2 to 3 familiar with safe and effective methods for shark fishing/removal would be tasked with conducting boat surveys and fishing/removing Galapagos sharks that they encounter in the vicinity of pupping sites (location depending on conditions required for fishing technique used). Boat surveys would occur during daylight hours at select times/days around each main pupping site on a regular basis throughout the field season. Additionally, if observers sight a shark from shore of a pupping site (ground or observation tower if/when erected on Trig islet) they would alert the fishing crew, who would commence fishing at that time. If the fishing crew deems a removal personally unsafe or unfeasible, they would attempt to harass the shark away from shore by throwing coral and/or herding the shark into deeper water.

Shark fishing and removals would be conducted primarily at those locations previously identified or suspected of having the greatest likelihood of catching predatory Galapagos sharks. Similar sites may be identified in the vicinity of the Gins Islets or other less frequently used pupping sites.

Sharks would be removed by one or a combination of five fishing techniques:

- **Hook and line**
- **Spear or harpoon from shore**
- **Trolling from small boat**
- **Bottomset**
- **Drumline**

For the hook and line technique, a line would be baited with dead tuna or mackerel, seal placenta, or seal tissue from any available carcasses and fished from shore or from a small boat in water <2 m and up to 20 meters from shore. Once a shark has been targeted for removal, the line would be baited. Bait soak time would be limited to one hour following the last sighting of a targeted shark to reduce the possibility of attracting additional sharks to the area. Currents would be noted, and the bait would be placed in an area that would avoid excessive risk of scent emanating from the bait to attract other sharks or put seals at additional risk. Gear would be tended to ensure that only Galapagos sharks are hooked. No personnel would enter the water during fishing activities.

A spear gun or harpoon may be used from shore or small boat near to shore when a shark is observed to be very close to the shoreline. A barbed shaft, shot from a spear gun or delivered by hand, would be attached to wire cable and connecting line that would be used to retrieve sharks to the beach for euthanasia. The spear gun may be powered by elastic bands, as commonly used by

sport divers, or by a small caliber (.223) cartridge. In all instances, the spear or barbed head of the spear would be tethered by line so that the shark can be brought to shore for euthanasia.

The trolling method involves trailing an artificial lure from a small boat, using a heavy line and a spring (bungee) cord, with a chain trace and/or wire leader near to the lure. Boat travel speed would be 5-7 knots. Any shark caught would be hauled alongside the small boat, euthanized with a .44 caliber bang stick, and taken to shore for necropsy. Most common bycatch, ulua (Carangidae), would not be attracted to the lure. Trolling would not occur if seals are observed swimming in the area.

The bottomset method is a method deployed from a small boat, with the gear modified for fishing for Galapagos sharks. Humans may be remote from, but in visual contact with, the gear. A weighted long line about 100 feet long would be placed on the seabed where there are openings in the reef adjacent to pupping sites within FFS, <60 ft in depth. The bottom gear would be a heavier gauge than pelagic gear, and would comprise a heavy monofilament mainline with lighter weight monofilament gangions attached about 10 feet apart. A flexible 1/16" wire rope would be used as a short leader above each hook to prevent sharks from biting through the leader. Hooks would be 14/0 to 16/0 circle hooks. If a monofilament bottom line proves problematic, such as drifting into coral structured areas, causing chafing or wear on the line or damage to coral, we may switch the bottom line from monofilament to another material, such as polypropylene, bloodline (a thin braided line made of synthetic line, commonly used in bottom fishing), or tarred OPI nylon mainline to alleviate the problem.

The number of hooks attached to each bottomset line would vary. In 2009, no more than 5 hooks would be deployed at one time, on a ~100' line, as submitted in the application for a permit from the Monument. A report to the Monument would be submitted for review after 5 Galapagos sharks are taken, to determine if more sharks could be taken by this method. In subsequent years, status reports would be prepared whenever 5 Galapagos sharks are taken, however, fishing may continue to meet stated objectives.

Catch per unit effort (CPUE—hook hours) of Galapagos sharks using handlines in the shallow waters near pupping sites has been documented at 0.015 (hours fished using one hook) (Wetherbee & Lowe 2003, NMFS 2008), so substantially more than 5 hooks simultaneously deployed would likely be required to catch up to 25 sharks in a pupping season (May through September). Nonetheless, boat size and personnel constraints would limit the number of hooks (and therefore length of bottomset), so no more than 20 hooks could be deployed simultaneously.

The bottomset would be attended appropriately at all times via short soak times or otherwise within the view of the fishing crew. The crew would also be experienced in the use of turtle dehooking devices, with dehooking devices on board at all times. However, the small number of hooks, the use of fish bait, and the use of large circle hooks substantially decreases the potential for a turtle hooking (Section 3.1).

The gear would be deployed and retrieved by hand from a small boat, and with short soak times of a maximum of 5 hours and would be checked in between when hooking is evidenced by observation of the attached marker device. The marker device would comprise a buoy with a flag to designate each end of the gear and would be connected to the monofilament mainline using a 1/2" diameter polypropylene buoy line. A brummel hook or similar type snap-on hook would be used to connect the buoy to each terminal end of the gear and then anchored to the seabed with a mushroom type

anchor or other anchoring device depending on the type of seafloor substrate. The gear would be deployed and anchored on sandy bottom, avoiding live coral areas.

The most effective time for fishing for sharks is at night. However, NMFS personnel are not permitted to be in a small boat in the dark. However, fishing could be conducted at dawn and dusk, as long as all lines are pulled and personnel on shore before dark.

Measures to prevent seal and turtle entanglement in the buoy line would include shielding the buoy line with segments of PVC pipe, or modification of the shape of the float buoy to add a rubber, tapered extension, a recent development to prevent cetacean and pinniped entanglement in float buoys. Any entanglement or hooking of a monk seal or sea turtle by the equipment would result in immediate cessation of fishing, pending review of methodology and consultation initiated with NMFS per the ESA.

A drum line with a single hook could also be used. The drumline method uses an air- or foam-filled drum or large buoy, with an attached chain trace and single baited circle hook, size 14/0 to 20/0, shackled to the other end of the chain trace. Bait would be the same as for bottomset fishing described above. The hook is suspended approximately 3m above the sea floor. A ground line is also shackled to the drum with a swivel and then attached to a Danforth or CQR anchor on the sandy bottom substrate. A scope of three to four times the water depth would be used. Precautions to prevent entanglement would be identical to those described for the bottom set method. The locations of sets would be in the sandy channels in the vicinity of pupping sites. This method may be used in addition to the bottom set method described above.

2.2.2 Alternative 2: Continue the Current Program, Adding Shark Removal using Expanded Bottomset Fishing in Deeper Waters (Proposed Action)

NMFS proposes to continue the actions described in the no action alternative as a long-term program, modifying specific activities as needed based on “lessons learned,” and further expanding the program to include bottomset fishing in deeper waters at FFS.

Due to the complex, and in some cases intractable, nature of the challenges facing the Hawaiian monk seal population, this proposed action may not lead to reversing the negative population trajectory into positive population growth. However, at a minimum, these efforts could reduce the rate of decline so that the population will be in a better position to rebound should environmental conditions in the NWHI improve. Further, the complex and fluctuating nature of these challenges will necessitate a multi-pronged strategy, with built in flexibility and discretion to afford rapid response to changes in ecosystems, habitat, and survival needs.

2.2.2.1 Introduction

At this time, likely avenues for reducing Galapagos shark predation on pre-weaned monk seals include limiting predation opportunities by removing prey (translocation of pups once weaned); deterring predation (with artificial devices harassment and human presence); and/or removing sharks. HMSRP has pursued all three fronts over the last decade but has had limited success in permanently curbing predation of pre-weaned pups below 20% of the FFS annual cohort, suggesting that an increased effort in all three areas is needed to make progress. Recommendations received from shark and seal experts and numerous stakeholders in attendance at two recent workshops devoted to this issue (January 8-9 and November 5-6, 2008) support this notion (NMFS 2008, NMFS 2009 *in prep*). Using expanded bottomset gear represents an increased effort to

contain the Galapagos shark threat when other methods of containment have failed. This method has proven to be effective in capturing Galapagos sharks at FFS in the past (Taylor and Naftel 1978, DeCrosta 1984, Vatter 2003). The expected take of Galapagos sharks from this method is not likely to adversely impact the greater FFS Galapagos shark population as assessed in ECOPATH/SIM models (NMFS 2008, NMFS 2009 *in prep.*).

Galapagos sharks at FFS have demonstrated an apparent wariness to humans over the last decade of observation. Efforts to remove overtly predatory Galapagos sharks in shallow nearshore waters (within visual range of pupping sites) have been met with limited success, likely due to this wariness. This wariness has also likely been paramount in reducing the efficacy of traditional fishing methods conducted from shore, small boats and weighted drum-line gear. Although twelve sharks were removed by the HMSRP via hook-and-line fishing or harpoon between 2000 and 2006, fishing effort (number of hook hours) was low, ranging from 10 to 30 hours of fishing, and efficiency (removals per effort hours) progressively deteriorated throughout that period. Therefore, we seek the maximum number of options to safely remove a defined number of Galapagos sharks if certain conditions are met. The additional fishing option is expanded bottomset fishing in areas adjacent to pupping sites at water depths slightly greater than past efforts. Therefore, HMSRP believes that removal using expanded bottomsets, set and monitored remotely, would act to moderate or circumvent shark wariness..

Expanded bottomset gear is primarily designed to be set at greater depths than those of the limited fishing methods used by the HMSRP in the past. Historically, expanded bottomset fishing is the most efficient and effective way of capturing Galapagos sharks at French Frigate Shoals to date (Taylor and Naftel 1978, De Crosta 1984, Vatter 2003, C. Boggs, NMFS, 2009, *per comm.*). Furthermore, CPU estimates (sharks/hour per hook) of Galapagos sharks appear to increase with water depth (0.015 within the atoll; 0.04 in the deep lagoonal areas; 0.15 outside the atoll) (C. Meyer, HIMB, *per comm.*, January 2009). Several studies and commercial operations have demonstrated the effectiveness of this technique for capturing Galapagos sharks. For example, commercial bottomset fishing occurred in FFS in July and October 1999, removing over 50 Galapagos sharks, demonstrating that this is a highly effective way of capturing sharks in the NWHI (Vatter 2003). Interestingly, this large take of Galapagos sharks was subsequently associated with the greatest decline in pre-weaned pup loss (in 2000) since the onset of the peak predation era commencing in 1997 (Vatter 2003, C. Boggs, NMFS, 2009, *per comm.*).

