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Recovery of the Hawaiian Monk Seal (*Monachus schauinslandi*): A Review of Conservation Efforts, 1972 to 2010, and Thoughts for the Future

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Abstract

The Hawaiian monk seal is one of the world's rarest marine mammal species and is listed as *depleted*, *endangered*, and *critically endangered* based on national and international criteria. Although its precarious status was already recognized by the 1950s, it was not until the 1970s that direct protection was afforded to monk seals by U.S. legislation. Many important actions were taken to try and recover the population during the following four decades, including developing a population monitoring program; controlling impacts of military facilities in the Northwestern Hawaiian Islands (NWHI); managing fisheries to reduce their impacts; removing marine debris; and responding to other issues, including die-offs, inadequate nutrition, aggression by male seals, and shark predation. Recently, monk seals have reoccupied the main Hawaiian Islands (MHI). While this may be good news for their recovery, the MHI are well-populated by humans and significant management issues have appeared as seal numbers have increased. In spite of all that has been done, Hawaiian monk seals are likely to go extinct unless current conditions change. At this time, the most crucial needs for the recovery are (1) maintaining an adequate research and management program throughout the Hawaiian Archipelago; (2) continuing to minimize all sources of mortality; (3) promoting an increase in the number of monk seals in the MHI; (4) considering bold actions that could create more favorable conditions for seals in the NWHI; (5) ensuring that bureaucratic requirements and processes do not impede recovery actions; and (6) designing, funding, and implementing a set of actions that will stop the Hawaiian monk seal's decline toward extinction and recover the population sufficiently so that it can be removed from the Endangered Species Act's list of endangered species.

Key Words: Hawaiian monk seal, *Monachus schauinslandi*, Endangered Species Act, extinction, recovery, marine mammal conservation, Northwestern Hawaiian Islands, main Hawaiian Islands

Introduction

Monk seals are an ancient lineage of pinnipeds that appeared in the warm waters of the eastern North Atlantic Ocean about 15 million years ago (Berta et al., 2006). They dispersed westward to the Caribbean and Central America, and then, sometime more than three million years ago, ancestors of the Hawaiian monk seal (*Monachus schauinslandi*) passed over the submerged Isthmus of Panama into the Pacific Ocean (Fyler et al., 2005; LeDuc, 2009). It is unknown exactly where they may have once ranged in the Pacific; but in recent times, they have lived almost entirely within the Hawaiian Archipelago. Today, the Hawaiian monk seal is the only pinniped that occurs exclusively within the jurisdiction of the United States. Their closest relatives are the extinct Caribbean monk seal (*M. tropicalis*) and the critically endangered Mediterranean monk seal (*M. monachus*; Rice, 1998).

Humans did not live in the Hawaiian Archipelago when monk seals arrived, but the seals almost certainly were there when the islands were discovered and colonized by Polynesian voyagers about 1,500 y ago. Although monk seals have a Hawaiian name (*'ilioholoikauaua*, loosely translated as "dog running in the surf"), they are mentioned infrequently in Hawaiian cultural records. Monk seals always

may have been more common at the sand and coral atolls of the Northwestern Hawaiian Islands (NWHI) where early humans rarely visited (Ziegler, 2002). It also is possible that they were once common in the main Hawaiian Islands (MHI) but were displaced shortly after the arrival of the Polynesians. Archaeological research indicates that monk seals were present in the MHI prior to European contact (Rosendahl, 1994), and there is a much more recent record of a seal being killed and eaten by Hawaiians at Hilo Bay (Dill & Bryan, 1912).

The first record of monk seals after European "discovery" of the Hawaiian Islands was by the Russian explorer Yuri Fedorovich Lisianski in 1805 at the island that now bears his name (Lisianski, 1814). By the early to mid-1800s, commercial seal hunting, together with killing for food by whalers and shipwrecked sailors, reduced monk seal abundance to such an extent that they had essentially disappeared (Bailey, 1952; Busch, 1985). Subsequent human activities in monk seal habitat (Rauzon, 2001; Culliney, 2006) included harvesting guano and feathers (1890 to 1915); fishing for pearl oysters (1927 to 1930), lobsters (1974 to 1999), and other species; and operating military facilities at Midway Atoll (1902 to 1997), French Frigate Shoals (1930s to 1979), and Kure Atoll (1961 to 1993). These provided ample opportunity for people to kill seals or displace them from their resting and pupping beaches. In spite of this, the monk seal population probably recovered somewhat during the first half of the 20th century (Ragen & Lavigne, 1999).

The current conservation program can be traced back to the first comprehensive counts of monk seals in the NWHI in the late 1950s (Kenyon & Rice, 1959; Rice, 1960) conducted under the auspices of the Department of Interior's Bureau of Sport Fisheries and Wildlife, predecessor to the current Fish and Wildlife Service (FWS). At that time, monk seal conservation fell to the Bureau by virtue of its responsibility for managing the Hawaiian Islands National Wildlife Refuge (HINWR), which included most of the NWHI. In the early 1970s, lead responsibility shifted to the National Marine Fisheries Service (NMFS) with passage of the Marine Mammal Protection Act (MMPA). This paper traces the history of the Hawaiian monk seal conservation program since the early 1970s. The intent is to identify strengths and weaknesses of past efforts as a means to benefit from lessons learned and make recommendations to improve the program's future direction.

Designation as *Depleted* and *Endangered*

Between 1972 and 1976, the U.S. Congress passed a wave of legislation that still forms the core of most of the nation's environmental protection programs. Two of those laws which were particularly important for marine mammal conservation were the MMPA, passed in 1972, and the Endangered Species Act (ESA), passed in 1973.

The MMPA made it U.S. policy to maintain marine mammals at "optimum sustainable population" levels to keep them as significant functioning elements of the marine ecosystem. The primary mechanism for doing so is a moratorium on "take" (defined to include direct and indirect removals and injuries of marine mammals, as well as acts of intentional and incidental harassment) in U.S. waters. When the MMPA was signed into law, the moratorium provided Hawaiian monk seals their first explicit protection from hunting and other forms of take.

The first management action specific to Hawaiian monk seals was a proposal by NMFS to designate the species as *depleted*, a classification at the time defined as a species declining to the extent that it could lead to their listing under the Endangered Species Conservation Act (the predecessor to the ESA). In June 1975, the NMFS reviewed information on the status of the species and consulted with the Marine Mammal Commission (MMC), an agency established by the MMPA to provide an independent source of scientific advice on marine mammal conservation issues. After the MMC expressed support for the action (MMC, 1976), the NMFS published a depleted listing proposal that was adopted in July 1976 (41 FR 30120[1]).This made the Hawaiian monk seal the first species to be designated as *depleted* under the MMPA.

In a December 1975 letter, the MMC (1976) also recommended that Hawaiian monk seals be designated as *endangered* under the ESA. In support of the listing, the MMC cited evidence of declining numbers and a population count conducted earlier in 1975 that suggested a total abundance of only about 1,000 ± 500 seals. The MMC noted a need for consultations with the U.S. Coast Guard (USCG), the U.S. Navy, and the FWS on new measures to restrict the activities of people and dogs on beaches used by monk seals, and it recommended that pupping beaches at atolls be designated as *critical habitat* under the ESA.

The NMFS agreed that monk seals met the definition of *endangered* and, after further consultation with the MMC and the FWS, a final rule listing them as *endangered* was published in November 1976 (41 FR 51611). Once listed, the ESA not only restricted take of Hawaiian monk seals, similar to the MMPA, but it also triggered other protective provisions, including those in

[1]This refers to a U.S. government legal action that was published in the *Federal Register*. *Federal Register* notices can be accessed at www.archives.gov/federal-register.

Section 7 of the ESA which requires all federal agencies to use their authorities to further the purposes of the Act (i.e., recovery of listed species). It also directs federal agencies to consult with the NMFS on any actions they plan to take or authorize that might jeopardize a listed species under their jurisdiction or result in destruction or modification of any habitat determined to be critical.

In response to those provisions and the MMC recommendations, consultations with the USCG, the U.S. Navy, and the FWS led to additional restrictions on activities at beaches used by monk seals. However, reluctant to curtail limited recreational opportunities for personnel stationed at remote NWHI outposts and citing limited information on causes of the species' decline, the USCG and U.S. Navy actions were less restrictive than those recommended by the MMC, and often were poorly enforced (Kenyon, 1980). Data limitations and the information standards required to justify monk seal conservation measures would become recurring obstacles for implementing important conservation actions.

Development of a Dedicated Monk Seal Recovery Program

Although the MMPA was signed into law in October 1972, it was not until 1974 that the NMFS and the MMC hired staff and established administrative structures to begin addressing the Act's directives in earnest. Hawaiian monk seals did not receive substantive attention until 1975. Initial efforts were constrained by enormous gaps in information about the biology of monk seals and threats to their survival, limited staff and funding, and logistical challenges related to working in the NWHI. Inception of the monk seal recovery program was shaped by several emerging issues, including the species' designations as *depleted* and *endangered*, new research results, the identification of and response to threats (particularly disturbance of seals on beaches, shark predation, effects of ciguatera poisoning, and the development of commercial fisheries in the NWHI), deliberations over critical habitat designation, and work to develop a recovery plan. After reviewing available information for listing monk seals as *depleted* and *endangered*, the NMFS supported another monk seal survey in early 1976 to provide more complete data on the species status. The results increased concern for the status of monk seals and indicated a 50% decline in abundance since the 1950s and 1960s (DeLong et al., 1976). This led the NMFS, the FWS, and the MMC to develop a cooperative plan for research to be done in 1977. The plan called for counts to estimate abundance and pup production at major breeding atolls, monitoring the response of seals to new restrictions on activities of USCG personnel at Kure Atoll, and assessment of possible causes for what appeared to have been a sharp decline in seal numbers at Pearl & Hermes Reef. To accomplish the latter, the plan called for comparing the situation at that colony with that at Laysan Island where the seal colony was thought to be healthy.

As planning progressed, the NMFS determined it would be unable to fund the planned 6-mo field camp at Laysan Island, and the MMC agreed to do so. When the same situation arose in 1978, the MMC again supported research on Laysan Island. Problems within the NMFS with programming sufficient funds for critical research suggested the need for a long-term research strategy to project funding needs well in advance for budget planning purposes. As part of a January 1978 letter to the NMFS, the MMC (1978) recommended that they convene a group of experts to develop a monk seal recovery plan that would include a long-term strategy for carrying out coordinated research activities.

Results of research during the 1977 and 1978 field seasons demonstrated the feasibility of extended field camps at remote NWHI atolls and the ability to collect valuable life history data using benign marking techniques (DeLong & Brownell, 1977; Johnson & Johnson, 1978, 1981). The results also heightened concern for the species when they revealed recruitment problems indicated by a low proportion of juvenile and subadult seals at some colonies, and a die-off of some 50 seals at Laysan Island.

In October 1978, the MMC convened a monk seal planning meeting with representatives of the NMFS, the State of Hawaii, and the U.S. Navy (DeLong & Kenyon, 1979). The following April, the MMC provided the NMFS with a draft 5-y research plan based on the meeting (MMC, 1980). The draft plan identified a schedule of research projects estimated to cost a total of $100,000 to $500,000 annually through 1982. The studies included projects to monitor population trends, identify habitat use patterns both at sea and on land, assess the effects of disease and biotoxins, and investigate the feasibility of a shark control program. At that time, the MMC recommended that the research plan be made part of the recovery plan, and again urged the NMFS to take steps to convene a recovery team.

At about the same time, the NMFS assigned responsibility for the monk seal recovery plan and establishment of a recovery team to its Southwest Regional Office; it also established a National Marine Mammal Laboratory in Seattle to take the lead in addressing marine mammal science issues. This created some confusion within the agency over roles and responsibilities, which was compounded by funding restrictions. In 1979, only $50,000 was made available for work on monk seals; and in 1980, that level was further reduced as part of budgetary cutbacks by the agency for all marine mammal and

endangered species work. The NMFS's inability to program funds for work on such a critically endangered species led the U.S. Congress to provide the MMC with a special one-time appropriation of $100,000 to initiate work based on the draft 5-y monk seal research plan. In consultation with the NMFS and a recovery team convened by the NMFS in 1980 (see below), those funds supported or supplemented projects to synthesize recent data on monk seals at Laysan Island, continue the Laysan Island field studies, undertake radiotelemetry work to assess the movements of seals at sea, develop a response plan to be used in the event of a die-off similar to the one that occurred at Laysan Island, assess the impact of shark predation and options to control it, and evaluate potential fishery impacts on monk seals. It was anticipated that the NMFS would be able to budget funds to carry monk seal studies forward in subsequent years.

