HAWAIIAN MONK SEAL (*Monachus schauinslandi*)

STOCK DEFINITION AND GEOGRAPHIC RANGE

Hawaiian monk seals are distributed predominantly in six Northwestern Hawaiian Islands (NWHI) subpopulations at French Frigate Shoals, Laysan and Lisianski Islands, Pearl and Hermes Reef, and Midway and Kure Atoll. Small numbers also occur at Necker, Nihoa, and the main Hawaiian Islands (MHI). Genetic variation among NWHI monk seals is extremely low and may reflect both a long-term history at low population levels and more recent human influences (Kretzmann et al. 1997, 2001, Schultz et al. 2009). On average, 10-15% of the seals migrate among the NWHI subpopulations (Johnson and Kridler 1983; Harting 2002). Thus, the NWHI subpopulations are not isolated, though the different island subpopulations have exhibited considerable demographic independence. Observed interchange of individuals among the NWHI and MHI regions is rare, yet preliminary genetic stock structure analysis (Schultz et al. in review) suggests the species is appropriately managed as a single stock.

POPULATION SIZE

The best estimate of the total population size is 1,161. This estimate is the sum of estimated abundance at the six main Northwest Hawaiian Islands subpopulations, an extrapolation of counts at Necker and Nihoa Islands, and an estimate of minimum abundance in the main Hawaiian Islands. The number of individual seals identified was used as the population estimate at NWHI sites where total enumeration was achieved according to the criteria established by Baker et al. (2006). Where total enumeration was not achieved, capture-recapture estimates from Program CAPTURE were used (Baker 2004; Otis et al. 1978, Rexstad & Burnham 1991, White et al. 1982). When no reliable estimator was obtainable in Program CAPTURE (i.e., the model selection criterion was < 0.75, following Otis et al. 1978), the total number of seals identified was the best available estimate. Finally, sometimes capture-recapture estimates are less than the known minimum abundance (Baker 2004), and in these cases the total number of seals identified was used. In 2008, total enumeration was not definitively achieved at any site, however analysis of discovery curves (Baker et al. 2006) suggested that nearly all seals were identified at Laysan Island and Kure Atoll. Except at Midway Atoll, capture-recapture analysis either found no suitable estimator was available or the estimate was lower than known minimum abundance. Thus, abundance at the six main subpopulations was estimated to be 914 (including 138 pups). Monk seals also occur at Necker and Nihoa Islands, where counts are conducted from zero to a few times in a single year. Abundance is estimated by correcting the mean of all beach counts accrued over the past five years. The mean (±SD) of all counts (excluding pups) conducted between 2004 and 2008 was 15.5 (±5.1) at Necker Island and 27.1 (±5.7) at Nihoa Island (Johanos and Baker in press, in prep., Johanos in prep.). The relationship between mean counts and total abundance at the reproductive sites indicates that the total abundance can be estimated by multiplying the mean count by a correction factor of 2.89 (NMFS unpubl. data). Resulting estimates (plus the average number of pups known to have been born during 2004-2008) are 47.8 (±14.7) at Necker Island and 86.5 (±16.5) at Nihoa Island.

The only complete and systematic surveys for monk seals in the MHI were conducted in 2000 and 2001 (Baker and Johanos 2004). The NMFS collects information on seal sightings reported by a variety of sources. Recently, the number of such reports has increased and related database improvement efforts have been underway. The total number of individually identifiable seals documented in this way in 2008 was 113, the current best minimum abundance estimate.

Minimum Population Estimate

The total number of seals (913) identified at the six main NWHI reproductive sites is the best estimate of minimum population size at those sites. Minimum population sizes for Necker and Nihoa Islands (based on the formula provided by Wade and Angliss (1997)) are 37 and 74, respectively. The minimum abundance estimate for the main Hawaiian Islands in 2008 is 113 seals. The minimum population size for the entire stock (species) is the sum of these estimates, or 1,136 seals.