We expect to capture a greater number of Galapagos sharks of varied life history and behavioral characteristics than with previous limited methods. Lethal removal would be limited to adult Galapagos sharks (as determined by pre-caudal length; De Crosta 1984); however, observation of shark predatory behavior or its proxy, proximity of Galapagos sharks to pupping sites, would not be prerequisites because individual predation history would not be discernable before capture. Bycatch is substantially reduced with expanded bottomsets when fish are used for bait on large diameter circle hooks and soak times are limited (NMFS 2008b, NMFS 2009).

A standing hypothesis developed by experts familiar with this predator-prey system in FFS is that a small number of site-specific Galapagos sharks is likely involved in pup predation. This hypothesis was formed, in part, by the distinctiveness of this behavior for the species and the apparent low density of Galapagos sharks in the atoll (reflected by low CPUE and rarity of sightings despite over 3,000 daytime hours of observation) (Harting et al. *in prep.*). Globally, the species is known to be resident insular, typically found in depths of 150m, and feed primarily on cephalopods, elasmobranchs, and reef, demersal and bottom fishes (D. Grubbs 2009, *per comm.*, Vatter 2003).

However, Galapagos sharks are the only shark species observed by HMRSP to be near pupping sites charging, chasing, biting and killing pre-weaned pups. Thus, we expect that increased fishing pressure targeting adult Galapagos sharks at water depths of approximately 10 fm to 12 fm adjacent to pupping sites within FFS would include a significant proportion of this predatory subset, reducing this predation threat overall and resulting in a corresponding decrease in pre-weaned pup loss (Table 1).

Population size of Galapagos sharks at FFS is difficult to determine; however a likely range is determinable from recent research. DeCrosta (1984) estimated the population to be 703 individuals based on the area within the 30 m depth contour of the atoll. However, the Galapagos shark population has likely grown since then as a result of an ecological release when longline fishing within vicinity of FFS was restricted (Holzworth et al. 2006). Based on data from towed-diver surveys conducted in 2000 through 2003 (Holzworth et al. 2006), the population can be estimated at 4,380 individuals (based on an area of 1540 km², 80% of shark biomass as Galapagos shark species, and average Galapagos shark weight of 0.15 metric tons), though this is likely an overestimate because Galapagos sharks are attracted to towed divers (Parrish et al. 2008). Based on an ECOPATH model approach, the population is estimated at 1,604 individuals (F. Parrish, NMFS PIFSC EOD, *per comm* March 2009). In sum, the removal of 40 individuals is a small fraction (0.01-5.7%) of whichever estimated is used.

This work would also contribute to filling critical gaps in our knowledge about Galapagos shark diet, population structure, and abundance of at FFS. Diet analysis would be conducted on all caught sharks by examining their stomach contents, which may include genetically screening for monk seal tissue. Shark tissue samples would be retained for future DNA extraction and microsatellite analysis to determine effective population size if the total number of Galapagos sharks caught approaches at least 40 individuals. An estimate of minimum population size can be identified by the asymptote of a curve relating the number of distinct genotypes to the number of samples, given a set of sufficiently heterozygous microsatellite primers for the species (Creel et al. 2003). Additionally, estimated rate of gene flow between FFS and nearby atolls, such as Laysan and Mokumanana, may be possible in the future if samples are collected from these sites as well. Change in population structure derived from growth curves may also be possible if pre-caudal lengths of all Galapagos sharks caught are compared to those from previous studies and sample sizes are sufficient (DeCrosta 1984). The proposed expanded bottomset fishing methods mirror data collection methods used by shark researchers in previous years. Therefore, CPUE estimates would be directly comparable to those determined by previous researchers and may inform determination of Galapagos shark population growth and change. In sum, these analyses would greatly improve our baseline understanding of the current dynamics of the Galapagos shark population at FFS (NMFS 2009 *in prep.*).

On balance, the loss of a small fraction of the Galapagos shark population in order to reduce the loss of approximately 20% of the monk seal annual cohort is appropriate to retain the greatest diversity of life at FFS ecosystem while gaining valuable insight on Galapagos shark population dynamics. Due to shark predation (confirmed and inferred), 201 pre-weaned pups have been lost or injured since 1997 (based on data from March-September for those years). Our removal methods have been designed to have a minimal impact on the physical environment and the other species that utilize it. The gear we propose to use, duration and location of fishing, and the total number of sharks we propose to remove allow for appropriate targeted catch and minimal bycatch to achieve our objective of protecting the maximum number of monk seal pups.

2.2.2.2 Action Contingencies

Expanded removal would be warranted if deterrents and/or limited removal methods are not successful in reducing the number of pups lost to predation to goal levels (see detailed contingencies below). Given the reasonable effort expended by HMSRP, limited removal and use of various deterrents has, in the past, not limited pre-weaned pup predation to desired levels. Lack of efficacy and feasibility of limited removal and deterrents are likely to continue to occur due to experienced low CPUE, few shark observations, and/or lack of effective equipment (deterrents and fishing gear). All codes discussed in these contingencies are discussed in Appendix 1.

This more expansive/less specific method of shark removal would be implemented once HMSRP documents a shark predation incident (inferred or confirmed pup loss or confirmed bite) in a given season and if:

- 1) The prior season's limited removal was unsuccessful because no Galapagos sharks were removed given a reasonable effort, **OR**
- 2) The prior season's limited removal was successful at removing multiple Galapagos sharks at one or more sites, subsequent pup loss decreased at those sites but atoll-wide pup loss was not within the specified goal range (0-2 pups or 5% of the annual cohort, whichever is less/season), **OR**
- 3) Acoustic shark tag data further substantiate that a small subset of site-specific Galapagos sharks is involved in pre-weaned pup loss. A panel of experts at a Workshop held by HMSRP on this issue concluded that expanded removal was likely warranted if the Galapagos shark population at FFS could be characterized as such (NMFS 2009 *in prep*). Data would indicate that:

Small means: A minority (greater than 1 individual and less than one third of individuals tagged) of the total sampled Galapagos shark population consistently frequents at least one of the five pupping sites within a distance of approximately 500m [NMFS WII p10] from shore **AND**

Subset means: Their presence at pupping sites is statistically greater than the population-wide incidence during the pupping season, based on the tagged population of Galapagos sharks (HIMB study), **AND**

Site-specific means: This subset remained within FFS atoll environs (approximately the 180m contour based on De Crosta 1984, but depending on receiver coverage) for the entire pupping season for which pup loss occurred at typical levels (~15-20% of pups born per year)

OR

- 4) Predation is occurring at catastrophic levels ($\geq 50\%$ of pups born by the middle of the pupping season are shark mortalities (confirmed or inferred) and/or suffer near-lethal bites (severity 2-3) atoll-wide.

Conversely, if any of the following conditions are met, then expanded removal of Galapagos sharks will not be initiated or would be discontinued if initiated:

- 1) The acoustic tag data indicate that a majority of the tagged Galapagos shark population frequents pupping sites within in the pupping season and that at least some of this majority disperses to other atolls within this time period, **OR**

2) Evidence suggests that the action may inadvertently increase shark predation on pups. This will be determined when a higher proportion of pups born subsequent to the initiation of the action suffer shark-mortality (confirmed and inferred) and/or near-lethal bites (severity 2-3) as compared to the number of incidents occurring during the similar time period in the two seasons prior, **OR**

3) An unusual shark mortality event unrelated to the HMSRP program, such as a disease outbreak or entanglement occurs in which a high number of Galapagos sharks die within the 30 fm depth contour of FFS. De Crosta (1984) identified the 'border' of FFS at the 30 fm depth contour in his study examining Galapagos shark abundance, **OR**

4) Observational data demonstrates that tiger sharks preyed on multiple pre-weaned pups within one pupping season. Observational data will include a witnessed accounting of charging, chasing, biting, or attacking behavior of a tiger shark on a pre-weaned pup, **OR**

5) Acoustic tag data demonstrates that tiger sharks preyed on multiple pre-weaned pups within one pupping season. Acoustic tag data will include a tagged tiger shark detected near a pupping site and at that time no tagged or observed Galapagos sharks are present on the day of or the day prior to a pre-weaned pup bite or disappearance, assuming that an appropriate number of Galapagos sharks are tagged in 2009 (approaching the 100 individuals stratified across depths as expected by C. Meyer, HIMB). Admittedly, this is extremely conservative approach. Acoustic tag data for pupping seasons 2005 through 2007 and May 2008 at Tern, East, and Trig Islets revealed no tagged tiger shark presence at the same time as a pre-weaned pup bite or disappearance occurred (K. Gobush, HMSRP, *pers. comm.*, January 2009 based on C. Meyer HIMB tiger shark data).

2.2.2.3 Action Duration

If the above conditions are met and application of expanded removal is initiated, it would continue until at least one of the following conditions is met, with one notable exception:

1) 40 sharks have been removed in a single season, **OR**

2) Subsequent pre-weaned pup loss has decreased to zero for the remainder of that season and at least half of the typical pupping season is included in that remainder, **OR**

3) The action has continued for two consecutive seasons. If a statistically significant correlation exists between the number of Galapagos sharks removed and the decrease in the proportion of pre-weaned pups lost to shark predation (confirmed and inferred), then continuing the action will be evaluated and considered.

2.2.2.4 Combining Actions in the Toolbox

Expanded removal may occur singly or concurrently with other management actions to mitigate pre-weaned pup loss, including deterrents (human presence, proxies, electro-magnetic devices), limited fishing in shallower waters, and barriers, as well as actions taken by other components the HMSRP, including moving weaned pups. An ability to apply multiple management actions simultaneously allows HMSRP to respond to changing dynamics of the FFS ecosystem and the movement and behavior of both Galapagos sharks and monk seals. However, if multiple fishing methods are deployed at one time, the total number of hooks and associated amount of bait would be closely monitored and limited if necessary to avoid attracting unusual numbers of sharks within a 200m radius of any pupping site.