Work over the first 5 y left a lasting mark that has served the monk seal program well. Opportunities to apply a full measure of legal protection under the MMPA and ESA were secured through quick action (especially by today's standards) to list Hawaiian monk seals as *depleted* and *endangered*. Management issues that remain at the forefront of concern today were identified, and initial steps were taken to address them. Fundamental research began on marking and censusing seals that formed the foundation of studies to track trends in abundance, survival, reproduction, and age-sex composition at individual colonies. In addition, steps were taken to apply state-of-the-art tracking technology to determine at-sea habitat use patterns.

However, experience over the first 5 y also revealed problems that would become recurring obstacles. These included inconsistent commitments by NMFS leadership to allocate funding and pursue management decisions (which sometimes competed with or conflicted with other agency mandates intended to promote fisheries), the logistical difficulty and expense of working in the NWHI, and the certainty of scientific information required to convince managers to adopt protective management measures.

Recovery Team and Recovery Plans

To promote well-conceived recovery programs, Section 4(f) of the ESA authorized the preparation of recovery plans to identify needed conservation tasks, and the formation of recovery teams to assist with and provide advice on implementing recovery activities. Shortly after the MMC's December 1979 recommendation that the draft five-year research plan for Hawaiian monk seals be incorporated into a recovery plan, the NMFS hired a recovery program leader and appointed the Hawaiian Monk Seal Recovery Team (HMSRT), charging it with drafting a recovery plan. Recognizing the lack of basic biological and ecological information for identifying and analyzing recovery needs, the 12-member team was composed principally of scientists to help interpret the limited available data and to identify studies that could provide missing, but needed, data. Most members had either direct experience in monk seal studies or with related disciplines in the NMFS, the FWS, the State of Hawaii, and other organizations.

The team met four times in 1980, and during that first year, they identified research and management projects that became central components of the recovery program in subsequent years. The team compiled available research results, reviewed the draft 5-y research plan, and recommended adjustments to the MMC's $100,000 spending plan for 1980 (MMC, 1981). Among the major initiatives begun or identified that year under the team's guidance were (1) refinements in marking and tagging studies begun at Laysan Island in 1977 to monitor survival, reproduction, and population trends; (2) plans to expand that monitoring approach to French Frigate Shoals and other atolls; (3) research to assess monk seal prey preferences and foraging patterns using radio tracking, depth-of-dive technology, and scat analyses; (4) establishment of a Head Start program to take weaned pups born at Kure Atoll into captivity for several months to mitigate high mortality of pups born at that atoll; (5) development of a statement urging the NMFS to adopt a critical habitat boundary set at the 36-m isobath around all NWHI atolls and reefs; (6) analyses of options to mitigate shark predation on monk seal pups; and (7) implementation of actions to control human activities, principally at the USCG LORAN station at Kure Atoll and the Naval Air Station on Midway.

The team also began work on a recovery plan. With little experience at the time in what such a plan should entail, they used as a model a step-down outline developed by the MMC in consultation with the FWS for West Indian manatees (*Trichechus manatus*). Its basic organization, later refined and adopted by both the NMFS and the FWS in their general guidelines for preparing recovery plans, included introductory sections summarizing relevant information on the species' biology, ecology, and management issues, followed by sections identifying broad research and management objectives, specific studies and management tasks under those objectives, and projections of cost estimates for each task over a foreseeable planning period (usually 5 y).

After completing a working draft plan in November 1981 and incorporating comments from the MMC, the draft plan was circulated for

public and agency review in December 1982 and approved by the NMFS in March 1983 (Gilmartin, 1983; Table 1). Most recovery actions were listed under four broad objectives: (1) identifying and mitigating natural factors limiting monk seal survival and reproduction, (2) identifying and characterizing habitat requirements, (3) monitoring the population, and (4) implementing management actions to protect monk seals from the effects of human activities. Actions in the plan, however, were described in broad terms, often by title only, and cost estimates by year and task were not well-developed. The team therefore considered the plan a "strategic plan" and envisioned preparing an operational plan with a more detailed description of actions and costs once the recovery plan was adopted.

Table 1. Major Hawaiian monk seal recovery plan and work plan topics and cost projections

1983 Recovery Plan

1. Identify and mitigate factors causing or contributing to decreases in survival and productivity.
2. Identify habitat requirements and determine, characterize, and monitor areas of special biological importance.
3. Monitor monk seal populations.
4. Document effects of human disturbance.
5. Implement management actions.
6. Develop an educational and interpretive program.

Projected Costs: $413,000/y + $465,000 in single-year projects

Hawaiian Monk Seal Work Plan: Fiscal Years (FY) 1991-1993

1. Recovery of the western population (Head Start project and pup rehabilitation-release project)
2. Mobbing research
3. Population monitoring
4. Data analyses, field reports, and publications

Projected Costs: FY 1991 – $450,000; FY 1992 – $467,000; FY 1993 – $487,000

Research and Management Plan for the Hawaiian Monk Seal at French Frigate Shoals, 1993-1996

1. Monitor the population.
2. Rehabilitate and relocate seals.
3. Monitor the growth rate of juvenile seals.
4. Complete French Frigate Shoals data analysis and field reports.
5. Conduct disease monitoring.
6. Study foraging patterns and prey preferences.
7. Assess French Frigate Shoals seal movement and tag loss.
8. Evaluate more practical permanent marking methods.
9. Compare seal hauling behavior at French Frigate Shoals with single island sites.

Projected Costs: Included in FYs 1994-1996 work plan below

Hawaiian Monk Seal Work Plan: FYs 1994-1996

1. Island-specific population monitoring
2. Mobbing problem research
3. French Frigate Shoals research and management plan implementation
4. Recovery of the western populations
5. Data analyses/field reports/publications

Projected Costs: FY 1994 – $844,000; FY 1995 – $978,000; FY 1996 – $791,000

NMFS Evaluation and Allocation Process for Funding Protected Species Research and Management: FYs 1995-2010

1. Evaluate and mitigate factors limiting population growth.
2. Monitor population trends throughout the range.
3. Conduct epidemiological investigations.
4. Define diet composition based on fatty acid analysis.
5. Determine habitat use and foraging behavior (satellite telemetry and crittercam).
6. Evaluate abundance of marine debris in submerged coral reef habitats and mitigate impacts.
7. Assess habitat loss.
8. Mitigate shark predation on monk seal pups at French Frigate Shoals.
9. Enhance monk seal pup survival at French Frigate Shoals through translocation.
10. Assess *in situ* captive care and release.
11. Conduct de-worming trials.

Projected Costs: Initial estimates at approximately $1.5 mil/FY increasing to $7.55 mil in FY 2008, $7.19 mil in FY 2009, and $7.19 mil in FY 2010

2007 Recovery Plan Revision

1. Investigate and mitigate factors affecting food limitation.
2. Prevent entanglement.
3. Reduce shark predation on monk seals.
4. Minimize exposure and spread of infectious diseases.
5. Conserve monk seal habitat.
6. Reduce monk seal interactions with fisheries.
7. Reduce male aggression toward pups/immature seals and adult females.
8. Reduce the likelihood and impact of human disturbance.
9. Investigate responses to biotoxin impacts.
10. Reduce impacts from compromised and grounded vessels.
11. Reduce impacts of contaminants.
12. Continue population monitoring and research.
13. Create a main Hawaiian Islands monk seal management plan.

Projected Costs: FY 2008 – $7.55 mil; FY 2009 – $7.19 mil; FY 2010 – $7.19 mil; FY 2011– $6.99 mil; FY 2012 – $6.99 mil

The team's intentions, however, fell victim to a contentious debate over designating critical habitat and the effects of that action on an initiative by the State of Hawaii to promote the development of commercial fisheries in the NWHI (see below). Based on available information indicating that monk seals regularly disappeared from atoll islands for weeks at a time on long foraging trips, occasional sightings of seals far from shore, and the limited shallow water foraging area around atolls, most team members strongly urged adoption of a seaward boundary set at the 36-m isobath around all atolls, and they appended a statement to that effect to the recovery plan.

The NMFS Regional Office leadership, however, was committed to supporting the State of Hawaii's fishery development interests and chose a preferred option with the boundary set at the 18-m isobath. In late 1984, when research results revealed that most monk seal foraging dives occurred at depths greater than 18 m (DeLong et al., 1984; Schlexer, 1984), the team more strongly promoted its earlier boundary recommendation; but the NMFS's leadership remained unwilling to change their opinion despite the new information. Moreover, concerned that the team's advice would be used to justify legal challenges to their boundary choice, the NMFS leadership withheld funding for further recovery team meetings. As a result, from December 1984 until December 1989 the team was rendered inactive. The course of events and actions to subvert recovery team opinions and important recovery decisions raised concern over the threat to impartial decision-making when officials with responsibility for, and a long tradition of, promoting commercial fishing are also responsible for approving analyses of threats to monk seals and the actions needed to mitigate them. This concern, while now largely moot for monk seals, still arises at times today on conservation issues involving fisheries and other marine mammal species under NMFS jurisdiction.

In late 1989, the NMFS reconvened the HMSRT, but only after NWHI fisheries had become well-established and several other developments had occurred. Among those were the preparation of a report by the NMFS required by ESA Section 7 consultations that reached questionable conclusions that NWHI fisheries posed no significant risk to monk seals, repeated recommendations to reconvene the team by the MMC, and appointment of a new agency administrator more concerned about the importance of monk seal conservation. At the urging of the MMC and with HMSRT assistance, the NMFS developed several short-term planning documents: a 3-y work plan for Fiscal Years 1991 to 1993 (Gilmartin, 1990), a 4-y research and management plan for French Frigate Shoals (Gilmartin, 1993a), and a follow-up work plan for Fiscal Years 1994 to 1996 (Gilmartin, 1993b). Those detailed work plans provided a useful basis for identifying specific management actions, priorities, and projected recovery costs, and they were used by the MMC to urge the U.S. Congress to provide additional funding beyond that being requested by the NMFS for monk seal research (Table 1).

In the 1990s, the HMSRT met annually to review recent recovery activities and recommend research and management actions for the upcoming field seasons. Because most research and management actions were carried out by field crews in the NWHI, the team's science-oriented composition remained essentially unchanged during this period. By 2000, however, monk seals had begun reoccupying habitat in the MHI, raising many new management issues. With new management issues to be addressed, an outdated recovery plan, and substantial new information on monk seal biology, the NMFS reconstituted the HMSRT in 2001 and charged it with drafting a new recovery plan. Recognizing that the NMFS alone could not undertake all the actions needed to promote monk seal recovery and that assistance of other agencies and groups was essential for implementing recovery work, the new team included two previous members and ten new members representing science, stakeholder groups, and state and federal agency partners who had been assisting the NMFS with recovery tasks. Since it was reconstituted, the team has met annually.

Over the next three years, the HMSRT, with assistance from NMFS staff, developed a draft revised recovery plan that was submitted to the NMFS late in 2005. The NMFS prepared a revised plan based on the team's draft that was released for agency and public comment late in 2006 and adopted with further changes in August 2007 (NMFS, 2007). The recovery plan revision reflects enormous improvements not only in the understanding of the species' biology and ecology, but also in the sophistication of recovery planning efforts. Reflective of the number and magnitude of identified tasks required to reverse the decline of Hawaiian monk seals toward extinction, it projected cost estimates averaging about $7.2 mil/y over a 5-y planning period. It recommended considering the species for downlisting to *threatened* once abundance increased to at least 2,900 animals in the NWHI and 500 in the MHI. Particularly important initiatives set forth in the plan included the development of major new programs to promote the reoccupation of the MHI by monk seals and to improve the survival of juvenile seals in the NWHI (Table 1).

Designation of *Critical Habitat* and Revision of Critical Habitat Boundaries

As noted earlier, in 1975, the MMC recommended that the NMFS designate the major monk seal breeding atolls in the NWHI as *critical habitat*. At that time, critical habitat had yet to be designated for any listed species, and guidelines to interpret the provision had only recently been adopted jointly by the NMFS and the FWS. Thus, use of the provision was still very much a case of uncharted waters. Today, critical habitat designations serve as guideposts for consultations with federal agencies by describing geographic areas and their habitat features or *constituent elements* that are critical for a species' survival. Activities that might threaten those habitat elements and require special management consideration must then also be considered during consultations. In 1975, however, there was no precedent for identifying critical habitat boundaries or for how special regulatory or management needs identified during the course of designation should be addressed.