Current Population Trend

Current population trend is based solely on the six NWHI subpopulations because these sites have historically comprised virtually the entire species, while information on the remaining smaller seal aggregations have been inadequate to reliably evaluate abundance or trends. The total of mean non-pup beach counts at the six main reproductive NWHI subpopulations in 2008 is 68% lower than in 1958. The trend in total abundance at the six main NWHI subpopulations estimated as described above is shown in Figure 1. A log-linear regression of estimated abundance on year for the past 10 years (1999-2008) estimates that abundance declined -4.5% yr^{-1} (95% CI = -5.0% to -3.9% yr^{-1}).

The MHI monk seal population appears to be increasing with an intrinsic population growth rate estimated at 5.6% per year based upon Leslie matrix analysis (Baker et al., in review). Likewise, sporadic beach counts at Necker and especially Nihoa Islands, suggest positive growth. While these sites have historically comprised a small fraction of the total species abundance, the decline of the six main NWHI subpopulations, coupled with growth at Necker, Nihoa and the MHI may mean that these latter three sites now substantially influence the total abundance trend. Unfortunately, because we lack reliable abundance estimates for these areas, their influence cannot currently be determined.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Trends in abundance vary considerably among subpopulations. Mean non-pup beach counts are used as a long-term index of abundance for years when data are insufficient to estimate total abundance as described above). Prior to 1999, beach count increases of up to 7% yr^{-1} were observed at Pearl and Hermes Reef, and this is the highest estimate of the maximum net productivity rate (R_{max}) observed for this species. Since 2000, low juvenile survival, thought to be due largely to food limitation, has resulted in population decline in the six main NWHI subpopulations (Fig. 1).

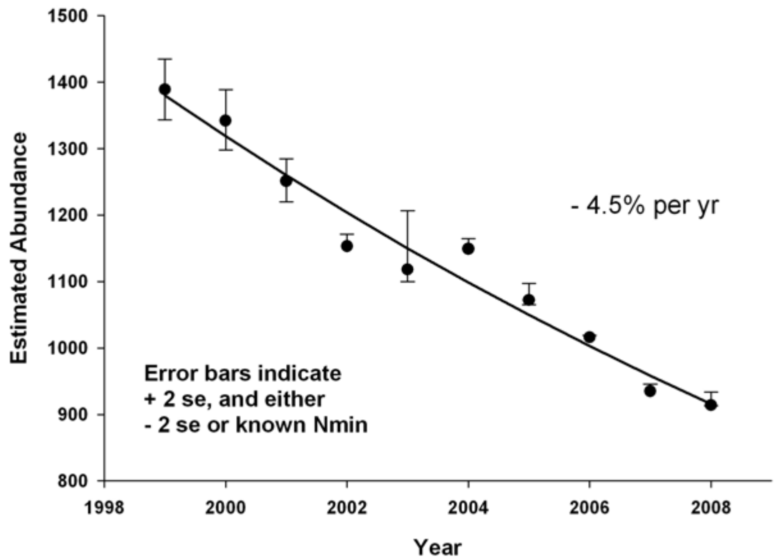

Figure 1. Trend in abundance of monk seals at the six main Northwestern Hawaiian Islands subpopulations, based on a combination of total enumeration and capture–recapture estimates. Error bars indicate ±2 s.e. (from variances of capture-recapture estimates). Fitted log-linear regression line is shown.

POTENTIAL BIOLOGICAL REMOVAL

Potential biological removal (PBR) is designed to allow stocks to recover to, or remain above, the maximum net productivity level (MNPL) (Wade 1998). An underlying assumption in the application of the PBR equation is that marine mammal stocks exhibit certain dynamics. Specifically, it is assumed that a depleted stock will naturally grow toward OSP (Optimum Sustainable Population), and that some surplus growth could be removed while still allowing recovery. The Hawaiian monk seal population is far below historical levels and has declined 4.5 % yr^{-1} on average since 1999. Thus, the stock's dynamics do not conform to the underlying model for calculating PBR such that PBR for the Hawaiian monk seal is undetermined.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Human-related mortality has caused two major declines of the Hawaiian monk seal (Ragen 1999). In the 1800s, this species was decimated by sealers, crews of wrecked vessels, and guano and feather hunters (Dill and Bryan 1912; Wetmore 1925; Bailey 1952; Clapp and Woodward 1972). Following a period of at least partial recovery in the first half of the 20^{th} century (Rice 1960), most subpopulations again declined. This second decline has not been fully explained, but trends at several sites appear to have been determined by human disturbance from military or U.S. Coast Guard activities (Ragen 1999; Kenyon 1972; Gerrodette and Gilmartin 1990). Currently, human activities in the NWHI are limited and human disturbance is relatively rare, but human-seal interactions have become an important issue in the MHI.