2.2.2.5 Methods: Expanded Bottomset

Crew: A crew comprised of up to 5 members familiar with bottomset fishing would be tasked with setting gear and dispatching of up to a maximum of 40 adult Galapagos sharks in one pupping season.

Gear: Expanded bottomset gear proposed for use here is patterned after that successfully used in previous studies (Table 1). Expanded bottomset gear would include horizontal weighed polypropylene ground line with circle hooks (largest commercially available 16/0- 20/0 Mustad) on steel swivels or steel leaders on gangions (approximately 6 to 12 feet of galvanized cable or microfilament line) set on or near the ocean bottom on sandy or rubble substrate (non-coral) attached to two or more vertical dropper lines with floats and weights. The number of circle hooks per set would average 32, reduced if initial catch rates are exceedingly high in a single set or as the shark removal quota is approached. The number of hooks could also be increased to 48 if initial catch rates are exceedingly low in a single set. Based on calculations by Vatter (2003), catch rates are less than the number of hooks deployed. Furthermore, catch rates here are expected to be lower than that experienced in previous studies (Table 1) because soak times used by HMSRP would be substantially shorter than in those studies. Therefore, the number of hooks deployed may be more than that used in previous studies to account for this difference in methods.

Table 1. Galapagos Shark Catch using Expanded Bottomset Fishing Gear at FFS.

Date	Study	# Sets With G. Sharks	Soak Time (Hrs)	# Hooks/Set	Set Depth (Fm)	Bait	Galapagos Sharks Caught	Monk Seal, Green Turtle Bycatch
5/77	Taylor and Naftel 1978	1	n/a	32	15-20	fish, shark	2	0
11/78, 3/79, 10/79, 5/80, 10/80	De Crosta 1984	28	12	16-32	20	n/a	34	0
7/99; 10/99	C. Boggs NMFS, <i>per comm.</i> Vatter 2003	2	~ 20	420	35	fish, shark, ray	52	0

Bait may include elasmobranch species, including dispatched Galapagos sharks caught with this method, tuna, mackerel and/or other fish species. Sets would be made in depths of 10 fm to 12 fm, balancing the need to set in deeper water than previous efforts as well and be located adjacent to pupping sites. However, sets would not be made within in 200m of pupping sites; pre-weaned pups were not known to swim greater than 200m from shore in one study that followed 30 mother-pup pairs for the entire nursing period (Boness 1990). Sets would be made and retrieved during day or nighttime hours. The latter would focus on pre-dawn soaks retrieved during daylight hours. Soaks would be for approximately 3-6 hours and made back-to-back for a maximum of 12 consecutive hours. The gear would be deployed and retrieved from a small boat or fishing vessel; a winch will likely be used.

Information on each set would be recorded, including gear set and retrieval times, latitude and longitude of both ends of the bottomset, bait used, weather conditions, hours soaked (including time of day), depth of fishing sea surface temperature, sea state, number of hooks, buoys, anchor weights, number of hooks lost, number of hooks straightened, number of hooks with targeted catch, number of bycatch caught and released, with condition at release and species, length of groundline (nm), species caught, number, relative condition, and sex. Tape measure and calipers would be used to measure shark pre-caudal length. A post-fishing report would be prepared at the end of each season and submitted to the Monument

2.2.2.6 Post-catch procedures:

Hooked sharks would be brought adjacent to the vessel or aboard and euthanized with a 0.44 caliber bang stick. As agreed upon by USFWS and NMFS (August 18, 2001), information concerning the removal of each shark would include environmental conditions at the time of removal, criteria used to determine the shark targeted for removal, identifying tags and physical features of the shark removed, history of previous shark sightings, removal methodology, and method of euthanasia. Information and materials collected from each shark carcass would include morphometric measurements, genetic samples, stomach contents, vertebrae and reproductive status. Tissue samples from sharks would be analyzed to quantify compounds of potential concern at acceptable detection limits to include total metals, polychlorinated biphenyls, organochlorine pesticides, percent lipid and moisture, and fatty acid profile analysis for detection of possible monk seal consumption. Teeth and ventral (belly) skin would be retained and made available for cultural purposes. Vertebrae and skin samples would be collected for isotope to detect marine mammal consumption and genetic analysis. Stomach contents would be retained for diet analysis; genetic screening for monk seal DNA may occur on unidentified digesta if necessary. Preservation of samples would be as follows: vertebrae samples in 95% ethanol or frozen and tissue samples for DNA analysis in a 20% dimethyl sulfoxide solution or frozen. After all samples and data have been collected, shark carcasses would be discarded at several of the closest deep water locations outside FFS; every attempt will be made to distribute carcasses at several points to avoid infusing one location with an excess of biomass.

Hawaiian cultural protocols, based on extensive practitioner input, would be included in all shark removal efforts. Ongoing consultation with Hawaiian practitioners would advise fishing personnel on traditional fishing techniques, along with the feasibility for an on-site practitioner to conduct activities, including the collection of shark parts for cultural use (remains to be determined).

Any species other than Galapagos sharks that are caught as part of this project would be released immediately alive. Bycatch may include tiger sharks, reef sharks, or other top predators such as

ulua. We anticipate that bycatch would be minimal, as the hooks should be too large to catch small reef sharks or ulua, and would be small enough to be bent (straightened) by large tiger sharks. Moreover, circle hooks are less prone to accidentally snag non-target animals and, if snagged, tend to catch the animal in the mouth, where it can be easily removed with no injury. Furthermore, use of fish rather than squid substantially reduces the potential for sea turtles to swallow the hook (NMFS 2009). If a monk seal were observed approaching the fishing gear, the management action (expanded bottomset) would discontinue at this location.

2.2.3 Monitoring Activities Common to All Alternatives

An effective monitoring system would be continued to attempt to document changes in shark activity at pupping sites, detect instances of shark predation on monk seal pups, assess shark response to deterrent devices, observe changes in monk seal and green sea turtle behavior in response to actions implemented, and maintain deterrent and fishing gear which has been deployed. All codes used in monitoring are described in Appendix 1.

2.2.3.1 Monitoring Shark Presence and Behavior

Observation using systematic surveys from a 12-foot tower, the ground, patrolling small boats and/or remote cameras would be the primary methods of monitoring shark presence and movement patterns at two main pupping sites with historically high shark incidence. As described in the previous permit applications, the tower is a 12-foot structure made of scaffolding that would be erected on Trig, located approximately 40 meters from the south end of the island. The geography and land mass of other pupping sites prohibits observation tower installation because of the relatively large footprint and little available land mass; therefore, surveys would be conducted from the ground or small patrolling boat at these sites. Any installation of a remote camera recording system(s) would allow shark observation during days and times when HMSRP staff are not present. We expect to be able to observe shark activity via remote cameras, pending consideration of this method under the manager's permit (under consideration by the Monument for the 2009 season; OMB Control #0648-0548).

On the rare occasion when a Galapagos or tiger shark is sighted within the vicinity of pupping sites (including exhibiting predatory behavior or attacking), identifying characteristics and behaviors would be recorded on a standardized data form. This standardized form is based on worksheets used in "time scan sampling" in the tower observation procedure (2000-2004) and an International Shark Attack File questionnaire created by the Elasmobranch Society. Historically, "time scan sampling" involved intensive, continuous observation of shark activity in the nearshore waters surrounding major pupping sites (a detailed description of the monitoring protocols are available in previous reports or upon request). Observations were historically conducted from both the ground and from an elevated tower on Trig Island. Continuous monitoring was extremely labor intensive and the rarity of shark sightings led to little data collected using this method for the effort involved. Therefore, this procedure is not planned to be used at this time; however, intensive monitoring may be reinitiated if it becomes evident that it might be effective, because multiple deterrent systems would be deployed and it is essential that the effectiveness of each component be assessed. This would also enable the program to progressively refine such aspects of the system as physical placement, timing, etc., and to ascertain whether undesirable effects associated with deterrent application may occur.

2.2.3.2 Monitoring Green Turtle Land-Based Behavior in Response to Monk Seal Activities

Coordination with the PIFSC Green Turtle Research Program would be conducted to determine if their monitoring indicates that changes in turtle behavior apparently occurred in areas where shark predation mitigation activities were conducted. For the islands where shark predation mitigation actions are occurring but green sea turtle information is not routinely collected on nesting and basking, HMSRP would attempt to collect information as part of routine monitoring assessment, such as during atoll counts, on the number of basking green turtles and nest pits to determine if HMSRP actions might be affecting green turtle behavior and nesting.

2.2.4 Native Hawaiian Practices and Participation

Hawaiian cultural protocols, based on extensive practitioner input, will be included in all shark removal efforts. NMFS has conducted numerous group and individual meetings with Native Hawaiian cultural practitioners and advisors to incorporate appropriate actions into proposed shark fishing activities and to ensure that shark removal and disposal of remains are in keeping with Hawaiian cultural practices. Ongoing consultation with Hawaiian practitioners will advise fishing personnel on traditional fishing techniques, along with the feasibility for an on-site practitioner to conduct activities, including collection of shark parts for cultural use remains to be determined. If a Hawaiian practitioner is on site, his/her observational activities related to shark removal efforts and monk seal population assessment will be in accordance with the guidelines outlined in existing permits from NMFS and the Monument. NMFS has also added a native Hawaiian as a member of the Hawaiian Monk Seal Recovery Team to improve cultural components of all Hawaiian monk seal recovery efforts.

3 Evaluation of Environmental Consequences

The following impacts apply to the alternatives considered in detail and described in Chapter 2. The no action alternative is the current program as described and analyzed in the Environmental Assessment on the Effects of NOAA Fisheries Permitted Scientific Research and Enhancement Activities on Endangered Hawaiian Monk Seals (Permit No. 848-1695) and further described in Chapter 2 of this PEA. The proposed action (Alternative 2) is expanding this program to include additional actions, with focus on additional medical activities and holding weanling and juvenile seals in captivity, either in situ in pens or in facilities in Honolulu for enhancing survival. Alternative 3 considers temporarily translocating weanling and juvenile seals to the MHI for enhancing the nutritional condition before translocating them back to suitable habitat in the NWHI. Abandoning the program is not allowable by law.