In December 1976, the MMC again wrote to the NMFS about the need to establish critical habitat for Hawaiian monk seals. Because of the importance of waters surrounding the NWHI for monk seal foraging, the MMC recommended that, in addition to atoll beaches, waters out to 5.6 km from shore be included as critical habitat and that commercial and recreational fishing in most waters within that area be prohibited. NMFS agreed that atoll beaches and nearshore waters around islands merited designation; and in 1977, they began considering options and developing a designation proposal.

At about the same time, the State of Hawaii began to promote the development of commercial fisheries in the NWHI, including alternatives for constructing a facility for moving fish caught in that area to market. To help assess development prospects, the State entered into a cooperative agreement with the NMFS and the FWS to study the region's marine resources and economic potential. Concerned about potential conflict between fishery development and monk seal protection, the NMFS moved ahead slowly with its critical habitat proposal. In early 1980, the NMFS released a draft environmental impact statement (EIS) analyzing three alternative seaward boundaries: (1) the 18-m depth contour, (2) the 36-m depth contour, and (3) 4.8 km offshore. After considering comments on the options, NMFS deferred action while efforts proceeded to develop lobster and bottomfish fisheries in the NWHI. As fishing began, it was determined that the most productive lobster fishing areas were deeper than 18 m, while bottomfish fishing concentrated in even deeper water around the reefs. In 1983, confident that the 18-m boundary would not affect fishing interests, the NMFS adopted a zone closed to lobster fishing in waters shallower than 18 m as a refuge for lobster reproduction.

Further action on critical habitat designation for monk seals was not taken until 1985 after an environmental organization filed a notice of intent to sue the NMFS for failing to complete the designation process in a timely manner. In January of that year, the NMFS published a proposal to designate waters out to the 18-m isobath as monk seal critical habitat (50 FR 1088). This matched the seaward boundary for most of the HINWR as well as the zone the NMFS had closed to lobster fishing. However, it also formed a complex patchwork that included only the shallowest areas and reef outcrops surrounding atoll islets. In selecting this boundary, NMFS asserted that information was insufficient to confirm that waters deeper than 18 m were important for monk seal foraging.

The NMFS proposal elicited considerable opposition. Citing research showing that monk seals foraged at depths deeper than 18 m (DeLong et al., 1984; Schlexer, 1984), and also noting that the 36-m depth contour provided a boundary that more clearly delineated most atoll reefs, the newly appointed HMSRT, the MMC, and others strongly urged adoption of the 36-m option. The NMFS leadership, however, was unwilling to change its position, and in April 1986, the agency adopted rules designating the 18-m option (51 FR 16047). This time, the NMFS based its decision not on uncertainty as to foraging areas but on an assertion that it had found no special management considerations relevant to monk seals in waters deeper than 18 m.

The NMFS's 1986 decision was made by agency leaders confronted with conflicting interests in promoting Hawaiian fisheries and protecting an endangered species. The NMFS was more concerned about restricting demonstrated economic returns from lobster fishing than preventing uncertain impacts on monk seals. Thus, even given the precarious state of the monk seal population, information demonstrating that monk seals fed in deeper waters and ate lobsters, and judgments by monk seal biologists (including some members of its own staff and the HMSRT), NMFS leaders exercised their discretion and limited the seaward boundary for critical habitat. The precautionary principle—erring on the side of conservation when doubt exists (Meffe et al., 1999)—was not followed.

Shortly after the leadership of the National Oceanic and Atmospheric Administration (NOAA) changed late in 1986, the MMC asked the NMFS to reconsider its finding that there were no special management considerations for monk seals in waters deeper than 18 m. Again under threat of

a lawsuit, the NMFS did so, and after requesting public comments on the issue, they adopted a rule (53 FR 18988) extending the boundary to 36 m in May 1988. Although the extension better reflected what was then known about the monk seal foraging range, and it required managers of the lobster fishery to consider the effects of the fishery on monk seal prey, it resulted in no new restrictions on fishing. Because the NMFS was responsible for both managing NWHI fisheries and conducting ESA consultations, the same regional officials charged with approving fishery management measures were also responsible for approving the results of ESA Section 7 consultations.

Developing information strongly indicated that inadequate prey resources was a factor in the species' decline. Also, telemetry data indicated that monk seal foraging areas overlapped lobster fishing grounds (DeLong et al., 1984; Schlexer, 1984). Nevertheless, the NMFS's internal ESA consultations on the effects of lobster fishing on monk seal prey consistently concluded that information was insufficient to assess how important lobsters were in monk seal diets and that no special restrictions on fishing effort could therefore be justified. Although the NMFS initiated a research program to assess the relative importance of lobsters and other species in monk seal diets in the 1990s, the studies were still ongoing in 1999 (MMC, 2000) when the agency finally closed the NWHI lobster fishery due to overfishing that led to a collapse of the lobster stocks.

In the 20 y following designation of critical habitat for the Hawaiian monk seal, telemetry studies have produced a wealth of new information on monk seal at-sea movements, habitat use, behavior, and foraging patterns in the NWHI (Abernathy, 1999; Parrish et al., 2005, 2008; Stewart et al., 2006). During that period, monk seals also began reoccupying habitat in the MHI. Concerned about the species' steady decline and anxious to ensure that all possible legal protection was accorded to the species, several environmental groups petitioned NMFS in July 2008 to expand critical habitat boundaries (Center for Biological Diversity, 2008). The petition sought to include nearshore waters and beaches at Midway Atoll (which had been excluded from the earlier designation in deference to U.S. Navy operations at that atoll), waters around the NWHI out to the 500-m isobath, and all beaches and adjacent waters around the MHI out to the 200-m isobath.

Available information indicated that the 1988 designation did not include all critical monk seal habitat, and the NMFS is now proceeding to reevaluate the boundaries. Decisions to reevaluate critical habitat boundaries, however, can be a double-edged sword. Because of limited public understanding about its implications, critical habitat decisions commonly cause controversy that can polarize public attitudes toward species protection. As noted above, regulations defining critical habitat boundaries serve only to expand the scope of ESA consultations between federal agencies pursuant to Section 7. *Critical habitat* designations for marine mammals have not imposed any limitations on public activities or rights. Yet, some segments of the public invariably argue otherwise, asserting that draconian restrictions on access to public areas or resources inevitably ensue from any such designation. This unfounded assertion by critics of critical habitat proposals often provides fodder for generating public animosity against the species that the measure is designed to protect. The designation process also imposes significant demands for funding and staff time to prepare decision documents and to attempt to correct public misperceptions.

At the present time, all fisheries in the NWHI have been closed, and human activities potentially affecting monk seals are under strict control (see next section). In the MHI, limited food availability and competition with fisheries do not appear to be affecting monk seals at this time. Instead, the interactions of greatest concern are between people and seals on beaches, and nearshore fishing that is not managed by the NMFS and generally does not involve federal actions that trigger Section 7 consultations. Coming as it does at a time when managers must generate support for public cooperation in accommodating monk seals on MHI beaches and developing plans for improving juvenile monk seal survival in the NWHI that could involve temporary relocation of seals to the MHI, controversy over revising critical habitat boundaries could have more negative than positive consequences for progress on other important recovery tasks just as they are beginning to be addressed.

Creation and Role of Other Marine Protected Areas

The natural resources of the NWHI have a long history of legislative protection. In 1909, U.S. President Theodore Roosevelt created the Hawaiian Islands Reservation through Executive Order #1019 to prevent the overharvesting of seabirds and protect their nesting grounds. Subsequently, this Reservation was renamed as the Hawaiian Islands National Wildlife Refuge (HINWR), and a series of protections for terrestrial and marine habitats followed, including establishment of the separate Midway Atoll National Wildlife Refuge (MANWR) in 1988 and the Kure Atoll State Wildlife Sanctuary in 1993.

Interestingly, NMFS's poor management of the lobster fishery and its steadfast refusal to consider

curtailing the fishery as a precautionary measure to reduce possible competition with monk seals became important considerations that led to designation of the entire NWHI as a marine protected area. Prominently citing the need for better protection of monk seals among his reasons, in early 2000, President William J. Clinton designated all federal waters within 93 km of the NWHI as the Coral Reef Ecosystem Reserve (CRER) and directed that a permanent ban be imposed on all lobster fishing within its boundaries. To complement that action, Hawaii's Governor, Linda Lingle, signed regulations in 2005 establishing all state waters in the NWHI (i.e., out to 4.8 km except at Midway Atoll where nearshore waters are federally owned) as a State Marine Refuge that prohibited fishing and all other extractive uses of the region, except those permitted for research or other purposes that benefited management. Those actions were further strengthened by President George W. Bush in 2006 when he designated all of the NWHI and surrounding waters as the Papahānaumokuākea Marine National Monument (PMNM) and initiated steps to phase out the remaining commercial fishing in the NWHI.

The region covered by the PMNM overlays the NWHI CRER, the HINWR, the MANWR, and the State's Kure Atoll Sanctuary and NWHI Marine Refuge. To coordinate management of this area, the U.S. Secretaries of Commerce and the Interior and the Governor of Hawaii were assigned as co-trustees of the Monument. As a result, commercial fisheries have been banned within 93 km of the NWHI, and human activities potentially affecting monk seals in that area are under strict control through management by the PMNM and its cooperators (PMNM, 2008).

Recovery Program Administration and Funding

The NMFS monk seal research and recovery program began at the Southwest Fisheries Science Center (SWFSC) Honolulu Laboratory in 1980 with a single full-time individual dedicated to the effort. Funding that year for a combined monk seal and sea turtle conservation program totaled $150,000 (Figure 1). In 1982, Congress directed a one-time $400,000 appropriation to monk seal research, but the SWFSC, in a demonstration of the low priority it assigned to monk seals relative to their other programs, did not provide the $150,000 for the basic program it had supported in 1981. This lack of priority given to the monk seal program continued, with most NMFS administrators routinely requesting and providing inadequate funding. In subsequent years, primarily due to recommendations from the MMC, Congress directed NMFS to budget $150,000 for monk seal work in 1983, $300,000 in 1984, and $350,000 in 1985. For the remainder of the 1980s, NMFS requested and received $325,000 as its base budget for monk seal program operations. This funding level was adequate for little more than basic population monitoring, and even then monitoring and important recovery actions undertaken during these years relied heavily on volunteers who contributed significant labor to the projects.

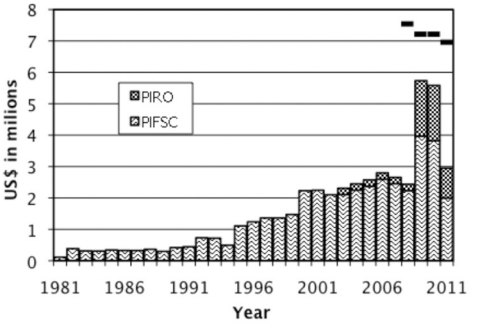

Figure 1. Approximate expenditures by NMFS for Hawaiian monk seal research (PIFSC; called the NMFS Honolulu Laboratory pre-2003) and management (PIRO) programs, 1981 to 2011; prior to 2003, an additional $15,000 to $40,000 (not shown) was spent for management in years when the HMSRT was convened. Figures for 2011 are best estimates. Horizontal bars show annual funding requirements for 2008 to 2011 from the Hawaiian Monk Seal Recovery Plan (NMFS, 2007).

To better document the need for additional funding, the MMC suggested that the monk seal program generate short-term planning documents that could be used to better inform Congress and program administrators of funding needs. Three such documents were generated in the early 1990s that briefly described priority projects and their costs (Table 1) and provided the justification for a congressionally mandated annual funding of about $800,000 (Figure 1).

From 1995 to 2010, the NMFS conducted an annual evaluation and allocation process for supporting high priority research and management of protected species. During this period, funding for the NMFS monk seal program gradually increased to approximately $2.2 mil in 2000 and 2001 then declined slightly to $2.1 mil in 2002 and 2003 at which time the NMFS created the Pacific Islands Region and with it the Pacific Islands Regional Office (PIRO) and Pacific Islands Fisheries Science Center (PIFSC). This action resulted in the transfer of all responsibility for management and research relative to marine resources in federal waters surrounding the U.S. Pacific Islands from the NMFS Southwest Regional Office and

SWFSC to PIRO and PIFSC. Organizationally, this provided an administrative staff much more responsive to the needs of Hawaiian monk seal recovery efforts, but it also increased the overall programmatic cost of administrative activities.