Fishery Information

Fishery interactions with monk seals can include direct interaction with gear (hooking or entanglement), seal consumption of discarded catch, and competition for prey. Entanglement of monk seals in derelict fishing gear, which is believed to originate outside the Hawaiian archipelago, is described in a separate section below.

Fishery interactions are a serious concern in the MHI, especially involving State of Hawaii managed nearshore fisheries. Three seals have been found dead in nearshore (non-recreational) gillnets (in 1994, 2006, and 2007), and a seal was found dead in 1995 with a hook lodged in its esophagus. A total of 52 seals have been observed with embedded hooks in the MHI during 1989-2008 (including 9 in 2008, of which 3 constituted serious injuries entered in Table 1). Several incidents, including the dead hooked seal mentioned above, involved hooks used to catch ulua (jacks, *Caranx* spp.). Interactions in the MHI appear to be on the rise, as most reported hookings have occurred since 2000, and five seals have been observed entangled in nearshore gillnets during 2002-2008 (NMFS unpubl. data). The MHI bottomfish handline fishery may also interact indirectly with monk seals as evidenced by fatty acid research, though no mortality or serious injuries have been attributed to the fishery (Table 1).

In the past, monk seal interactions with fisheries in the NWHI were documented, but direct interactions have since become rare or non-existent, and issues related to competition have also somewhat abated. Possible reduction of monk seal prey by the NWHI lobster fishery has also been raised as a concern, though whether the fishery indirectly impacted monk seals remains unresolved. However, the NWHI lobster fishery closed in 2000 and on June 15, 2006, the Northwestern Hawaiian Islands (later renamed *Papahanaumokuokea*) Marine National Monument was established. Subsequent regulations prohibit commercial fishing in the Monument except for the bottomfish fishery (and associated pelagic species catch), which may continue until 2011 (U.S. Department of Commerce and Department of the Interior, 2006). In the past, interactions between the Hawaii-based domestic pelagic longline fishery and monk seals were documented (NMFS 2002). This fishery targets swordfish and tunas and does not compete with Hawaiian monk seals for prey. In October 1991, in response to 13 unusual seal wounds thought to have resulted from interactions with this fishery, NMFS established a Protected Species Zone extending 50 nautical miles around the NWHI and the corridors between the islands. Subsequently, no additional monk seal interactions with either the swordfish or tuna components of the longline fishery have been observed. The NWHI bottomfish handline fishery landed between 66 and 201 metric tons per year from 1989-2008 (Kawamoto 1995; Kawamoto, pers. comm.) and the number of vessels is currently capped at 9 (8 made NWHI trips in 2008, Kawamoto, pers. comm.). Nitta and Henderson (1993) documented reports of seals taking bottomfish and bait off fishing lines, and reports of seals attracted to discarded bycatch. A Federal observer program of the fishery began in the fourth quarter of 2003 and no monk seal interactions were observed through the program's conclusion in 2006. NMFS prepared a Section 7 Biological Opinion on the Fishery Management Plan for the bottomfish fishery, and concluded that the operation of this fishery is not likely to jeopardize the continued existence of the Hawaiian monk seal nor would it likely destroy or adversely modify the monk seal's critical habitat (NMFS 2002). The Biological Opinion has no incidental take statement. An EIS for the bottomfish fishery management plan has also been prepared. Fishermen indicate that they have engaged in mitigating activity over the past several years, e.g., holding discards on-board, etc. (NMFS pers. comm.). The ecological effects of this fishery on monk seals (e.g., competition for prey or alteration of prey assemblages) are unknown. However, published studies on monk seal prey selection based upon scat/spew analysis and seal-mounted video revealed some evidence that monk seals fed on families of bottomfish which contain commercial species (many prey items recovered from scats and spews were identified only to the level of family; Goodman-Lowe 1998, Longenecker et al. 2006, Parrish et al. 2000). Recent quantitative fatty acid signature analysis (QFASA) results support previous studies illustrating that monk seals consume a wide range of species. However, deepwater-slope species, including two commercially targeted bottomfishes and other species not caught in the fishery, were estimated to comprise a large portion of the diet for some individuals. Similar species were estimated to be consumed by seals regardless of location, age or gender, but the relative importance of each species varied. Diets differed considerably between individuals. These results highlight the need to better understand potential ecological interactions with the Hawaiian bottomfish fishery.