3.1 Potential for Bycatch of Monk Seals, Sharks, and Green Sea Turtles in Bottomset Fishing

3.1.1 Potential for Adverse Impacts to Sea Turtles and Monk Seals from Nearshore Fishing

The Pacific Islands Regional Office (PIRO) of NMFS conducted an Section 7 consultation on limited bottomset and drumline fishing methods in July 2007. In agreement with the Biological Evaluation prepared by PIFSC for this consultation, PIRO stated that “overnight soaking is key to catching Galapagos sharks...but day fishing may still be successful in catching these animals.” The PIRO consultation concluded:

- **Any behavioral disturbances to monk seals or green sea turtles caused by shark removal activities would be “temporary and insignificant and result in no adverse changes to feeding, breeding, or resting behaviors.”**
- **The likelihood of entanglement or hooking to monk seals and green sea turtles to be discountable. At the most, “only a possible alteration in their behavior, to investigate either the equipment or the baited hooks” would occur, and “result in no adverse changes to feeding, breeding, or resting behaviors.**
- **The likelihood of a vessel collision with a monk seal or green sea turtle “is discountable.”**
- **No destruction or adverse modification of monk seal critical habitat will occur.**
- **“Cumulative impacts associated with the shark removal operations pose insignificant or discountable effects to listed species” and as the action would provide “beneficial effects for monk seals, cumulative impacts from this action are negligible.”**
- **“This project is Not Likely to Adversely Affect ESA-listed Hawaiian monk seals and green turtles, and will have no effect on designated critical habitat.”**

Consultation would require re-initiation if a take of a monk seal or green turtle occurs; new information reveals effects that have not been considered; the action is modified in such a way that

effects that have not been considered might occur; or a new species is listed or critical habitat designated.

3.1.2 Potential for Bycatch of Green Turtles in by Bottomset Fishing in Deeper Waters

Summaries of records of turtle bycatch in commercial shallow-set fisheries compiled by Beverly and Chapman (2007) document that most sea turtles hauled in alive are released alive. However, turtles that swallow the hook have a higher risk of dying after release. Modified gear, including large diameter circle hooks with fish bait, used on boats with dehooking equipment by a trained crew such as is required in the Hawaii-based longline fishery, substantially reduced sea turtle bycatch and mortality of bycaught turtles (Figures 9 and 10) (Boggs and Swimmer 2007, Read 2007, Gilman et al. 2007). In addition, all FFS shark studies to date that used bottomset gear did not catch any sea turtles incidental to fishing activities (Table 1).

Therefore, since these numbers are based on commercial fisheries using up to a thousand hooks on overnight soaks, our proposal of using 32 hooks on multiple short soaks with viewing by fishers should have negligible potential to incidentally catch a sea turtle. In the unlikely situation where a sea turtle is caught, trained personnel using proper dehooking devices will dehook the animal. If we observe a turtle displaying interest in the gear, we will remove the gear and make the set elsewhere. If a turtle is caught, fishing would cease and consultation would be initiated.

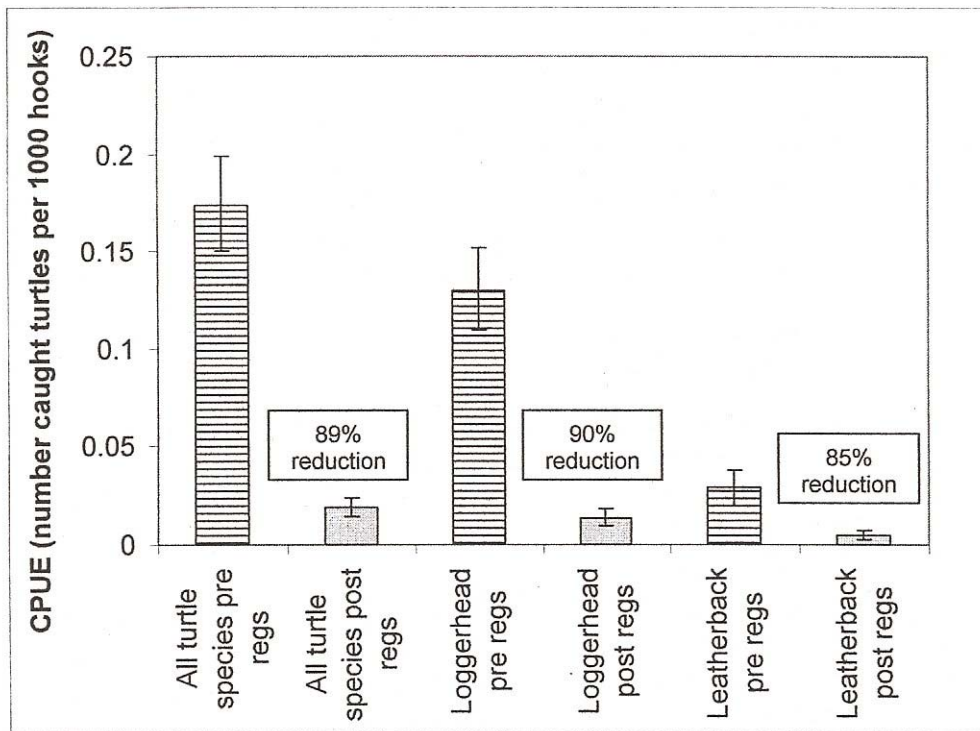


Figure 9. Change in sea turtle capture after implementation of bycatch regulations (large diameter circle hooks and fish bait) in the Hawaii swordfish longline fishery.

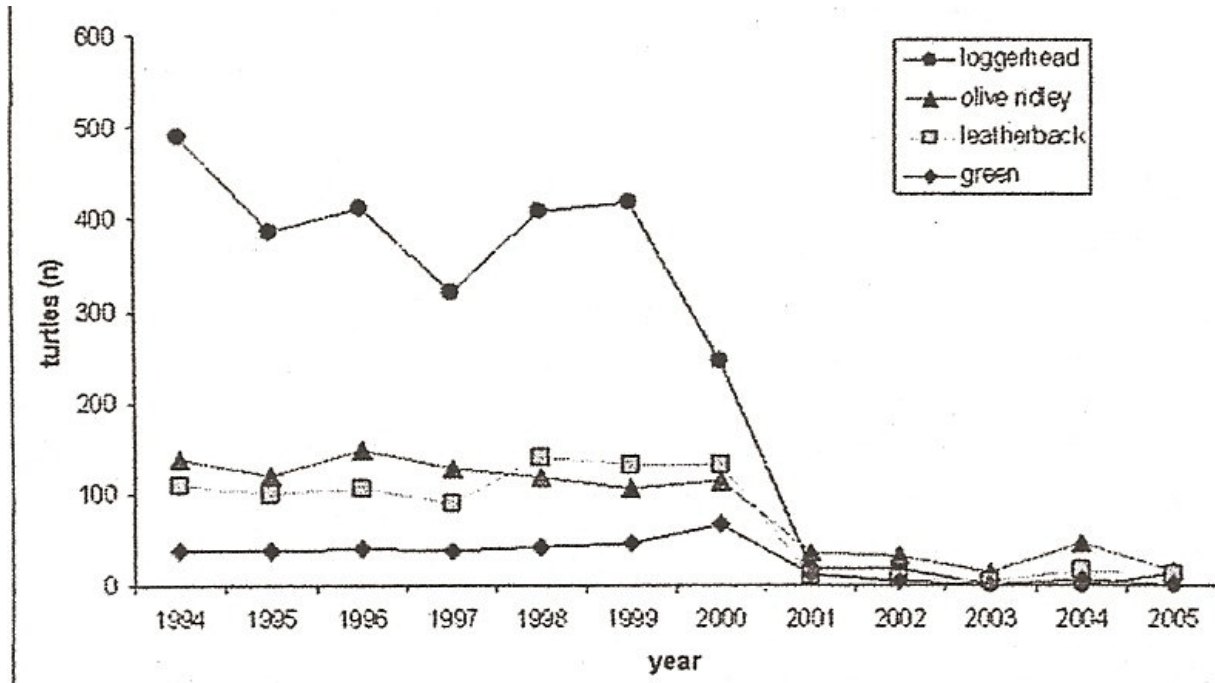


Figure 10. Estimated turtle interactions in the Hawaii-based longline fishery (deep-set and shallow-set combined) 1994-2005. (WPRFMC 2008)

3.1.3 Potential for Bycatch of Monk Seals

Monk seals are known to interact with fisheries, and the possibility exists that seals will become hooked during the proposed activity. In the early 1990s commercial pelagic longline operations in close proximity to the NWHI may have been adversely affecting monk seals, as indicated by the sighting of a few animals with hooks and non-natural injuries. Three seals were observed at FFS hooked by longline J-hooks, 2 in 1991 (NMFS, unpub. data), and 1 in 1994 (NMFS, 2001). In 1991, ‘atypical’ injuries were observed on 11 monk seals at FFS (NMFS unpub. data). The injuries were lacerations and tears around the mouth or on the head, and were consistent with either propeller cuts or a hook having been torn from the animal. In 1991, Amendment 3 to the NMFS Pelagic Fisheries Management Plan established a permanent 50-mile protected species zone around the NWHI that closed the area to longline fishing. Establishment of the protected species study zone around the NWHI appears to have eliminated monk seal interactions with the longline fleet. Since 1994, no interactions with monk seals in the pelagic longline fishery have been reported.

A total of 55 hooking incidents involving monk seals have been observed in the MHI during 1982 through 2008 (NMFS unpub. data). None of these incidents involved bottomset fishing methods, but nonetheless provide further evidence that monk seals may be caught by a baited hook. Most of the baits in these incidents are not known, although octopi and eels were being used in a few instances. Octopi and eels will not be used for bait in the proposed action.

No seals were observed or reported hooked during bottomset fishing in the NWHI as listed in Table 1.

Because of the possibility that seals may interact with fishing gear, HMSRP will retrieve and move to another area any gear which is being investigated by a seal. If any seal should become hooked during the proposed activity, all fishing using the method that hooked the seal will cease.