NMFS funding for Hawaiian monk seal recovery started to increase in 2004 and was at about $2.7 mil in 2007, the year that the revised Hawaiian Monk Seal Recovery Plan was approved. In that plan, the annual funding required to meet the needs identified in the "Implementation Schedule" for recovery of Hawaiian monk seals was estimated at $7.0 to $7.5 mil/y over a 5-y period (NMFS, 2007). In 2008, funding for monk seal recovery dropped to approximately $2.4 mil, but pressure on the NMFS and Congress by nongovernmental organizations and the MMC helped bolster support to $5.7 mil in 2009 and $5.6 mil in 2010. During this period, increased funding allowed a much needed expansion in high priority research activities that included work on population assessment, epidemiology, foraging ecology, mitigation of juvenile mortality, MHI ecology and population monitoring, infrastructure/equipment, and database enhancement. It also allowed new high priority management activities, including hiring PIRO's first staff members dedicated exclusively to monk seal management (i.e., a monk seal recovery coordinator and other response personnel), support for the State of Hawaii's efforts in monk seal conservation (funded largely though a separate mechanism under Section 6 of the ESA for cooperative state endangered species programs), public outreach and response networks throughout the MHI, preparation of EISs for enhancement of juvenile seal survival and designation of critical habitat, and annual HMSRT meetings.

As in the past, however, the NMFS relied on Congress to provide those increased funding levels and did not take the opportunity to increase its base monk seal funding requests above the 2008 funding level. As a result of budget cuts and the elimination of "earmarks," in 2011, NMFS funding for monk seal recovery declined to about $3.0 mil (Figure 1). Current funding is once again less than half of what was specified in the recovery plan.

Major Research and Management Activities in the NWHI

Population Monitoring

Although counts of Hawaiian monk seals at some sites in the NWHI prior to the 1950s have been reported (Hiruki & Ragen, 1992), the first counts commonly used as reference points for monitoring the population began in the late 1950s (Kenyon & Rice, 1959; Rice, 1960). During the following two decades, annual counts across the NWHI were conducted in some years (DeLong et al., 1976; Johnson et al., 1982), with occasional short intensive efforts at Kure Atoll (Wirtz, 1968; Johnson et al., 1982), French Frigate Shoals (Johnson & Johnson, 1980; Schulmeister, 1981; Johnson et al., 1982), and Laysan Island (Johnson & Johnson, 1978, 1981).

The current NMFS long-term monk seal monitoring program in the NWHI began in the early 1980s. Its strategy focused on (1) counting, identifying when possible, classifying by size, and determining the sex of all seals at all major breeding atolls in the NWHI at least once annually; (2) standardizing methods with observations recorded on forms that would facilitate database entry; (3) flipper tagging as many pups as possible each year; and (4) documenting any observed threats to seal survival. This population monitoring program continues today in the NWHI and in the MHI but with much less effort in the latter area.

This monitoring program, now three decades old, has produced an enormous database that has changed the Hawaiian monk seal from a little known and poorly understood pinniped into a species with well-documented demographics, trends, and threats. Demographic and life history data have enabled development of a comprehensive stochastic simulation model for the NWHI seal population, a valuable tool for predicting population abundance over time and assessing the effects of proposed management actions (Harting, 2002).

Since intensive monitoring began, individual island subpopulations have varied widely in demographics and numbers. At one point, positive annual growth rates were as high as 5% at Kure Atoll and 7% at Pearl & Hermes Reef. However, beginning in the 1990s, in the central and eastern atolls of the NWHI and in 2000 at the far western sites, all major breeding colonies began to suffer from high juvenile mortality and low recruitment (NMFS, 2007). In 2002, the overall Hawaiian monk seal population was undergoing the most dramatic decline in recent history; and by 2009, only an estimated 1,146 monk seals remained, with estimates of 1,056 in the NWHI and 90 in the MHI (Carretta et al., 2009). The NWHI-wide rate of decline is currently about 4.5%/y (Baker et al., 2011). In contrast to the NWHI trend, monk seal counts and the number of births in the MHI have been increasing; and in 2010, the MHI population probably exceeded 150 seals (Baker & Johanos, 2004; Baker et al., 2011).

While the increase in seals in the MHI provides some hope for the recovery of the species, those increases have been too small to offset losses in the NWHI, and the population as a whole is declining. Because the population is so

small and continuing to decline, the international conservation community recently changed the listing of Hawaiian monk seals from *endangered* to *critically endangered* on the *IUCN Red List* (Lowry & Aguilar, 2008).

Laysan Island Die-off and Die-off Response Plans

In the spring of 1978, researchers at Laysan Island observed some monk seals that were emaciated or becoming listless and losing weight while lying on the beach, with this condition progressing to extreme weakness and then death (Johnson & Johnson, 1981). Most victims were either young (1 to 5 y old) or very old (18 to 30 y old) seals (Gilmartin et al., 1980). In response, the NMFS sent a team to investigate the problem, but by the time the team arrived in May, the number of affected seals appeared to have subsided, and many of the more severely affected animals had been lost in a storm. Remaining sick, dead, and some apparently healthy seals were examined, but pathology, cultures, and blood and clinical chemistry tests were inconclusive, with the exception of heavy gastrointestinal parasite loads, a condition common in pinnipeds (Gilmartin et al., 1980). Radioimmunoassay for ciguatoxin and bioassay for ciguatoxin and maitotoxin were performed on liver tissues of dead seals. Bioassay results indicated very high levels of toxin compared to a control seal's tissue, but the radioimmunoassay results were equivocal. At least 50 seals were believed to have died during the 2- to 3-mo event (Johnson & Johnson, 1981). In an experiment to assess whether ciguatoxin might kill a seal and determine the clinical signs, ciguatoxic eels (a known monk seal prey item) were collected in the NWHI and fed to two young elephant seals, both of which died after consuming as little as 1.7% of their body weight of eel and exhibiting symptoms similar to the dying seals at Laysan Island (DeLong & Gilmartin, 1979).

Following the Laysan Island die-off investigation, the MMC funded the NMFS to conduct a workshop to develop a "die-off response plan" to guide investigations into any future monk seal mass mortality events. The workshop was held in April 1980, and the plan that resulted described the permit needed (noting that it should be continuously held by the NMFS), the membership of a response team, equipment requirements, field procedures, sampling priorities, and laboratory studies to be performed. It also addressed logistical support and funding requirements (Gilmartin, 1987). The NMFS has since published a National Contingency Plan (Wilkinson, 1996) for responding to unusual marine mammal mortality events. In addition, the monk seal die-off response plan has been updated and revised with supplemental methods, suggested memoranda of understanding with potential participants, and rescue and rehabilitation guidelines (Yochem et al., 2004).

Impacts of U.S. Navy and Coast Guard Operations in the NWHI

While monk seals in the NWHI have a long history of interactions with humans, it was not until good quality counts of seals were being made that the effects of human disturbance on the seal populations could be documented. One of the best examples is the decline in seal hauling and pupping on Green Island at Kure Atoll after the USCG built and began operating a LORAN station there in 1960 (Kenyon, 1972; Johnson et al., 1982; Reddy, 1989; Gerrodette & Gilmartin, 1990). In contrast, there was a dramatic increase in seal counts on Tern Island at French Frigate Shoals after the USCG left in 1979 (Schulmeister, 1981). Following the USCG departure from Tern Island, the island continued to be occupied by FWS staff and other scientists, but their activities were carefully restricted, allowing seals essentially undisturbed use of the beaches.

Counts of seals at Midway in the late 1950s ranged from 43 to 76 (Kenyon & Rice, 1959; Kenyon, 1972; Rice, 1960). By the early 1970s, the human population at Midway had grown to nearly 3,000, and monk seals were rarely seen at the atoll. Later in the 1970s, the U.S. Navy began scaling down its activities and personnel at Midway and then monk seals were again seen occasionally. Two pups were born there in 1981, and beach counts of seals slowly increased as the human population and Navy activities declined. In 1988, with the Navy still on Sand Island (the only human-occupied island at the atoll) the atoll became a FWS "overlay" wildlife refuge, and management of the unused islands (East and Spit Islands) came under FWS jurisdiction, thus providing some protection for seals on those beaches. In 1997, the Navy transferred ownership of Midway to the FWS, which designated the entire atoll the MANWR. However, Midway's airfield was still needed as an emergency runway for trans-Pacific air traffic and also provided an opportunity for financial support for the Refuge by facilitating visitor access. To meet both needs, the FWS contracted with a private concessionaire to maintain the runway and cover those costs by bringing tourists to the atoll for wildlife viewing, fishing, diving, and other activities. Although at the time concerns were raised about the wisdom of allowing visitor access given possible effects on monk seals (Ragen & Lavigne, 1999), restrictions on visitor movements kept them off of almost all beaches. As a result, seal use of Sand Island beaches increased; and after a hiatus of some 30 y,

its beaches again began to be used by small numbers of monk seals to give birth and nurse their young.

Head Start and Rehabilitation Programs

One of the first concerns raised by the HMSRT in 1980 was the declining seal population at Kure Atoll. Pup survival was poor, and births were declining (Johnson et al., 1982). The problem was believed to be shark predation as a consequence of disturbance by USCG personnel that led to displacement of pregnant females to ephemeral sand islets where their pups were periodically forced into the water by rising tides. Attacks by adult male seals were also recognized as a cause of pup deaths. To address those losses, the NMFS captured female pups after weaning and held them in a fenced shoreline pen at Kure through the spring and summer months when shark predation and adult seal attacks were most likely to occur (Gilmartin et al., 2011a). This Head Start project began in 1981 and continued until 1991 when the USCG began to shut down the LORAN station. Survival of female pups increased dramatically to a mean of 85% surviving to 1 y of age. Survival of unpenned male pups also increased during those years. A consequence of the long NMFS presence on the island each year for the Head Start initiative was a decrease in USCG disturbance, and that in turn resulted in adult females returning to preferred birthing and nursing habitat on the human-occupied Green Island. Therefore, while the immediate cause of pup losses in the 1960s and 1970s was likely shark predation, the seals' return to protected birthing habitat and undisturbed nursing and resting on Green Island beaches was likely the key that facilitated increased survival of both female and male pups.

Experience with the Head Start program led to another project to enhance the survival of young seals. Biologists monitoring seals at French Frigate Shoals during the early 1980s observed that some pups were being weaned at a size too small to survive the months required to learn to forage on their own. NMFS scientists, therefore, began collecting underweight but otherwise apparently healthy female pups at French Frigate Shoals in 1984. The pups were taken to care facilities on Oahu where they were fed, fattened, and then released back into the wild at Kure Atoll 1 y after collection (Gilmartin et al., 2011b). This project was successful at changing the survival prospects for those seals, many of whom have contributed pups to the Kure population.

In the late 1980s and early 1990s, another source of underweight pups began contributing to the problem of young seal survival at French Frigate Shoals—prey availability. When this problem became apparent, the successful rehabilitation program was expanded to take in even smaller, and sometimes ill, pups (Gilmartin et al., 2011b). Usually the criterion for collection of these seals was their poor condition late in their first year through their third year, and their problems required more intensive individual care and veterinary attention. Even then, however, their survival through captive care was lower than in the prior effort. This entire rehabilitation program was suspended after 1995 when 10 of 12 captured female pups developed an eye condition of uncertain etiology that affected their vision and made them unsuitable for release (Hanson et al., 2009). Much was learned in this process, however, that has been used to build a program to assist monk seals in poor health.

In 2006, the NMFS, in collaboration with the FWS, The Marine Mammal Center, and Hubbs-Sea World Research Institute, conducted a Head Start project on Midway and successfully provided nutritional support to six weaned monk seal pups held in shoreline pens over the winter. In March 2007, the pups were released into the wild at the atoll in excellent condition. All of the captive-care seals and three other pups of the same cohort that were not held in captivity were instrumented with satellite-linked tags and VHF radios. Within 7 to 21 d, all of the previously captive seals were diving and behaving much like the control seals, indicating normal foraging behavior post-release (Norris et al., 2011). However, none of the captive-care seals were alive 2 y later, perhaps due to poor feeding conditions at the release site. Winter captive-care efforts of this type were not recommended in the future due to the extreme difficulty in maintaining shoreline pens caused by inclement weather and storm surf.