Fishery Mortality Rate

Total fishery mortality and serious injury cannot be considered to be insignificant and approaching a rate of zero. Monk seals are being hooked and entangled in the MHI at a rate which has not been reliably assessed but is certainly greater than zero. The information above represents only reported direct interactions, and without purpose-designed observation effort the true interaction rate cannot be estimated. Monk seals also die from entanglement in fishing gear and other debris throughout their range (likely originating from various countries), and NMFS along with partner agencies is pursuing a program to mitigate entanglement (see below). Indirect interactions (i.e., involving competition for prey or consumption of discards) remain the topic of ongoing investigation.

Table 1. Summary of mortality and serious injury of Hawaiian monk seals due to fisheries and calculation of annual mortality rate. n/a indicates that sufficient data are not available.

Fishery Name	Year	Data Type	% Obs. coverage	Observed/Reported Mortality/Serious Injury	Estimated Mortality/ Serious Injury	Mean Takes (CV)
Pelagic Longline	2004	observer	24.6%	0	0	0 (0)
	2005	observer	26.1% & 100%[1]	0	0	
	2006	observer	22.1% & 100%[1]	0	0	
	2007	observer	20.1% & 100%[1]	0	0	
	2008	observer	21.7% & 100%[1]	0	0	
NWHI Bottomfish	2004	observer	18.3%	0	0	0 (0)
	2005	observer	25.0%	0	0	
	2006	observer	3.9%	0	0	
MHI Bottomfish[2]	2004	n/a	none	0	n/a	n/a
	2005			0		
	2006			0		
	2007			0		
	2008			0		
Nearshore[3]	2004	n/a	none	2	n/a	n/a
	2005			1		
	2006			1		
	2007			1		
	2008			3		

Entanglement in Marine Debris

Hawaiian monk seals become entangled in fishing and other marine debris at rates higher than reported for other pinnipeds (Henderson 2001). A total of 289 cases of seals entangled in fishing gear or other debris have been observed through 2008 (Henderson 2001; NMFS, unpubl. data), including eight documented deaths resulting from entanglement in marine debris (Henderson 1990, 2001; NMFS, unpubl. data). The fishing gear fouling the reefs and beaches of the NWHI and entangling monk seals only rarely includes types used in Hawaii fisheries. For example, trawl net and monofilament gillnet accounted for approximately 35% and 34% of the debris removed from reefs in the NWHI by weight, and trawl net alone accounted for 88% of the debris by frequency (Donohue et al. 2001). Yet trawl fisheries have been prohibited in Hawaii since the 1980s.

The NMFS and partner agencies continue to mitigate impacts of marine debris on monk seals as well as turtles, coral reefs and other wildlife. Marine debris is removed from beaches and entangled seals during annual population assessment activities at the main reproductive sites. Since 1996, annual debris survey and removal efforts in the NWHI coral reef habitat have been ongoing (Donohue et al. 2000, Donohue et al. 2001).

Other Mortality

Since 1982, 23 seals died during rehabilitation efforts that ceased in 1994. Additionally, two died in captivity, two died when captured for translocation, one was euthanized (an aggressive male known to cause mortality), four died during captive research and four died during field research (Baker and Johanos 2002; NMFS unpubl. data). Other sources of mortality that impede recovery include food limitation (see Habitat Issues below), single and intra-species multiple-male aggression (mobbing), shark predation, and disease/parasitism. Multiple-male aggression has primarily been identified as a problem at Laysan and Lisianski Islands, though it has also been documented at other subpopulations. In 1994, 22 adult males were removed from Laysan Island, and 11 seals are thought to have died from multiple-male aggression at this site since their removal (1995-2008).