3.1.4 Potential for Bycatch of Other Fish

The size and shape of hooks should be selective for Galapagos sharks: too large to catch small reef sharks or ulua and small enough to be bent by large tiger sharks. Thus, circle hooks are less likely to accidentally snag non-target animals. Any living bycatch will be released immediately during the short soaks. In Hawaii's shallow-set (swordfish-directed) longline fisheries, in which sharks are quickly released from fishing line, survivorship of the most commonly-caught species has been estimated at 95%, 76% and 92% for blue sharks, short fin mako sharks, and oceanic white tip sharks, respectively (Walsh et al. 2002). It is expected that survival rates of any sharks caught as bycatch (i.e. sharks other than Galapagos sharks) would have higher survival rates because of short soak times.

3.1.5 Potential for Entanglement of Turtles or Monk Seals

All lines for fishing and anchoring structures to the bottom will include shielding of the buoy line with segments of PVC pipe or modification of the shape of the float buoy to add a rubber, tapered extension, a recent development to prevent cetacean and pinniped entanglement in float buoys. In the highly unlikely event of an entanglement or injury of a monk seal or green turtle would result in immediate cessation of fishing and a review of the methodology to determine any needed adaptations. No entanglement is expected in bottomset gear based on the 1999 commercial fishing work conducted at the outer boundary of FFS with 840 hooks, with no entanglements. Moreover, 7,506 hooks were deployed during that entire fishing trip, with no seal, turtle or cetacean interaction documents (Vatter 2003).

3.2 Acoustic Disturbance to Pinnipeds and Cetaceans

Twenty-five cetacean species, of which 6 are ESA listed, occur within the EEZ around the Hawaiian Archipelago. Two of the 25 species, Hawaiian spinner dolphins and bottlenose dolphins (*Stenella longirostris* and *Tursiops truncatus*), occur within the atolls and in close proximity to the islands at which the proposed action would occur. The only pinniped species occurring in the area is the Hawaiian monk seal.

The primary action which could acoustically impact marine mammals is broadcast of boat sound underwater as a proxy for human presence. By design, these sounds would approximate noise of routine small boat traffic attendant to management activities and resource monitoring within the Monument. Frequencies and amplitude will be at levels which will not adversely impact marine mammals. Maximum speaker output will be 180 dB, the maximum desired output to be used will be 120dB (a boat at high speed overhead) and the average target output will be 80-100 dB (a boat at slow speed). Frequency would cover a broad range from 200 Hz to 800 Hz.

Southall et al. (2007) report results of a panel of experts which reviewed behavioral and physiological responses of marine mammals to acoustic stimuli. Impacts of sounds on marine mammals were also considered at length by NMFS in proposing rules regarding take and importation of marine mammals by the U.S. Navy in the Hawaii Range Complex (Fed. Reg. Vol.

73, No. 121, pp 35510 - 35577). Unless otherwise noted, information below is documented in these two references.

NMFS uses three acoustic criteria to evaluate impacts of sound on marine mammals: Permanent Threshold Shift (PTS), which is permanent loss of hearing at certain frequencies—i.e. injury; Temporary Threshold Shift (TTS), which is temporary loss of hearing at certain frequencies; and Behavioral Harassment, which comprises a suite of highly variable and context-specific responses to sound.

3.2.1 Temporary Threshold Shift

The auditory bandwidth of pinnipeds in water is 75 Hz – 75 kHz, with the greatest sensitivity between ~700 Hz and 20 KHz. Hawaiian monk seals are sensitive at somewhat higher frequencies, with greatest auditory sensitivity from 12 kHz to 28 kHz (Thomas et al., 1990). TTS occurs in harbor seals at 25 minute exposure to 152 dB, California sea lions--174 dB, and Northern elephant seal --72 dB. While the TTS of monk seals is likely just within the range of the 180 dB maximum output of our proposed speaker, our target output of 80-100 dB would be below TTS levels, and would be in shorter duration (<5 min). Moreover, the seals are not captive and could easily move away from the sound source.

TTS in cetaceans has been measured primarily on bottlenose dolphins, using a variety of frequencies, sound pressure levels (amplitude), and exposure durations. Generally the longer the exposure duration, the lower the amplitude required to induce TTS. At 30 – 30 minutes exposure, 160 db induced TTS, whereas using 1 – 2 second exposures, 192 – 201 db were required to induce TTS. Frequencies used in testing ranged from 3 kHz to 20 kHz. No data exist on TTS using low frequencies within the 200 – 800 Hz range of the proposed action.

Cetaceans were categorized by Southall et al (2007) into ‘functional hearing groups’ based upon behavioral data, available audiograms, anatomical modeling, and other data, to indicate the frequency range of functional hearing. Low frequency cetaceans (7 Hz – 22 kHz) comprise all mysticetes; mid-frequency cetaceans (150 Hz – 160 kHz) comprise 32 dolphin species, 6 species of larger toothed whales, and 19 species of beaked and bottlenose whales; high frequency cetaceans (200 Hz – 180 kHz) comprise river dolphins, true porpoises, and pygmy/dwarf sperm whales. Only mid-frequency cetaceans will occur within range of the proposed action. At Trig, the minimum distance of speaker deployment to any cetaceans is likely to be >1 mile, where spinner dolphins are occasionally seen north of the island outside of the reef. At the Gins, spinner dolphins are occasionally seen with ¼ mile on the west side of the islets. To further reduce possible impacts speakers may be oriented toward the island and away from open water. Bottlenose dolphins are occasionally observed within the atoll typically at distances of several miles from the proposed deployment locations.

3.2.2 Permanent Threshold Shift

Data on sound pressure levels which induce PTS do not exist for marine mammals and are unlikely to be obtained due to ethical concerns. Nonetheless, using TTS data from marine mammals and relationships between TTS and PTS from studies of terrestrial mammals, NMFS uses the following acoustic criteria for injury: Cetaceans—215 db, and pinnipeds—224 db. The proposed sound output would be well below PTS.

3.2.3 Behavioral Responses

Southall et al. (2007) summarizes reports that address responses of cetaceans to sound, and was unable to come to a clear conclusion regarding reports of mid-frequency cetaceans. In some cases, animals in the field showed significant responses to sound levels between 90 and 120 db, while in other cases these responses were not seen in the 120 – 150 db range. The reports included field and laboratory data, and animals in the field responded at lower levels than in captivity. Spinner and bottlenose dolphins in the NWHI occasionally approach small boats to bow-ride, so some possibility exists that some individuals will visually investigate the source of small boat sounds. Nonetheless, no such behavior was observed during a single season using these devices in 2007.

Beached Hawaiian monk seals occasionally alert to the presence of a nearby small boat, but it is not known whether they are alerting to visual or acoustic cues. Monk seals may approach a boat while in the water, or if on land, will flee if a boat lands in close proximity to them, the latter case no doubt responding to visual presence. Monk seals did not appear to react in any way to the sound broadcast during 2007.

3.3 *Potential Effect of Shark Removal on the Galapagos Shark Population at FFS*

Removal of a small fraction of the greater FFS Galapagos shark population is not likely to have a significant impact on its function or survivalability. Until 1991, commercial fishing operations likely routinely removed Galapagos sharks from the ecosystem. Research removals and recent commercial take (1999), all involving the removal of tens of Galapagos sharks at a time, did not appear to have adversely impacted the population. Population size of Galapagos sharks at FFS is difficult to determine; however a likely range is determinable. DeCrosta (1984) estimated the population at that time to be 703 individuals based on the area within the 180 m depth contour of the atoll. However, the Galapagos shark population has likely grown with a likely ecological release associated with the restriction of longline fishing in the Monument since then (Holzworth et al. 2006). Based on data from towed-diver surveys conducted in 2000 through 2003 (Holzworth et al. 2006), the population can be estimated at 4,380 individuals (based on an area of 1540 km², 80% of shark biomass as Galapagos shark species, and average Galapagos shark weight of 0.15 metric tons), though this may be an overestimate because Galapagos sharks are attracted to towed divers (Parrish et al. 2008). Based on an ECOPATH model approach, the population is estimated at 1,604 individuals (J. Parrish, NMFS PIFSC EOD *per comm*, March 2009). Thus, the available data and population estimates suggests a stable or increasing population, though survey methods were admittedly not consistent across studies. In sum, the removal of 40 individuals is a small fraction (0.01-5.7%) of whichever estimated is used.

3.4 *Potential Effect of Magnetic and Electromagnetic Deterrents on Green Turtles, Other Elasmobranchs, and Teleost Fish*

Electromagnetic technology is selective to sharks and rays (elasmobranchs), as other animals including other fish lack the specialized sensory organ system that detects these fields, the Ampullae of Lorenzini. Therefore, these species should not display aversive behavior when in close proximity to generated magnetic or electromagnetic fields. However, non-target elasmobranch species (those that do not prey on monk seals) such as reef sharks and rays, may be affected, causing them to avoid areas where stimuli are deployed.

Bony fishes (teleosts), marine mammals, and turtles also do not contain electro-receptors, so the use of permanent magnets and electromagnetic devices is a selected repellent technology that should have not effects on non-elasmobranch species within the atoll. The magnetic deterrents may be deployed on arrayed floats in an effort disrupt known Galapagos shark patrolling routes, though this arrangement is not an enclosure. As with all deterrents, this deterrent type would be modified or suspended if any unforeseen risk or behavioral reactions by non-target species are detected.

Green sea turtles (*Chelonia mydas*) are thought to be declining throughout the Pacific Ocean, with the exception of Hawaii, as a direct consequence of a historical combination of overexploitation and habitat loss (Eckert 1993). The species is listed as threatened under the ESA, except for the breeding populations found in Florida and the Pacific coast of Mexico, which are listed as endangered. In Hawaii, green turtles nest primarily on six small sandy islands at FFS. Unlike any other regional sea turtle populations, green turtles in Hawaii are genetically distinct and geographically isolated. Ninety percent of the nesting and breeding activity of the Hawaiian green sea turtle occurs at FFS. Additional important areas of resident sea turtles have been identified and are being monitored along the coastlines of Oahu, Molokai, Maui, Lanai, Hawaii and at large resting areas in the reefs and islands surrounding FFS, Lisianski Island, and Pearl and Hermes Atoll. Since the establishment of the ESA in 1973, the nesting population of Hawaiian green turtle has shown a gradual but definite increase, although turtles in some areas have fibropapillomas of unknown origin and unknown effect on health and reproductive capacity (Balazs et al. 1998).