Prey Limitation

Prey limitation is believed to be the primary reason for the decline of monk seals in the NWHI and began to be apparent at French Frigate Shoals in the late 1980s and early 1990s with decreased pup girth at weaning, higher mortality of young seals, reduced population growth, delayed age at first birth, low birth rate, and animals dying of starvation (Craig & Ragen, 1999; Antonelis et al., 2006; NMFS, 2007). During the following decade, many of these same indicators of low prey availability showed up at the other NWHI breeding sites as well. Possible causes included fisheries impacts, oceanographic changes affecting productivity, and competition with other predators for available prey (NMFS, 2007).

Most monk seals forage relatively near the atolls where they haul out, but some travel hundreds of kilometers and may dive to nearly 500 m seeking

prey (Parrish et al., 2002; Stewart et al., 2006). They eat a wide variety of prey species, including some that have been commercially exploited or taken as bycatch, making competition with fisheries a potential limiting factor (Goodman-Lowe, 1998; Iverson et al., 2011). As noted above, the designation of the PMNM now ensures that commercial fishing will no longer occur in the NWHI. However, fishing's effect on the distribution, abundance, and productivity of monk seal prey species may require years to return to pre-exploitation conditions, if it occurs at all.

Variations in oceanographic conditions also likely affect the abundance of monk seal prey (Antonelis et al., 2003; Baker et al., 2007). Decadal shifts in productivity have been associated with 30 to 50% declines at various trophic levels in the central North Pacific during the mid-1970s through the 1980s (Polovina et al., 1994). Change of this magnitude would certainly exacerbate competition for food (Parrish et al., 2008) in the NWHI apex predator dominated ecosystem (Friedlander & Demartini, 2002). This situation could easily lead to more difficult foraging for monk seals and poorer body condition, especially for young seals learning to find prey after weaning.

Direct Interactions with Fisheries

Direct interactions have occurred between monk seals and commercial, subsistence, and recreational fishing. Between 1982 and 2006, 55 interactions were recorded throughout the Hawaii Archipelago (Carretta et al., 2006; NMFS & Western Pacific Regional Fishery Management Council [WPRFMC], 2006; NMFS, unpub. data), including one entanglement in the bridle above a lobster trap, five entanglements in nearshore gillnets, 48 hookings, and one seal observed stealing bait from a recreational shore fisher. Hookings that occurred in the NWHI were principally in the commercial bottomfish fishery and the longline fishery for swordfish (*Xiphias gladius*), while those in the MHI were principally in the recreational shore fishery for ulua (giant trevally; *Caranx ignobilis*) (Carretta et al., 2009).

Blunt trauma injuries on the heads of monk seals observed in the NWHI in 1990 also were attributed to interactions with the longline fishery. Since 1991, when a protected species zone was adopted prohibiting longline fishing within 93 km of the NWHI, there have been no confirmed interactions between that fishery and monk seals (Carretta et al., 2009).

Male Aggression

At most major breeding sites, adult male monk seals, either as individual attackers or in groups, have been observed biting and attempting to mount adult females, weaned pups, and juveniles in shallow nearshore water, sometimes drowning or injuring them (Hiruki et al., 1993). Attacks on pups usually involve single adult males, and three individual male aggressors have been removed from the population (Antonelis et al., 2006). In cases of multiple male aggression, groups of up to 28 adult males have been seen attacking adult females during mating bouts in the water during which the females' backs were sometimes severely injured (Johnson & Johnson, 1981; Johanos & Kam, 1986; Alcorn & Buelna, 1989). Female victims have died as a direct result of these injuries or have disappeared likely due to shark predation. Some have recovered from the injuries. Multiple male aggression events (also called *mobbing incidents*) have been observed most commonly at Laysan Island where they accounted for a mean annual loss of 4.1% of adult females during the period 1983 to 1994, with a peak of eight females killed in 1 y (Johanos et al., 2010). During those years, Laysan had a male-biased adult sex ratio of over 2:1, resulting in a functional sex ratio (the actual number of males and females present at the time) at some island beaches where attacks occurred of up to 25:1.

The female losses threatened population recovery, and several strategies to mitigate the male aggression problem were considered (Gilmartin & Alcorn, 1987). Testosterone suppression with the goal of reducing aggression was evaluated and appeared promising, but the expense and potential high disturbance to the population to deliver the GnRH-agonist to target males up to three times during each breeding season resulted in rejection of that approach (Yochem et al., 1991; Atkinson et al., 1993). Therefore, despite some risk of exacerbating the problem if dominant males were removed, 37 adult males observed in multiple male aggression, or with behavior similar to males observed in attacks, were captured and either held in captivity or relocated to Johnston Atoll or the MHI between 1984 and 1994, leaving the sex ratio at about 1:1. Female losses dropped abruptly and significantly after the last removal (22 males in 1994). Between 1995 and 2005, mean female losses to adult male aggression fell to 0.3%/y, with only three females killed (Johanos et al., 2010). Although this action was very successful at reducing female losses at Laysan Island, the lack of timely public education about the relocation of male seals to the MHI led to the misconception that NMFS was responsible for the increase of seals in the MHI during the 2000s, even though most of the males had probably died of old age during the intervening years.

Marine Debris

Hawaiian monk seals have a high rate of entanglement in a wide range of marine debris items, with pups observed entangled most frequently (Laist,

1996; Henderson, 2001). The gravity of this problem was confirmed when in-water surveys conducted in the late 1990s found several entangled juvenile seals dead or struggling to free themselves in debris caught on coral heads (Donohue et al., 2001; Boland & Donohue, 2003). A total of 268 entanglements, including eight deaths (seven from fishing gear) and 57 serious injuries (32 from fishing gear) were observed from 1982 to 2006 (NMFS, 2007). Those entanglements occurred in spite of aggressive annual summer efforts to remove potentially entangling debris from NWHI beaches that began in 1982 and multi-agency efforts that removed 671 mt of fishing gear and other debris from the nearshore reefs from 1996 to 2009 (National Oceanic and Atmospheric Administration [NOAA], 2010). Nonetheless, it is widely believed that entanglement-related deaths have been reduced by some unknown number as a result of clean-up efforts. Peak observed entanglement years were in the late 1990s just before large-scale clean-up work began (NMFS, 2007).

Field efforts to remove debris from beaches and disentangle seals are a part of the overall NMFS population monitoring program, but because it occurs for only a few months each summer and it is unknown how many seals die at sea unable to reach monitored beaches, overall entanglement rates and potential seal losses due to entanglement are unknown. However, based on entanglements observed during beach counts and the total estimated sizes of colonies, annual entanglement rates were at least as high as 7.5% at Kure Atoll and 2.1% at Lisianski Island in the 1990s (Laist, 1996).

Shark Predation

Historically, there is good evidence that shark predation is a cause of mortality to monk seals (Nolan, 1981; Bertilisson-Friedman, 2002), but the severity of this problem is not well-known largely because of the difficulty in detecting mortality that occurs at sea. Scars from shark attacks have been observed commonly on monk seals, and shark predation on seals in the NWHI was occasionally observed prior to the mid-1990s (Hiruki et al., 1993). During the late 1990s, nursing and weaned pups became the targets of Galapagos shark (*Carcharhinus galapagensis*) attacks along the shores of Trig Island at French Frigate Shoals (Hawn, 2000; Hayes, 2002). This predation was considered serious enough to warrant efforts to selectively kill sharks exhibiting predatory behavior targeting monk seals by using baited hook and line or handheld harpoons (Antonelis et al., 2006).

Concerns expressed by co-managers of the NWHI CRER (now managed as part of the PMNM), Hawaiian cultural practitioners, and the public led to limitations on efforts to remove predatory sharks (e.g., requiring harassment of sharks as a deterrent before attempting lethal removals which resulted in making the sharks much more wary of humans) and slowed efforts to assess a working hypothesis that a small number of Galapagos sharks was responsible for the mortality (NMFS, 2007; Harting, 2010). Consequently, only 12 of the estimated 20 "problem" sharks were removed during culling efforts from 2000 to 2007. During that period, estimated annual shark predation on pups was reduced from a high of 21 in 1999 to 6 to 11/y in the following years (Gobush, 2010). Galapagos sharks that evaded the culling effort became extremely wary and altered their behavior to avoid human activity and any attempts to remove them. In 2008 and 2009, only nonlethal efforts to deter sharks from pupping sites were used. These involved playing outboard motor sounds, anchoring a small boat, and placing magnetic devices and floats in the nearshore water. The hope was that the sharks learned human-avoidance behavior could be used as a means of deterrence, but the shark predation on pups continued (Gobush, 2010). In 2010, the NMFS reinitiated shark removals at French Frigate Shoals but was able to catch only one immature shark. The NMFS would like to continue shark predation mitigation efforts into the future (C. Littnan, pers. comm., 13 January 2011), especially since a shark tagging study initiated in 2008 supported the hypothesis that only a few individual Galapagos sharks are involved and that removals would have no significant impact on the local shark population estimated to number more than 600 individuals (Dale et al., 2011). Moreover, an environmental analysis of shark removal plans has concluded that there would be no significant impact to the ecosystem (NMFS, 2009). In spite of this supporting information, some parties remain reluctant to permit removal of a relatively small number of Galapagos sharks that threaten population recovery at this site.

Current and Future Issues and Challenges

Reducing Sources of Mortality

It is generally agreed that low juvenile survival has been the main cause of the decline in monk seal numbers in the NWHI during the last two decades (Craig & Ragen, 1999; Antonelis et al., 2006). The proximate causes of juvenile mortality include starvation, shark predation, entanglement in marine debris, and male aggression. Efforts to mitigate starvation by rehabilitating weaned pups in captivity ended in 1995. The recent working paradigm has been to keep post-weaned pups in the "the wild" and, where practical, relocate them to sites where there is evidence of higher survival than at their place of birth. Most of those efforts have occurred within French Frigate Shoals with

the relocation of pups immediately after weaning from shark predation "hot spots" to other islets at the atoll with less shark activity. Also, in 2008 and 2009, six pups were moved each year from French Frigate Shoals to Nihoa at approximately 1 to 2 mo after weaning. The translocation was predicated on evidence of high survival at Nihoa (increasing numbers of seals) and the presence of good foraging habitat near the recipient location. Preliminary results showed that survival to age 1 for translocated seals was at least 50%—much higher than the 27% first-year survival of pups that were left at French Frigate Shoals (Norris & Gulland, 2011). Unfortunately, these methods only treat symptoms and not causes of the problem (e.g., site-specific limited food availability and shark predation).

There is compelling evidence that low food availability is contributing to low juvenile survival (Craig & Ragen, 1999; Antonelis et al., 2006), and this dilemma is being exacerbated by competition for prey with other more abundant and aggressive apex predators (Parrish et al., 2008). While this problem has been most severe at French Frigate Shoals, the predominance of non-monk seal apex predators exists throughout the NWHI (Friedlander & Demartini, 2002). If monk seal numbers in the NWHI are to stop declining and begin increasing, some believe it will be necessary to either manipulate populations of certain other top predators or take other steps to increase available monk seal prey. Suggestions to try such manipulations would undoubtedly be controversial with co-managers of the PMNM and at least some stakeholders, but should be seriously considered from a large-scale ecological perspective and evaluated based on their potential scientific and conservation merits vs ecosystem risks.

From 1993 to 2010, an estimated 173 monk seal pups were killed by Galapagos sharks at French Frigate Shoals (NMFS, unpub. data). During this same time period, annual pup births dropped from 91 to 37 (J. Baker, pers. comm., 1 June 2011), illustrating how grave the situation is for monk seal recovery at this site. This problem continues as a relatively small subset (Harting, 2010) of the locally abundant Galapagos shark population (DeCrosta, 1984; Dale et al., 2011) continues to prey on the critically endangered monk seals. There is no indication that this problem is being adequately resolved under the current PMNM management regime, and the likelihood of monk seal recovery at French Frigate Shoals is low unless protection and conservation of monk seals is given a higher priority by all agencies and interest groups concerned with the health and diversity of the NWHI marine ecosystem.