The current and proposed programs could potentially impact green sea turtles through both land-based and boat-based activities. The Environmental Assessment on the Effects of NOAA Fisheries Permitted Scientific Research and Enhancement Activities on Endangered Hawaiian Monk Seals (Permit No. 848-1695) (FONSI signed June 2003) includes monitoring Hawaiian monk seals and states: “Incidental harassment of basking adult green sea turtles may occur during ground monitoring of monk seals... Individual basking turtles are incidentally harassed when they alert to the presence of humans and flee into the water... Turtles which are asleep and basking on the beach are generally unaware of any unobtrusive human presence such as observing seals. However, some activities, such as landing a boat may waken some basking turtles, causing them to move into the water.”

Impacts to green turtles would be minimized by researchers being aware and avoiding resting turtles whenever possible. In order to avoid nesting and hatchling turtles, no personnel would walk the beaches from dusk to dawn where nests are known to occur.

Therefore, the activities on beaches where sea turtles occur would be minimized.

Sea turtles are known to exploit variations in the Earth’s magnetic field as a “magnetic map” to find their natal beaches after many years at sea. Different coastal regions have unique “magnetic signatures” based on the angle of inclination and intensity of the magnetic field. It is hypothesized that simple strategies of geomagnetic imprinting can return turtles to an appropriate geographic region, even after more than a decade’s absence. It has been hypothesized, based on data on Kemp's Ridley turtles (*Lepidochelys kempii*), that turtles arrive near natal nesting beaches on coasts of continents using the magnetic cues, at which time they use other local cues to pinpoint particular nesting beaches. These short-range cues might be pheromones secreted by other turtle females already aggregating, visual cues, or distinctive chemical cues from the beaches themselves leaching into the sea. Experimental evidence also indicates that adult turtles use magnetic cues when navigating to islands, although in what exact way is not known (Lohmann et al. 2008, Putman and

Lohmann 2008). No studies exist regarding sea turtle geomagnetic imprinting for natal beaches on oceanic islands, such as the FFS. If green sea turtles reach FFS using geomagnetic imprinting, the electromagnetic deterrent devices would be placed no more than 50m from shore, and more than likely within 10m to 20m from shore. At this point, turtles would most likely be using non-magnetic cues for finding the actual beaches. Therefore, it is not expected that electromagnetic devices would impede sea turtle perception, navigation and access to nesting beaches at FFS.

Potential impacts to sea turtles as bycatch in the limited and expanded bottomset fishing are evaluated in Section 3.1.

3.5 Potential Effects to Endangered Birds and Seabirds

No endangered birds populate FFS. The short-tailed albatross (*Phoebastria albatrus*) has been sighted on six occasions at FFS since 1938 (USFWS 2000), with the most recent sighting at Tern Island in 2002 (USFWS unpub. data). A number of ESA-listed bird species occur in the NWHI at sites other than FFS. Three of the four endangered birds in the NWHI (Nihoa millerbird (*Acrocephalus familiaris kingi*), Nihoa Finch (*Telespyza ultima*), and Laysan duck (*Anas laysanensis*)) occur primarily in the vegetated interior of the islands and therefore would not be impacted by any of the activities under the current and proposed program. The fourth endangered bird in the NWHI, the Laysan finch (*Telespyza cantans*), occurs at both Laysan Island and Pearl and Hermes Atoll. HNSRP personnel adhere to procedures mandated by the Monument to avoid injury or death of Laysan finches.

The NWHI provide vital habitat for more than 14 million nesting seabirds and breeding species, including 99% of the world's Laysan albatross (*Phoebastria immutabilis*) and 98% of the world's black-footed albatross (*P. nigripes*) populations. Of the 18 seabird species nesting at FFS, the black footed albatross, Laysan albatross, red-footed booby (*Sula sula*), masked booby (*Sula dactylatra*), brown noddy (*Anous stolidus*), black noddy (*A. minutus*), and frigate bird (*Fregata minor*) regularly nest on Trig, East, Little Gin, and/or Gin Islands.

The potential exists that seabirds could fly into the temporary observation tower with resultant injury or mortality. However, such incidents did not occur when the observation tower was erected from 2000-2004 (for over 3000 hours). This risk is therefore likely to continue to be negligible. In the highly unlikely event that a seabird does hit the tower, the tower will be taken down and the Monument will be contacted for guidance.

3.6 Potential Effects to Coral Reefs

The healthy and extensive coral reefs of the NWHI encompass over 11,000 square kilometers of coral reef habitat. The reefs comprise 47 species of hard coral and eight species of soft coral. Within the NWHI, the reefs differ in coral cover and species organization. Coral cover gradually declines to the northwest due to the slower growth rates and the increased frequency of storm disturbances (Grigg & Tanoue 1984).

The most likely actions to impact coral reefs would be associated with small boat activities, placement of objects in the water to deter sharks and bottomset fishing gear. Small boats will only be anchored on sand and anchors are never dropped on coral reefs, as required by Monument objectives. Boats operate at low speeds in shallow waters to avoid striking the reef. Objects or devices placed in the water to deter sharks and all fishing gear set may be placed near reefs but not

anchored, bolted or otherwise attached to the living reef structure. All objects placed in the water would be temporary and easily removed.

3.7 Potential Impacts of Global Climate Change

Ocean climate fluctuations that change the habitat quality or the prey availability of ocean resources have the potential to affect their short- or long-term distribution and abundance. Changes in oceanographic conditions may alter rates of direct and incidental takes of ocean resources in commercial fisheries as well as research. Rises in sea levels could adversely affect populations of monk seals as the potential exists that pupping beaches could be inundated. Rises in sea level might adversely impact important nesting habitat for sea turtles, but no analyses of these impacts are available. The magnitude of potential effects is uncertain, but as applied to the smaller scale nature of the research considered here, is not likely to affect the analysis presented. As indicated in Section 1.10, any changed circumstances that would have environmental relevance would require additional analysis and appropriate management changes that might be integrated into the HMSRP research program as appropriate.

3.8 Potential for Boat Strikes

Boat strikes during small boat activities are unlikely to occur. No documented accounts exist of seals or cetaceans being struck or injured by boats operated for the HMSRP activities since 1981. The moderate rate of speed and awareness of boat operators makes a strike unlikely. The same is true for larger boats operating in deeper water for the bottomset fishing for sharks. The boat would move at a moderate rate of speed to reach and return from the fishing site, and it is likely that the boat would remain in deeper water for time periods to conduct any night soaks, minimizing travel through the shallow water areas.

3.9 Archaeological and Cultural Resources

Archaeological and cultural resources are present in the NWHI primarily at Nihoa and Necker (Mokumanamana) Islands at the eastern end of the chain. Actions will not occur at either of these locations. No archaeological or cultural resources exist at FFS.

3.10 Potential to Spread Invasive Species

Significant effort is given to avoid introducing invasive species into the NWHI, including the Monument. A number of plant and animal species have previously become established on various islands in the NWHI. Alien species have had a profound effect on the native flora and fauna of the NWHI by outcompeting, preying on, and replacing native species, as well as providing habitat for non-native species, requiring large-scale efforts to eradicate these species, although with mixed results.

Extensive remediation efforts have been necessary at Laysan Island to control an introduced annual grass, sandbur (*Cenchrus enchinatus*) which was crowding out the native bunch grass (*Eragrostis variabilis*), the primary nesting habitat for the endangered Laysan finch. Golden crown-beard (*Verbesina enceloides*), found extensively on Midway and Kure Atolls, as well as Southeast Island in Pearl and Hermes Atoll, is believed to play a key role in the spread of avian pox by providing roosting sites for two non-native avian disease vectors: a mosquito and green-bottle flies. *Verbesina*

also crowds out other native plants and severely reduces ground-nesting habitat for both Laysan and black-footed albatross.

Rabbits and several species of rodent in the NWHI have severely adversely impacted the native flora and fauna. Rabbits were introduced to Laysan Island about 1903 and quickly stripped the island of vegetation and destabilized the sand. Unknown varieties of insects, plants, and three of five endemic birds went extinct on Laysan during this period. On Midway atoll, black rats (*Rattus rattus*) rats and house mice (*Mus musculus*) have caused the extinction of the translocated population of Laysan rails (*Porzana palmeri*), the last surviving population of the species. Rats and mice also prey on seabird eggs, chicks, and even adults. Polynesian rats (*Rattus exulans*) and black rats have been successfully removed from Kure Atoll and Midway respectively. Currently, the only invasive mammal in the NWHI is the house mouse on Midway Atoll.

Exotic ants have recently been implicated in the deaths of nestling Laysan finches, brown noddies, and sooty terns, and in the nest abandonment and hatching failure of several other species of seabirds.

On Midway Atoll, canaries (*Serinus canaria*) and common mynas (*Acridotheres tristis*) were introduced in 1910 and 1974 respectively and have become established. These species may compete for food with migratory shorebirds and could introduce, spread, or serve as reservoirs or avian diseases and parasites.

Strict procedures are used to minimize the potential introduction of alien species by research activities conducted at the remote uninhabited field sites. All tents are placed and all work is done on the perimeter of the island, generally seaward of the vegetation zone. Stringent protocols are used to ensure that no species are introduced to the islands. These protocols include:

- **48-hour freezing of all non-sensitive food and equipment,**
- **removal of all packaging materials which may harbor foreign plants or animals;**
- **packing all food, personal effects, and small equipment in plastic bags which are in turn placed in sterilized 5-gallon plastic buckets;**
- **packing all large equipment in either plastic cases or pallet tubs, all of which are fumigated prior to landing;**
- **all soft gear (daypacks, straps, nets, bags, bedding, tents, clothing, footwear) used at each field site is either new or has not been used at any other location; and**

No use of any fresh food item which either may become established (tomatoes, sunflower, mustard, or alfalfa seeds) or foods which may harbor molds or fungi will be used.

All quarantine and transport procedures between and among NWHI sites are stipulated as Special Rules and Conditions attendant to all permits issued by the Monument, and such procedures will therefore be followed as part of the action.