Hawaiian monk seals have one of the highest entanglement rates of any pinniped species (Laist, 1996), and marine debris and derelict fishing gear from countries around the Pacific Rim accumulate continually in the NWHI coral reef ecosystem (Henderson, 2001) as well as in the MHI. In spite of substantial efforts to disentangle seals and remove debris, seals continue to die from entanglement. Unfortunately, annual funding for this work, which benefits many ecosystem components in addition to monk seals, has decreased from $3 mil in 2001 to $280,000 in 2011 (R. E. Brainard, pers. comm., 30 November 2010). Estimates indicate that the rate of debris removal has been insufficient to keep up with the accumulation rate (Dameron et al., 2007). Hence, entanglement in marine debris remains a serious concern for the recovery of monk seals and will require major national and international efforts if the problem is to be mitigated.

Adult male aggression toward adult females at Laysan Island has been a problem that was dealt with by the removal of males during the period 1984 to 1994. While this mitigation was apparently effective (Johanos et al., 2010), there has been a recurrence of this problem, with eight male aggression events recorded there during 2008 to 2010. Because animals that are wounded or killed are often females of reproductive age, this situation requires close monitoring. When problems are documented and response options have been evaluated, action should be taken promptly to prevent additional deaths. Weaned pups are also killed in attacks by individual adult males, and effort to identify and deal with those males is also important. The NMFS has prepared a detailed protocol determining when response to aggressive males is appropriate (J. Baker, pers. comm., 18 May 2011).

Monk Seal Reoccupation of the MHI

Monk seals were rarely reported in the MHI prior to the 1990s, but their numbers have increased (Baker & Johanos, 2004; Baker et al., 2011). As a result, the number of seals in the MHI subpopulation now exceeds that of some of the subpopulations in the NWHI.

The increase in numbers of seals using the MHI is a bright spot in monk seal recovery. When compared with the NWHI, seals in the MHI grow faster, reproduce earlier, and survive at higher rates (Baker et al., 2011). The length of shoreline in the MHI (about 1,610 km) vastly exceeds that of the NWHI (about 97 km) (State of Hawaii, 2009), indicating that there is ample coastal habitat in the MHI to support more monk seals. Much of that shoreline and nearshore habitat, however, is used by people for commercial (e.g., resort and residential developments, ports and harbors, commercial

fishing) and recreational (e.g., fishing, surfing, boating, swimming, sunbathing) purposes and for Native Hawaiian cultural and traditional purposes. Monk seals' ability to use the MHI for feeding, resting, and pupping can be impeded by such human activities and interests. In 2009, the MHI supported about 1.3 million residents, and another 6.4 million people visited the islands (State of Hawaii, 2009). People can take relatively simple steps to minimize those impediments, however, by encouraging occupancy by seals and by promoting the coexistence of both seals and existing human activities (MMC, 2003). The greatest challenge will be to convince local recreational and commercial fishermen that monk seal conservation and protection is a priority that needs to be embraced by the entire state of Hawaii.

If the number of seals in the MHI is to continue to increase, either naturally or with the aid of recovery actions, a carefully designed and comprehensive plan should be developed and implemented to (1) identify and mitigate potential negative interactions between seals and people, (2) document the biology and ecology of seals in the region, and (3) understand the role of MHI monk seals in the overall recovery of the species (MMC, 2003; NMFS, 2007). A complete list of specific actions that need to be taken would be long but should include at least the following, many of which have already been started:

- Improving outreach and education to inform Hawaii residents and visitors about the importance of the MHI to monk seal recovery and how to behave around seals
- Coordinating MHI monk seal research, management, and enforcement among the NMFS, the State of Hawaii Department of Land and Natural Resources, and other relevant agencies and groups
- Monitoring the number of seals in the MHI and their biological characteristics (e.g., behavior, growth, reproduction, and survival)
- Protecting seals on beaches, especially mothers and pups, from human disturbance
- Identifying shoreline attributes preferred by seals in the MHI, and protecting areas with those attributes
- Identifying shoreline areas where seals could occur in high numbers with minimal human interactions
- Improving methods to mitigate interactions between seals and nearshore fishermen
- Developing methods to prevent aggressive behavior by seals toward people
- Developing ways to monitor and minimize exposure of seals to potential disease vectors

Climate Change and Loss of Habitat in the NWHI

The loss of terrestrial habitat for Hawaiian monk seal pupping, molting, and resting has been recognized as an issue of concern in the NWHI ever since the disappearance of Whaleskate Island at French Frigate Shoals due to erosion from severe winter storms in the late 1990s. Data are sparse, but other islets at French Frigate Shoals showed substantial reductions in size when data from 1923 and 1963 are compared to 2004 (Antonelis et al., 2006). Some of the changes are due to storms, ocean currents, and perhaps variations in coral growth, but it is not unreasonable to assume that sea level rise due to global climate change has also been a partial cause. Predictions indicate that sea level rise will seriously reduce land habitat for monk seals, nesting seabirds and turtles, and endemic vegetation in the NWHI within the foreseeable future (Baker et al., 2006). Little has been done by agencies with responsibilities for managing the NWHI to study or pursue mitigation of this problem. Action should be taken to identify, evaluate, and, where possible, implement options for providing adequate monk seal haulout habitats, particularly those suitable for pupping and nursing.

Role of Healthcare Facilities

Each year, some monk seals need medical attention for various reasons. Among other things, this includes pups abandoned by their mothers; sick and/or starving seals; and seals with injuries from hookings, boat strikes, shark predation, or interactions with other seals. Efforts to save the lives of these seals are of great interest to the public, and they are important for preventing mortality especially if they are females that could contribute to future pup production. Some of these situations have been dealt with *in situ* by NMFS staff and contract veterinarians (especially if they occurred in the NWHI), but others have required the equivalent of a seal hospital. To date, most of the latter situations have been dealt with using opportunistically available facilities in the MHI because no dedicated monk seal care facility existed in Hawaii.

The need for and characteristics of a captive-care program were explored in detail in an NMFS-sponsored Monk Seal Captive Care Workshop. The report of that workshop noted that "A key missing component is a captive-care facility in the MHI capable of supporting animals requiring care" (Baker & Littnan, 2008, p. vi). Such a facility would need to be capable of housing a substantial number of seals over protracted periods of time. A captive-care program would be operated by a consortium, which would include the NMFS, other resource management agencies, and private organizations with expertise in caring for seals.

The future need for captive-care facilities to rehabilitate and nourish young seals as was done in the past is somewhat uncertain at this time, but evaluation of strategies to get the best results from a rehabilitation program should be continued. Additionally, the "routine" need for health care is likely to increase with more seals in the MHI, if future translocation efforts are pursued, and to ensure adequate response to disease outbreaks or other unforeseen events. For these purposes, a moderate-sized facility dedicated to providing health care to monk seals is still a high priority need. Progress has been made in organizing a consortium and obtaining a site for such a facility, and that effort needs to be carried through to its conclusion. The Marine Mammal Center, a nonprofit organization authorized by NMFS to provide care for ill or injured marine mammals, is taking the lead in this effort.

Balancing Recovery Needs in the NWHI and MHI

When the first recovery plan was written for Hawaiian monk seals (Gilmartin, 1983), there was no mention of seals in the MHI and the focus was entirely on the NWHI. Such an approach was appropriate as prior to 1988 there were few reported monk seal sightings and only one known birth in the MHI. That situation soon changed, with a minimum of 31 pups known to have been born in the MHI between 1991 and 2001, and aerial counts in 2000 and 2001 showing about 50 seals hauled out on beaches (Baker & Johanos, 2004). The revised recovery plan developed between 2004 and 2007 recognized that change and recommended taking steps to ensure continued growth of the MHI subpopulation as part of its recovery strategy (NMFS, 2007).

The relative status of monk seals in the MHI and NWHI continues to change. In 2008, about 1,000 seals were estimated to live in the NWHI and about 150 in the MHI (Carretta et al., 2009). Most importantly, seal numbers are estimated to be increasing by 6.5%/y in the MHI, while all NWHI subpopulations are declining at rates varying from 4 to 11%/y. If those rates of increase and decline continue, the number of seals in the NWHI and MHI would be approximately equal in 2023, with about 300 to 350 animals living in each region (Baker et al., 2011).

Monk seal recovery efforts have been chronically limited by available funding and staff. Resources have generally been only marginally adequate to address needs in the NWHI alone, and relatively little attention has been paid to research and management in the MHI. With additional funding in 2009 and 2010, NMFS has been better positioned to conduct a program that addresses priority recovery needs in these two regions. However, that situation reversed itself with budget cuts in 2011.

Clearly, at this point in time, circumstances in the NWHI do not favor monk seals—more seals are dying than are being born at every major breeding colony, and overall abundance is declining steadily. The situation is the opposite in the MHI. While we do not fully understand all of the reasons for either the NWHI decline or the MHI increase, a reasonable approach would be to take advantage of this situation as much as possible. One potential recovery action would be to move young seals from the NWHI to the MHI with the expectation that they would experience vital rates similar to seals born in the MHI. Those animals then could be returned to the NWHI after they have passed through the juvenile survival bottleneck. Of course, conducting a program of this nature successfully depends on many factors, including the issue of human–seal conflicts discussed above; the assumptions that MHI conditions will remain favorable for seal growth, productivity, and survival; and that seals once returned will forage successfully and have the same high survival rates as adults now living in the NWHI.

Although increased emphasis on seals in the MHI is warranted, research and management efforts in the NWHI should not be compromised. Our basic understanding of monk seal biology comes from studies done there, and those long-term datasets are extremely valuable for interpreting what is now happening and predicting what will happen in the future with seals and their ecosystems. Also, it is likely that the NWHI have always supported a large part of the monk seal population, and effectively the entire population for at least the last several hundred years. Essentially, all of their NWHI range is now encompassed in the PMNM, which provides strict controls over human activities, so there is no reason to think that seals should not persist in that region. Continued efforts are warranted to monitor the NWHI populations and to minimize all sources of mortality or disturbance as much as possible.

The waters of the NWHI, included in the PMNM, are often touted as being "pristine" and an example of a "predator-dominated" coral reef ecosystem. Non-seal apex predators, primarily jacks and sharks, comprise 35% of the total fish biomass (Friedlander et al., 2008). Large predators often follow foraging monk seals and take some of the prey that they flush, and it is likely that high numbers of predators more generally compete with seals for the limited supply of prey. Although the region is relatively pristine, the NWHI ecosystem has been impacted by commercial fishing for lobsters, bottomfish, jacks, and sharks. In addition to removal of target species, bycatch in

those fisheries and discards of bait from lobster traps may have altered trophic relationships and competition among top predators (Parrish et al., 2008).

With no accurate long-term datasets on abundance of affected marine species, one can only speculate about whether the current high biomass of predatory fish is typical for the NWHI and how that situation may be limiting the monk seal population's ability to recover. However, there are common sense reasons to think that reducing the abundance of large predatory fish might make it easier for seals to obtain adequate food, especially the juveniles that are experiencing the poorest survival. If the decline of monk seals in the NWHI continues, experimental reduction of fish predator populations is one of the few available options that could and should be considered to improve the situation. By the same token, other possible approaches to increasing foraging success should also be considered. For example, it might be possible to increase available monk seal prey by restoring or enhancing the abundance of key monk seal prey species through the introduction of artificial habitats or the augmentation of prey populations through the release of hatchery-reared individuals.

Interagency Cooperation and Coordination

The formation of the PMNM is one of the most significant conservation actions taken by the United States so far in the 21st century. With this designation comes a huge responsibility for conserving the biological, historical, and cultural resources found within this diverse set of habitats. Management of the PMNM has been designated to three trustee agencies: (1) the Department of the Interior's FWS, (2) the Department of Commerce's NOAA, and (3) the State of Hawaii Department of Land and Natural Resources. The intent was for the co-trustees to use their expertise and authorities together with other state and federal agency partners (particularly the NMFS, the USCG, the MMC, the Department of Defense, the Office of Hawaiian Affairs, and the Environmental Protection Agency) to provide comprehensive protection of the area's resources.

The PMNM Management Plan embraces the need for ecosystem management. Recognition of this need is shown in Goal 1 of the plan, which is to

> Protect, preserve, maintain, and where appropriate restore the physical environment and the natural biological communities and their associated biodiversity, habitats, populations, native species, and ecological integrity. (PMNM, 2008, p. 106)

The Plan also states,

> Maintaining ecological integrity is often cited as the primary goal of ecosystem-based management. Ecological integrity is the capability to support and maintain a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitats of the region. A system will retain its integrity if it preserves all its components, as well as the functional relationships among those components. (p. 101)

Statements such as these implicitly support the various types of interventions to help recover monk seals that have been carried out in the NWHI by NMFS for years (e.g., removal of aggressive male seals, translocation of weaned pups, selective removal of Galapagos sharks, and removal of marine debris). Similar interventions have been undertaken in PMNM to create new habitat and establish new populations of Laysan ducks as part of a translocation program.

One clear priority for the PMNM should be recovery of the critically endangered Hawaiian monk seal to the point that it is a fully functional element in this ecosystem. However, there continue to be delays and problems with implementing some important recovery actions within PMNM, partly because virtually all such activities require permits that are overly scrutinized by co-managers, their partners, and stakeholders. There is a need to improve communication, justification, and understanding of critical recovery needs, and for better coordination between managers, stakeholders, and the monk seal recovery program. Leaders and staff in all the main management agencies must treat monk seal recovery as one of their top priorities, and they must be accountable for decisions that are made regarding recovery actions for this critically endangered species.

Conclusions

Based on this review and our direct involvement in Hawaiian monk seal research, conservation, and recovery over the past 35+ years, we offer the following conclusions:

1. The NMFS must provide the monk seal program with sufficient staff and funding to cover all high priority research, management, and administrative responsibilities. To do so, it should request annual Hawaiian monk seal recovery budgets more in line with the cost estimates of $7 mil/y projected in the recovery plan.

2. The NMFS and its cooperating agencies must maintain a program of scientific research and monitoring in both the NWHI and MHI adequate to detect changes in abundance and vital rates of monk seals, and to understand the causes of any such changes. To provide proper guidance for this program, it will be necessary to update/revise the recovery plan and other key planning documents at appropriate intervals to keep abreast of current realities.
3. The NMFS must continually take action to minimize all sources of monk seal mortality, particularly those related to health and nutrition issues, shark predation, adult male aggression, marine debris, and fishery interactions.
4. The NMFS should promote recovery of monk seals in the MHI. This will require an increase in overall staff and funding to work with stakeholders to increase acceptance of monk seals in the MHI, and to increase overall support for monk seal recovery efforts.
5. Resource managers must be willing to take bold actions that could change the current downward trend in the population. Possibilities that should be considered include the following:
   - Translocating weaned pups from sites in the NWHI where survival rates are low to sites with higher survival rates in the NWHI or the MHI
   - Completing construction and beginning operations of a dedicated MHI monk seal healthcare facility
   - Thoroughly investigating options and, where warranted, intervening in parts of the NWHI ecosystem to make conditions more favorable for monk seals—Options include (1) reducing the abundance of monk seal predators (sharks) and competitors (sharks and jacks); (2) enhancing the abundance or availability of monk seal prey species; and (3) protecting, restoring, or building terrestrial habitat areas where seals can haul out to rest, molt, pup, and nurse their young.
   - Responding to situations wherein adult male seals are seriously injuring or killing adult females or young seals
6. Government agencies and stakeholders must focus even more attention on the key need, which is to design and implement, in a timely fashion, a set of actions that will stop the Hawaiian monk seal's decline toward extinction and recover the population sufficiently that it can be removed from the ESA's list of endangered species. As long as the population continues to decline, new approaches must be considered and tested as a matter of highest priority.

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Literature Cited

Abernathy, K. J. (1999). *Foraging ecology of Hawaiian monk seals at French Frigate Shoals, Hawaii* (Master's thesis). University of Minnesota, Twin Cities.

Alcorn, D. J., & Buelna, E. K. (1989). *The Hawaiian monk seal on Laysan Island, 1983* (Technical Memorandum NMFS-SWFSC-124). La Jolla, CA: National Marine Fisheries Service (NMFS).

Antonelis, G. A., Baker, J. D., & Polovina J. J. (2003). Improved body condition of weaned Hawaiian monk seal pups associated with El Niño events: Potential benefits to an endangered species. *Marine Mammal Science, 19*, 590-598. doi:10.1111/j.1748-7692.2003.tb01323.x

Antonelis, G. A., Baker, J. D., Johanos, T. C., Braun, R. C., & Harting, A. L. (2006). Hawaiian monk seal (*Monachus schauinslandi*): Status and conservation issues. *Atoll Research Bulletin, 543*, 75-101.

Atkinson, S., Gilmartin, W. G., & Lasley, B. L. (1993). Testosterone response to a gonadotrophin-releasing hormone agonist in Hawaiian monk seals (*Monachus schauinslandi*). *Journal of Reproduction and Fertility, 97*, 35-38. doi:10.1530/jrf.0.0970035

Bailey, A. M. (1952). The Hawaiian monk seal. *Museum Pictorial, Denver Museum of Natural History, 7*, 1-32.

Baker, J. D., & Johanos, T. C. (2004). Abundance of the Hawaiian monk seal in the main Hawaiian Islands. *Biological Conservation, 116*, 103-110. doi:10.1016/S0006-3207(03)00181-2

Baker, J. D., & Littnan, C. L. (Eds.). (2008). *Report of the Hawaiian Monk Seal Captive Care Workshop, Honolulu, Hawaii* (Administrative Report H-08-02). Honolulu, HI: NMFS.

Baker, J. D., Littnan, C. L., & Johnston, D. W. (2006). Potential effects of sea level rise on the terrestrial habitats of endangered and endemic megafauna in the Northwestern Hawaiian Islands. *Endangered Species Research, 4*, 1-10.

Baker, J. D., Polovina, J. J., & Howell, E. A. (2007). Effect of variable oceanic productivity on the survival of an upper trophic predator, the Hawaiian monk seal, *Monachus schauinslandi*. *Marine Ecology Progress Series, 346*, 277-283. doi:10.3354/meps06968

Baker, J. D., Harting, A. L., Wurth, T. A., & Johanos, T. C. (2011). Dramatic shifts in Hawaiian monk seal distribution predicted from divergent regional trends. *Marine Mammal Science, 27*, 78-93. doi:10.1111/j.1748-7692.2010.00395.x

Berta, A., Sumich, J. L., & Kovacs, M. (2006). *Marine mammals evolutionary biology* (2nd ed.). New York: Academic Press.

Bertilisson-Friedman, P. A. (2002). *Shark inflicted injuries to the endangered Hawaiian monk seal,* Monachus schauinslandi (Master's thesis). University of New Hampshire, Durham.

Boland, R. C., & Donohue, M. J. (2003). Marine debris accumulation in the nearshore marine habitat of the endangered Hawaiian monk seal, *Monachus schauinslandi*, 1999-2001. *Marine Pollution Bulletin*, *46*, 183-194. doi:10.1016/S0025-326X(03)00291-1

Busch, B. C. (1985). *The war against the seals: A history of the North American seal fishery*. Kingston & Montreal, Canada: McGill-Queen's University Press.

Carretta, J. V., Forney, K. A., Lowry, M. S., Barlow, J., Baker, J., & Carswell, L. (2009). *U.S. Pacific marine mammal stock assessments: 2009* (Technical Memorandum NOAA-TM-NMFS-SWFSC-453). La Jolla, CA: NMFS.

Carretta, J. V., Forney, K. A., Muto, M. M., Barlow, J., Baker, J., & Lowry, M. S. (2006). *U.S. Pacific marine mammal stock assessments: 2005* (Technical Memorandum NOAA-TM-NMFS-SWFSC-388). La Jolla, CA: NMFS.

Center for Biological Diversity. (2008). *Petition to revise critical habitat for the Hawaiian monk seal (*Monachus schauinslandi*) under the Endangered Species Act*. Retrieved 18 July 2011 from www.fpir.noaa.gov/Library/PRD/Critical%20Habitat/Petition-Monk-Seal-CH-07-02-08.pdf.

Craig, M. P., & Ragen, T. J. (1999). Body size, survival, and decline of juvenile Hawaiian monk seals, *Monachus schauinslandi*. *Marine Mammal Science, 15*, 786-809. doi:10.1111/j.1748-7692.1999.tb00843.x

Culliney, J. L. (2006). *Islands in a far sea*. Honolulu: University of Hawai'i Press.

Dale, J. J., Stankus, A. M., Burns, M. S., & Myer, C. G. (2011). The shark assemblage at French Frigate Shoals Atoll, Hawai'i: Species composition, abundance, and habitat use. *PLos One, 6*(2), e16862. Retrieved 18 July 2011 from www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0016962. doi:10.1371/journal.pone.0016962.

Dameron, O., Parke, M., Albins, M., & Brainard, R. (2007). Marine debris accumulation in the Northwestern Hawaiian Islands: An examination of rates and processes. *Marine Pollution Bulletin, 54*, 423-433. doi:10.1016/j.marpolbul.2006.11.019

DeCrosta, M. A. (1984). *Age determination, growth, and energetics of three species of carcharhinid sharks in Hawaii* (Master's thesis). University of Hawaii, Honolulu.

DeLong, R. L., & Brownell, R. L., Jr. (1977). *Hawaiian monk seal* (Monachus schauinslandi*) habitat and population survey in the Northwestern (Leeward) Hawaiian Islands, April 1977* (Northwest & Alaska Fisheries Center Processed Report). Seattle, WA: NMFS.

DeLong, R. L., & Gilmartin, W. G. (1979). *Ciguatoxin feeding experiment with a model phocid* (Unpublished Monk Seal Workshop Report). Washington, DC: Marine Mammal Commission.

DeLong, R. L., & Kenyon, K. W. (1979). *A five-year research plan for the Hawaiian monk seal: Results of an 18-19 October 1978 research planning meeting* (Unpublished report). Washington, DC: Marine Mammal Commission.

DeLong, R. L., Fiscus, C. H., & Kenyon K. W. (1976). *Survey of monk seals (*Monachus schauinslandi*) populations of the Northwestern (Leeward) Hawaiian Islands* (Unpublished report). Seattle, WA: NMFS.

DeLong, R. L., Kooyman, G. L., Gilmartin, W. G., & Loughlin, T. R. (1984). Hawaiian monk seal diving behavior. *Acta Zoologica Fennica, 172*, 129-131.

Dill, H. R., & Bryan, W. M. A. (1912). Report of an expedition to Laysan Island. *Biological Survey Bulletin, 42*, 1-30.

Donohue, M. J., Boland, R. C., Sramek, C. M., & Antonelis, G. A. (2001). Derelict fishing gear in the Northwestern Hawaiian Islands: Diving surveys and debris removal in 1999 confirm threat to coral reef ecosystems. *Marine Pollution Bulletin, 42*, 1301-1312. doi:10.1016/S0025-326X(01)00139-4

Friedlander, A. M., & Demartini, E. E. (2002). Contrasts in density, size and biomass of reef fishes: APEX predators. *Marine Ecology Progress Series, 230*, 253-264. doi:10.3354/meps230253

Friedlander, A., Aeby, G., Balwani, S., Bowen, B., Brainard, R., & Zamzow, J. (2008). The state of coral reef ecosystems of the Northwestern Hawaiian Islands. In J. E. Waddell & A. M. Clarke (Eds.), *The state of coral reef ecosystems of the United States and Pacific Freely Associated States: 2008* (Technical Memorandum NOS NCCOS 73, pp. 263-306). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Fyler, C. A., Reeder, T. W., Berta, A., Antonelis, G., Aguilar, A., & Androukaki, E. (2005). Historical biogeography and phylogeny of monachine seals (Pinnipedia: Phocidae) based on mitochondrial and nuclear DNA data.

Journal of Biogeography, 32, 1267-1279. doi:10.1111/j.1365-2699.2005.01281.x

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

Gilmartin, W. G. (1983). *Recovery plan for the Hawaiian monk seal,* Monachus schauinslandi. *In cooperation with the Hawaiian Monk Seal Recovery Team* (NMFS Technical Report). Washington, DC: NMFS.

Gilmartin, W. G. (1987). *Hawaiian monk seal die-off response plan, a workshop report* (Administrative Report H-87-19). Honolulu, HI: NMFS.

Gilmartin, W. G. (1990). *Hawaiian monk seal work plan: Fiscal years 1991-93* (Administrative Report H-90-14). Honolulu, HI: NMFS.

Gilmartin, W. G. (1993a). *Research and management plan for the Hawaiian monk seal at French Frigate Shoals, 1993-96* (Administrative Report H-93-08). Honolulu, HI: NMFS.

Gilmartin, W. G. (1993b). *Hawaiian monk seal work plan: Fiscal years 1994-96* (Administrative Report H-93-16). Honolulu, HI: NMFS.