3.11 Cumulative Effects

Research and management actions executed to reduce shark predation on pre-weaned monk seal pups in the NWHI are designed to stem the rate of decline of the Hawaiian monk seal. Thus, these activities and actions facilitate the implementation the Hawaiian Monk Seal Recovery Plan (NMFS 2007). Continuing the current program and including expanded bottomset fishing for Galapagos

sharks fosters these efforts. Given available information, the following discusses the incremental impact of the effects of research and management actions when added to other past, present, and reasonably foreseeable future actions.

Other aspects of the HMSRP occurring in the NWHI involve monitoring monk seal populations, translocating weaned pups and juveniles to from FFS islets to other FFS islets and from FFS to other areas within the NWHI, and monitoring and treating monk seals for disease and injury.

The 2003 EA for that current program states: “Cumulative impacts from NOAA Fisheries’ proposed issuance of an MMPA/ESA permit, including additional species conditions described, will be minor if at all measurable...” Prior to the permit issued in 2003, the HMSRP conducted similar activities under a previous permit and Biological Opinion (1997). The EA continues: “Issuance of the requested permit would allow for continued takes of Hawaiian monk seals and incidental disturbance of green sea turtles. Some of the activities would pose a potential risk of injury to Hawaiian monk seals, including sedation and handling activities, and some of the activities would result in intentional death from euthanasia, and potentially unintentional mortalities from sedation and/or handling. The effects on the individual target animals of disturbance, capture, restraint, and sampling proposed in the application [for the current program and permit] are known, as the activities proposed are commonly used and not new. A review of the literature on the effects of these research techniques on pinnipeds can be found in the EA on the Effects of NMFS Permitted Scientific Research Activities on Threatened and Endangered Sea Lions (NMFS 2002). In general, the available information (including that reviewed in the 2002 EA) indicates that, when performed correctly by experienced personnel, these types of research activities are not likely to pose a significant risk of adverse impacts on the animals. The Biological Opinion for Permit No. 848-1695 indicates that “NMFS is not aware of any future, State, tribal, local or private actions in the action area that have a bearing on the risk assessment contained in this biological opinion.”

“Prior to 1977, study of the Hawaiian monk seal was limited to occasional beach surveys in the NWHI conducted by the USFWS, the Territory/State of Hawaii, and NOAA Fisheries. In 1977 and 1978 extensive monitoring efforts were conducted at Laysan Island under contract to the Marine Mammal Commission. Commencing in 1980, monitoring and recovery actions have been undertaken by NOAA Fisheries Honolulu Laboratory under authority of 14 different scientific research and enhancement permits issued by the Office of Protected Resources. In 1980 a small study on foraging behavior was conducted at Lisianski Island. In 1981, population monitoring commenced at Kure Atoll, and over the next two years expanded to include all major subpopulations. Most activities comprise long term monitoring studies which document life history parameters such as reproductive rate, age specific survival, number of births, and population levels. In addition to long term monitoring studies, supplemental activities have included: epidemiological assessments, temporary maintenance of weaned pups in protective captivity (“Headstart Program”), rehabilitation and relocation of underdeveloped weaned pups, investigations into pelagic movements and foraging ecology using remote instrumentation, removal of adult male seals which were causing excessive injury and mortality to adult females and immature seals, and disentanglement of seals found caught in marine debris. Based on the knowledge obtained by NOAA Fisheries since the 1980s, the research and enhancement activities that have occurred under the authorization of permits by the Office of Protected Resources have not had any major adverse effects on the species, and therefore, no cumulative effects have occurred.”

The EA recognized the potential for the current proposed action and continuation of the current program, as well as construction of a sea wall at Tern Island and increased ecotourism at Midway Atoll.

The role of PIFSC research contributes to but does not include making management decisions that may affect population recovery. Rather, the PIFSC research undertakes research and monitoring activities to obtain scientific information in support of slowing the rate of population decline as a contribution to future recovery actions. All actions are identified in the interagency 2007 Recovery Plan for the Hawaiian Monk Seal.

With respect to field research activities, PIFSC research designs, research approaches, and standard operating research procedures are crafted to minimize the impact on the environment, including monk seals and other endangered and threatened species. The long and successful past history of the HMSRP and its development of standardized protocols that have proven effective ensures that the proposed action would continue the low risk to any of the resources evaluated in this PEA.

The 2008 NMFS EA for Issuance of a Research Permit for the Use of Shark Deterrents states: “Cumulative impacts resulting from the preferred alternative will be minor if at all measurable. One activity that was conducted in the same area in 2002, 2003, and 2007 was the lethal removal of [less than five per season] Galapagos sharks. An EA was prepared for this action (NMFS 2002). This activity had beneficial effects through the reduction of mortality of pre-weaned monk seal pups due to predation by the sharks, thus increasing recruitment of young seals into the breeding population... Under the proposed action, deterrent devices would be employed in an attempt to prevent the decimation of Hawaiian monk seal pups at FFS by Galapagos sharks. In addition to evaluating the effect of this work on pre-weaned monk seal pup survival, the preferred alternative would also document shark activity patterns near Trig Island. It is anticipated that the preferred alternative would have beneficial effects, in deterring Galapagos sharks from an area known to have high mortality rates of pre-weaned pups. If any problems, such as unacceptable disruption of normal activities by other species (excepting other shark species) are observed or suspected, the monitoring intensity will increase until such time as the problem is resolved. If observed problems cannot be mitigated by modification, relocation, or other measures, the crew will consult with PIFSC and Refuge or Monument personnel to determine if the observed problems are of sufficient concern to warrant removal of the deterrent device(s). Should the preferred alternative be successful in deterring sharks, it is anticipated that deterrent activities, along with intensive monitoring, would occur at Trig, the Gins and East Island during summer months in the future... There are currently no Monument applications pending which include activities proposed near any of the aforementioned islets within FFS.”

The only potential for cumulative effects with continuation of the limited removal of sharks and implementing the expanded removal using bottomset gear would involve potential effects on the Galapagos shark population. Based on recent modeled Galapagos shark population estimates, taking 40 sharks in one season would not cause a cumulative effect on the population to the point that the population began a declining trend.

Although assessing the cumulative effects of field research projects undertaken is speculative, the past, present, and future research activities of the PIFSC research have been shown not to have and are not likely have any significant adverse cumulative effects on the environment. This is because: (1) the scope and magnitude of field research is focused on known areas of monk seal presence and habitat use; (2) the PIFSC research is the field research of these species in the known ranges and

therefore no other research exists that could magnify consequences; and (3) applicable permit requirements, including permits from the Office of Protected Resources and the Monument, provide “checks-and-balances” safeguards.

Overall, the research activities of the PIFSC have been shown to have no cumulative impacts and the proposed expansion of the current program is not likely to have a cumulative adverse effect on any of the target and non-target populations evaluated or the environment.

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6 Appendices

6.1 *Appendix 1--Codes for Galapagos Shark and Hawaiian Monk Seal Monitoring*

A. Codes for Shark Behavior

Code 1: Cruising, no obvious signs of predatory behavior

Code 2: Patrolling, apparently hunting pups

Code 3: Making directed approach to a seal

Code 4: Charging Seal, clearly attempting to attack

Code 5: Injuring or killing pups

B. Codes for Hawaiian Monk Seal Age Classes

Definitions:

Pre-weaned or Nursing Pup: Pups sized as P1 through P-5 at last sighting, commonly still with mothers, and nursing.

Weaned Pup: Pups that have been weaned <30 days, when mothers are commonly absent and nursing behavior is not evident.

Codes:

P1: Pup that is nursing and has wrinkles, typically full term, as defined by full developed pelage, whiskers, nails, and oral cavity. If a perinatal death is evident and size is not given, pup is recorded as a P1, rather than as a fetus.

P2: Pup that is nursing, has no wrinkles and has black pelage.

P3: Pup that is nursing, has a blimps-shaped body and has black or reddish-brown pelage prior to molt.

P4: Pup that is nursing, has a blimp-shaped body and is molting.

P5: Pup that is nursing, has a blimp-shaped body and has molted (note: not all pups reach P5 before weaning).

C. Codes for Bite Severity Classes:

Severity 1: The total combined exposed area of all gaping injuries is < 8 cm (approximately 50 cm^2), less than half of a flipper is missing, and/or head/eye results in a partially opaque eye (Hawaiian Monk Seal Field Manual, Chapter 9: Survival Factors).

Severity 2: The total combined exposed area of all gaping injuries is \geq an 8 cm (approximately 50 cm^2) and a < 20 cm diameter circle area (approximately 314 cm^2), \geq half a flipper is missing and/or injury to head/eye results in a totally opaque/blinded eye (Hawaiian Monk Seal Field Manual, Chapter 9: Survival Factors).

Severity 3: The total combined exposed area of all gaping injuries \geq a 20 cm diameter circle area (approximately 314 cm^2) and/or total loss of function critical for survival, such as both hind flippers are amputated (Hawaiian Monk Seal Field Manual, Chapter 9: Survival Factors).

D1. Criteria for and Categorization of Shark Predation of Monk Seal Pups

Category 1 - Shark Confirmed Predation

Category 2 - Shark Inferred Predation

Shark Confirmed Predation:

Injured by Shark: A pup of the year sustains an injury inflicted by a large shark or any severity and “survives” or does not fall into the dead or probably dead categories below. Here, large sharks are defined as all sharks other than the cookiecutter shark (*Isistius brasiliensis*). These injuries include shallow punctures or lacerations in the skin, deep lacerations, gaping wounds, and amputated limbs. The characteristic crescent shape of these wounds reflects the shape of the shark’s jaw (Hiruki et al. 1993).

Died due to Shark Injury: Confirmed deaths only (the death or body of the pup is observed). A pup of the year is observed being killed by sharks, or sustains moderate to severe shark injuries and subsequently dies. To be considered a cause of death an injury must, at minimum be of the following severity: the total combined exposed area of all gaping injuries to the body must be \geq an 8 cm (approximately 50 cm^2), \geq $\frac{1}{2}$ flipper is amputated, and/or injury to the head/eye results in a totally opaque/blinded eye. Shark attack will be judged to be the primary cause of death if the seal is not otherwise compromised to a larger degree due to factors such as pre-existing emaciation or injury due to other causes (HMS Field Manual, Survival Factor Section).