Gilmartin, W. G., & Alcorn, D. J. (1987). *A plan to address the Hawaiian monk seal adult male "mobbing" problem* (Administrative Report H-87-12). La Jolla, CA: NMFS.

Gilmartin, W. G., Johanos, T. C., DeMaster, D. P., & Henderson, J. R. (2011a). Hawaiian monk seals (*Monachus schauinslandi*) at Kure Atoll: Some life history effects following effort to enhance pup survival. *Aquatic Mammals, 37*(3), 326-331. doi:10.1578/AM.37.3.2011.326

Gilmartin, W. G., DeLong, R. L., Smith, A. W., Griner, L. A., & Dailey, M. D. (1980). *An investigation into unusual mortality in the Hawaiian monk seal,* Monachus schauinslandi. In R. W. Grigg & R. T. Pfund (Eds.), *Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands* (UNIHI-SEAGRANT-MR-80-04, pp. 32-41). Honolulu: University of Hawai'i Sea Grant Program.

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

Gobush, K. S. (2010). *Shark predation on Hawaiian monk seals: Workshop II & post-workshop developments, November 5-6, 2008 (*Technical Memorandum NOAA-TM-NMFS-PIFSC-21). Honolulu, HI: NMFS.

Goodman-Lowe, G. D. (1998). Diet of the Hawaiian monk seal (*Monachus schauinslandi*) from the Northwestern Hawaiian Islands during 1991-1994. *Marine Biology, 132*, 535-546.

Hanson, M. T., Aguirre, A. A., & Braun, R. C. (2009). *Clinical observations of ocular disease in Hawaiian monk seals (*Monachus schauinslandi*)* (Technical Memorandum NOAA-TM-NMFS-PIFSC-18). Honolulu, HI: NMFS.

Harting, A. L. (2002). *Stochastic simulation model for the Hawaiian monk seal* (Unpublished doctoral dissertation). Montana State University, Bozeman.

Harting, A. L. (2010). *Shark Predation on Hawaiian Monk Seals Workshop, Honolulu, Hawaii, January 8-9, 2008* (Administrative Report H-10-02C). Honolulu, HI: NMFS.

Hawn, D. (2000). *Galapagos shark (*Carcharhinus galapagensis*) removal and shark sighting observations at Trig Island, French Frigate Shoals during the 2000 Hawaiian monk seal field s*eason (Unpublished report, Contract Order 40JJNF000208). Honolulu, HI: NMFS.

Hayes, S. (2002). *Galapagos shark predation of monk seal pups at Trig Island, FFS 2001* (NMFS unpublished report). Honolulu, HI: NMFS.

Henderson, J. R. (2001). A pre- and post-MARPOL Annex V summary of Hawaiian monk seal entanglements and marine debris accumulation in the Northwestern Hawaiian Islands, 1982-1998. *Marine Pollution Bulletin, 42*, 584-589. doi:10.1016/S0025-326X(00)00204-6

Hiruki, L. M., & Ragen, T. J. (1992). *A compilation of historical Hawaiian monk seal (*Monachus schauinslandi*) counts* (Technical Memorandum NOAA-TM-NMFS-SWFSC- 172). La Jolla, CA: NMFS.

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

Iverson, S., Piché, J., & Blanchard, W. (2011). *Hawaiian monk seals and their prey: Assessing characteristics of prey species fatty acid signatures and consequences for estimating monk seal diets using Quantitative Fatty Acid Signature Analysis* (Technical Memorandum NOAA-TM-NMFS-PIFSC-23). Honolulu, HI: NMFS.

Johanos, T. C., & Kam, A. K. H. (1986). *The Hawaiian monk seal on Lisianski Island: 1983* (Technical Memorandum NMFS-SWFSC-58). La Jolla, CA: NMFS.

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

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

Johnson, B. W., & Johnson, P. A. (1978). *The Hawaiian monk seal on Laysan Island: 1977* (Marine Mammal Commission Report No. PB-285428). Springfield, VA: National Technical Information Service.

Johnson, B. W., & Johnson, P. A. (1981). *Estimating the Hawaiian monk seal population on Laysan Island: 1978* (Marine Mammal Commission Report No. PB82-109113). Springfield, VA: National Technical Information Service.

Johnson, P. A., & Johnson, B. W. (1980). *Hawaiian monk seal observations on French Frigate Shoals, 1980*

(Technical Memorandum NMFS-SWFSC-50). La Jolla, CA: NMFS.

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

Kenyon, K. W. (1980). No man is benign—the endangered monk seal. *Oceans, 13*(2), 48-54.

Kenyon, K. W., & Rice, D. W. (1959). Life history of the Hawaiian monk seal. *Pacific Science, 31*, 215-252.

Laist, D. W. (1996). Entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In J. M. Coe & D. R. Roberts (Eds.), *Marine debris: Sources, impacts and solutions* (pp. 99-139). New York: Springer-Verlag.

LeDuc, R. (2009). *Biogeography*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 112-115). San Diego: Academic Press.

Lisianski, Y. (1814). *A voyage round the world in the years 1803-1806 in the ship* Neva. London: John Booth.

Lowry, L., & Aguilar, A. (2008). *Monachus schauinslandi*. In IUCN (Ed.), *2009 IUCN red list of threatened species*. Retrieved 13 July 2011 from www.iucnredlist.org.

Marine Mammal Commission (MMC). (1976). *Marine Mammal Commission annual report to Congress, 1976*. Retrieved from www.mmc.gov/reports/annual.

MMC. (1978). *Marine Mammal Commission annual report to Congress, 1978*. Retrieved from www.mmc.gov/reports/annual.

MMC. (1980). *Marine Mammal Commission annual report to Congress, 1980*. Retrieved from www.mmc.gov/reports/annual.

MMC. (1981). *Marine Mammal Commission annual report to Congress, 1981*. Retrieved from www.mmc.gov/reports/annual.

MMC. (2000). *Marine Mammal Commission annual report to Congress, 1999*. Retrieved from www.mmc.gov/reports/annual.

MMC. (2003). *Workshop on the management of Hawaiian monk seals on beaches in the main Hawaiian Islands*. Bethesda, MD: MMC.

Meffe, G. K., Perrin, W. F., & Dayton, P. K. (1999). Marine mammal conservation: Guiding principles and their implementation. In J. R. Twiss, Jr. & R. R. Reeves (Eds.), *Conservation and management of marine mammals* (pp. 437-454). Washington, DC: Smithsonian Institution Press.

National Marine Fisheries Service (NMFS). (2007). *Recovery plan for the Hawaiian monk seal (*Monachus schauinslandi*)* (Revision). Silver Spring, MD: NMFS.

NMFS. (2009). *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*. Honolulu, HI: NMFS.

NMFS and Western Pacific Regional Fishery Management Council (WPRFMC). (2006). *Draft supplemental environmental impact statement for bottomfish and seamount groundfish fisheries of the Western Pacific region: Measures to end bottomfish overfishing in the Hawaii archipelago*. Retrieved 18 July 2011 from www.wpcouncil.org/bottomfish/Documents/BottomfishOverfishingDSEIS-March302006.pdf.

National Oceanic and Atmospheric Administration (NOAA). (2010). *Marine debris survey and removal from the Papahānaumokuākea (Northwestern Hawaiian Islands) Marine National Monument*. Retrieved 18 July 2011 from http://marinedebris.noaa.gov/projects/removal_nwhi.html.

Nolan, R. S. (1981). *Shark control and the Hawaiian monk seal* (Marine Mammal Commission Report No. PB81-201808). Springfield, VA: National Technical Information Service.

Norris, T., & Gulland, F. (2011). *Evaluation of the foraging behavior, health and disease status, and survival of resident and translocated Hawaiian monk seals (*Monachus schauinslandi*) at Nihoa Island, Hawaii* (Unpublished final report, Contract No. NFFKPR00-09-23667). Honolulu, HI: NMFS.

Norris, T. A., Littnan, C. L., & Gulland, F. M. D. (2011). Evaluation of the captive care and post-release behavior and survival of seven juvenile female Hawaiian monk seals (*Monachus schauinslandi*). *Aquatic Mammals, 37*(3), 342-353. doi:10.1578/AM.37.3.2011.342

Papahānaumokuākea Marine National Monument (PMNM). (2008). *Papahānaumokuākea Marine National Monument management plan*. Retrieved 18 July 2011 from www.papahanaumokuakea.gov/management/mp.html.

Parrish, F. A., Abernathy, K., Marshall, G. J., & Buhleier, B. M. (2002). Hawaiian monk seals (*Monachus schauinslandi*) foraging in deepwater coral beds. *Marine Mammal Science, 18*, 244-258. doi:10.1111/j.1748-7692.2002.tb01031.x

Parrish, F. A., Marshall, G. J., Buhleier, B., & Antonelis, G. A. (2008). Foraging interaction between monk seals and large predatory fish in the Northwestern Hawaiian Islands. *Endangered Species Research, 4*, 299-308. doi:10.3354/esr00090

Parrish, F. A., Marshall, G. J., Littnan, C. L., Heithaus, M., Canja, S., Becker, B., & Antonelis, G. A. (2005). Foraging of juvenile monk seals at French Frigate Shoals, Hawaii. *Marine Mammal Science, 21*, 93-107. doi:10.1111/j.1748-7692.2005.tb01210.x

Polovina, J. J., Mitchum, G. T., Graham, N. E., Craig, M. P., Demartini, E. E., & Flint, E. N. (1994). Physical and biological consequences of a climate event in the central North Pacific. *Fisheries Oceanography, 3*, 15-21. doi:10.1111/j.1365-2419.1994.tb00044.x

Ragen, T. J., & Lavigne, D. M. (1999). The Hawaiian monk seal: Biology of an endangered species. In J. R. Twiss, Jr. & R. R. Reeves (Eds.), *Conservation and management of marine mammals* (pp. 224-245). Washington, DC: Smithsonian Institution Press.

Rauzon, M. J. (2001). *Isles of refuge*. Honolulu: University of Hawai'i Press.

Reddy, M. L. (1989). *Population monitoring of the Hawaiian monk seal,* Monachus schauinslandi*, and captive maintenance project for female pups at Kure Atoll,*

1987 (Technical Memorandum NMFS-SWFSC-123). La Jolla, CA: NMFS.

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

Rice, D. W. (1998). *Marine mammals of the world: Systematics and distribution* (Special Publication 4, The Society for Marine Mammalogy). Lawrence, KS: Allen Press.

Rosendahl, P. H. (1994). Aboriginal Hawaiian structural remains and settlement patterns in the upland archeological zone at Lapakahi, Island of Hawaii. *Journal of Hawaiian Archeology, 3*, 15-70.

Schlexer, F. V. (1984). *Diving patterns of the Hawaiian monk seal, Lisianski Island, 1982* (Technical Report NOAA-TM-NMFS-SWFSC-41). La Jolla, CA: NMFS.

Schulmeister, S. (1981). Hawaiian monk seal numbers increase on Tern Island. *Elepaio, 41*(7), 52.

State of Hawaii. (2009). *State of Hawaii databook*. Retrieved 18 July 2011 from http://hawaii.gov/dbedt/info/economic/databook/db2009/db2009.pdf.

Stewart, B. S., Antonelis, G. A., Baker, J. D., & Yochem, P. K. (2006). Foraging biogeography of Hawaiian monk seals in the Northwestern Hawaiian Islands. *Atoll Research Bulletin, 543*, 131-146.

Wilkinson, D. M. (1996). *National contingency plan for response to unusual marine mammal mortality events* (Technical Memorandum NMFS-OPR-9). Silver Spring, MD: NMFS.

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

Yochem, P. K., Atkinson, S., & Gilmartin, W. G. (1991). Effects of a GnRH agonist on plasma testosterone concentrations and socio-sexual behavior of harbor seals. *Proceedings of the Ninth Biennial Conference on the Biology of Marine Mammals*, Chicago, IL.

Yochem, P. K., Braun, R. C., Ryon, B., Baker, J. D., & Antonelis, G. A. (2004). *Contingency plan for Hawaiian monk seal unusual mortality events* (NOAA-TM-NMFS-PIFSC-2). Silver Spring, MD: National Oceanic and Atmospheric Administration.

Ziegler, A. C. (2002). *Hawaiian natural history, ecology, and evolution*. Honolulu: University of Hawai'i Press.