Disappeared/Probable Death due to Shark Injury: A pup of the year sustains a moderate to severe shark injury, subsequently disappears, and is classified as a probable death. Shark attack will be judged to be the primary cause of the disappearance if the seal is not otherwise compromised to a

larger degree due to factors such as pre-existing emaciation or injury due to other causes. To be classified as a probable death the minimum sustained injury must be of the severity level described above, and one of the following conditions must also be satisfied:

The pup is lethargic, has trouble moving, and/or floated listlessly in the water and disappears more than a week before the end of data collections, or

The pup is in deteriorating condition (loss of weight, enlargement of abscesses, sloughing skin) and disappears at least 10 surveys or a month before the end of data collection (whichever is longer).

Shark Inferred Predation:

Disappeared/Probable Death – Shark inferred: Young apparently healthy pups are also considered to have probably died if they disappear within 3 weeks of birth (>7 days old and ≤21 days old) and are not seen for at least 10 surveys or a month before the end of data collection. Unknown-age pups are also included in this category if they were unmolted at the time of disappearance. The cause of these probable deaths is unknown but considered shark inferred if the pup is over 7 days old, predatory shark behavior has targeted nursing/newly weaned pups in the current year and at that location, and there is no other probable cause. The pup's mother is typically observed to be in good condition, with a single pup, and parenting normally prior to disappearance and often searching for her pup at the time of disappearance. Other probable causes of disappearances that must be absent for a shark-inferred mortality to be concluded include: aggressive adult male monk seals, extreme environmental conditions and maternal abandonment. Adult male monk seals may injure weaned pups and inflict mounting injuries that are distinguished by their distinctive scars and lacerations (Hiruki et al. 1993). Adult female seals (mothers) vigorously defend their pups from adult males during the nursing period (Johanos et al. 1994). Thus, pre-weaned pups are typically not vulnerable to male aggression. Unless a flagrantly aggressive male is observed at a pupping site within the current year, pre-weaned pup disappearance in the historical data is safely attributed to shark predation unless other compromising factors are present, such as extreme environmental conditions. Extreme environmental conditions include high tides and/or strong currents. They are considered a factor in pup disappearance primarily for islets that would go awash at extreme high tides, e.g., Round, Mullet, Bare, Disappearing, and potentially Whaleskate & Shark.

Suspicious Disappearance/Likely Dead – Shark Inferred: Slightly older apparently healthy pups that disappear while still with their mothers or newly weaned are considered to have suspiciously disappeared, and to be likely dead if they are not seen for at least 10 surveys or a month before the end of data collection. Pups in this category are over 21 days old at the time of disappearance (or molting/molting if of unknown age), with a cut-off age of 2 weeks post-weaning. Pups over 2 weeks post-weaning are not included in any shark-inferred category. The cause of these suspicious disappearances is unknown but considered shark inferred if there is no other probable cause (see discussion above about probable cause above).

6.2 Appendix 2. Shark Barriers

Barriers to prevent sharks from entering nearshore areas has the potential to decrease the number of pre-weaned pups that are preyed upon because such devices could increase the safety zone for young seals to include both land and water. HMSRP has observed Galapagos sharks approaching, lunging, chasing and biting pre-weaned pups in water as shallow as the shoreline/wave wash zone. Pre-weaned pups enter the water to thermoregulate, practice swimming, learn about the ocean environment, and to otherwise stay in close contact with their mothers. Thus, the objective of a barrier is to prevent nearshore approaches by sharks while allowing pre-weaned pups to develop normally and experience the land and water environments as they typically would. Any barrier must also allow the typical movement between and land and water of other wildlife, especially breeding female monk seals and nesting/basking green turtles. This action is not expected to have adverse impacts on the coral reef ecosystem, including monk seal and Galapagos shark populations, and will likely be developed in the future. A general description follows providing a list of pilot studies that would aid in the further develop this action for implementation at FFS.

Barriers represent a non-lethal means of excluding predatory sharks when other means such as deterrents and limited removal have proven ineffective at bringing pup loss down to goal levels. Barriers would be semi-permeable with openings to allow monk seal and green turtle passage but prevent the passage of elasmobranchs, thus having the potential to swiftly reduce the amount of time pre-weaned pups are available prey. As such, effort required to construct, install, maintain and monitor barriers should be weighed against the benefit of this action that in itself causes no direct, purposeful loss of animal life.

Access to nearshore areas despite its hazards is important to monk seal development. A study following 30 FFS mother-pup pairs from birth to weaning demonstrated that preweaned pups entered the water 5.6 (SE 1.7) times a day, spending 24.1% (SE 6.86%) of the day in the water (Boness 1990). Pre-weaned pups were an average of 0.2 m (SE 2.57 m) from their mothers when on land and 1.3 m (SE 3.46 m) from their mothers when in the water based on daytime observation (Boness 1990). Average distance between pup and mother did not significantly change during the first 5 weeks of life; thereafter distance increased as weaning approached. Witnessed accounts suggest Galapagos sharks approach pre-weaned pups despite the close proximity they keep to their mothers. Shark predation on pups occurs throughout pup development; thus mother-pup distance is not likely to be a driving factor of this lethal interaction.

Possible Impact on Seal Movement

A barrier with openings may influence some seals' movement patterns by making it more difficult to swim out farther from shore as they might normally. Absolute distance from shore that pre-weaned pups venture in an effort to remain with their mothers is expected to be highly variable, depending on where a mother decides to swim and the topography of the island and its environs. At East Island, pre-weaned pups on the southwest side never ventured farther than 70 m, though this is the extent of the shallow reef habitat at this location (Boness 1990). This maximum distance is likely different for other pupping sites in which the shallow reef habitat extends farther. A barrier with openings may influence the length of time required for a seal to enter the nearshore area/beach. Barrier design would include multiple openings in an attempt to mitigate this potential side effect.

Possible Impact on Galapagos Shark Behavior

Shark experts familiar with Galapagos shark behavior and movement suggest that a Galapagos shark that is found in shallow water near pupping sites is likely an opportunistic pup predator; such nearshore behavior is highly unusual for the species on a global level (NMFS 2008, Meyer MHI tagging data). A barrier to exclude sharks from nearshore areas of pupping sites is therefore not likely to negatively impact the behavior or survival of the greater Galapagos shark population at FFS.

General Design

A semi-permeable barrier would be constructed out of multiple floating panels of a tensile, lightweight fencing material, such as that used in aquaculture pens (e.g. Kikkonet, lightweight mesh which has 4/5 tensile strength of 10-gauge steel wire, but only 1/5 the weight. The mesh is double twist knitted to prevent serial ripping, coated to be rust-proof and resistant to sea-water damage, www.kikkonetusa.com). The lattice design of the material would be chosen to maximize strength in the face of water surge, minimize entrapment of debris and small fish/invertebrates, and avoid entanglement of large animals or their body parts. Adjacent panels would be spaced to create approximately 2 m openings between them that function as wildlife passage ways. The length, width and height of each panel would depend on the bathymetry, current, and wave surge of the location. Parameters would be chosen that support the secure upright positioning of each panel at each location. Panels would be attached to surface floats along their top side. Panels will be secured at their bottom corners by: anchor (PVC tube shafts to cover line) when on sandy substrate or by being shackled to driven stakes/pipes if on hard pan or rubble substrate. Panels would be placed to avoid laying anchors or driving stakes into living coral.

Barriers would be erected on a seasonal basis (duration to coincide with the main pupping season at FFS: May –September) at pupping sites with a history of numerous pup births and shark incidents: possibly Trig, Gins and Round. This action would not occur at East or Tern islands because of their high human, green turtle and albatross traffic and historically low shark incidents; although initial pilot feasibility studies may occur off of Tern because of the ease of human monitoring there. The number of panels will depend on the area to be protected. Areas to be protected may be restricted to select segments or sides of islands where mother seals typically birth. Current observations and historical data on birthing will be examined to guide placement.

Electromagnetic devices designed to deter elasmobranchs (e.g. Shark Shield, see sec. 2.2.1.3.) will flank each opening. The impact zone of these devices on Galapagos shark is at least approximately 1 m based on field trials with wild Galapagos sharks near Halewia, Hawaii (Gobush & Meyer *per comm*). The size of barrier openings is based on this impact zone; if electromagnetic devices are found with a greater impact zone, opening size will be increased. These devices operate on rechargeable lithium batteries. If the technology is improved to work on longer-life DC batteries (solar powered), then cable used will be covered in PVC tubes to prevent entanglement hazard. Power stations will be placed on island (DC batteries and solar panels) as described in section 2.2.1.2. for underwater speaker deterrents.

Maintenance of barriers is expected to be similar to that of net-pen enclosures designed to retain juvenile monk seals in care programs by HMSRP in the past. Materials described here differ from those of past net-pens because they are sturdier, stronger and include anti-fouling coatings than materials used in temporary net-pens, as such, the day-to-day maintenance is expected to be less. Any trapped debris or growing algae would be removed to be routinely with a scrubbrush or other such implement.

Pilot Studies on Feasibility and Impacts

The following tests will likely be performed before the use of semi-permeable barriers at FFS is considered more fully:

1) Determination that seals (captive monk seal or other phocid) will navigate through a 2m opening between barrier material when installed in a way similar to above description in a enclosed area (e.g. captive tank or lagoon).

2) Determination that green turtles (captive) will navigate through a 2m opening between barrier material when installed in a way similar to above description in an enclosed area (e.g. captive tank or lagoon).

3) Determination that Galapagos sharks (captive or wild) will not enter a 2m opening flanked by operating electromagnetic devices between barrier material when installed in a way similar to above description.

4) Determination that barrier material will remain secure and erect when tested in the range of current, wind, wave surge and depth condtions expected to occur around pupping sites FFS.

5) Determination that barrier material and securing equipment will not foul or cause an aggregatation/accumulation of debris or living organisms found in the nearshore environment to an inappropriate level given a reasonable maintenance schedule.

6) Determination that barrier material and securing equipment can be quickly removed by as few as two people in the event that an emergency, such as inclement weather, were to occur at FFS.