Attacks by single adult male seals have resulted in several monk seal deaths, most notably at French Frigate Shoals in 1997, where at least 8 pups died from this cause. Many more pups were likely killed in the same way but the cause of their deaths could not be confirmed. Two males that killed pups in 1997 were translocated to Johnston Atoll, 870 km to the southwest. Subsequently, mounting injury to pups has decreased.

Shark-related injury and mortality incidents appeared to have increased in the late 1980s and early 1990s at French Frigate Shoals, but such mortality was probably not the primary cause of the decline at this site (Ragen

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[1] Observer coverage for deep and shallow-set components of the fishery, respectively

[2] Data for MHI bottomfish and nearshore fisheries are based upon incidental observations (i.e., hooked seals). All hookings not clearly attributable to either fishery with certainty were attributed to the bottomfish fishery, and hookings which resulted in injury of unknown severity were classified as serious.

1993). However, shark predation has accounted for a significant portion of pup mortality in recent years. At French Frigate Shoals in 1999, 17 pups were observed injured by large sharks, and at least 3 were confirmed to have died from shark predation (Johanos and Baker 2001). As many as 22 pups of a total 92 born at French Frigate Shoals in 1999 were likely killed by sharks. After 1999, losses of pups to shark predation have been fewer, but this source of mortality remains a serious concern. Various mitigation efforts have been undertaken by NMFS. While disease effects on monk seal demographic trends are uncertain, there is concern that diseases of livestock, feral animals, pets or humans could be transferred to naive monk seals in the MHI and potentially spread to the core population in the NWHI. In 2003 and 2004, two deaths of free-ranging monk seals were attributable to diseases not previously found in the species: leptospirosis and toxoplasmosis (R. Braun, pers. comm.). *Leptospira* bacteria are found in many of Hawaii's streams and estuaries and are associated with livestock and rodents. Cats, domestic and feral, are a common source of toxoplasma.

STATUS OF STOCK

In 1976, the Hawaiian monk seal was designated depleted under the Marine Mammal Protection Act of 1972 and as endangered under the Endangered Species Act of 1973. The species is well below its OSP and has not recovered from past declines. Therefore, the Hawaiian monk seal is characterized as a strategic stock.

Habitat Issues

Poor juvenile survival rates and variability in the relationship between weaning size and survival suggest that prey availability is likely limiting recovery of NWHI monk seals (Baker and Thompson 2007, Baker et al. 2007, Baker 2008). A variety of strategies for improving juvenile survival are being considered and will be developed through an experimental approach in coming years (Baker and Littnan 2008). A major habitat issue involves loss of terrestrial habitat at French Frigate Shoals, where pupping and resting islets have shrunk or virtually disappeared (Antonelis et al. 2006). Projected increases in global average sea level may further significantly reduce terrestrial habitat for monk seals in the NWHI (Baker, Littnan and Johnston, 2006).

Goodman-Lowe (1998) provided information on prey selection using hard parts in scats and spewings. Information on at-sea movement and diving is available for seals at all six main subpopulations in the NWHI using satellite telemetry (Stewart et al. 2006). Preliminary studies to describe the foraging habitat of monk seals in the MHI are reported in Littnan et al. (2006).

Tern Island is the site of a USFWS refuge station and is one of two sites in the NWHI accessible by aircraft. During World War II, the U.S. Navy enlarged the island to accommodate the runway, and a sheet-pile seawall was constructed to maintain the modified shape of the island. Degradation of the seawall created entrapment hazards for seals and other wildlife. Erosion of the sea wall also raised concerns about the potential release of toxic wastes into the ocean. The USFWS began construction on the Tern Island sea wall in 2004 to reduce entrapment hazards and protect the island shoreline. Vessel groundings pose a continuing threat to monk seals and their habitat, through potential physical damage to reefs, oil spills, and release of debris into habitats.

Monk seal abundance is likely increasing in the main Hawaiian Islands (Baker et al. in review). Further, the excellent condition of pups weaned on these islands suggests that there may be ample prey resources available, perhaps in part due to fishing pressure that has reduced monk seal competition with large fish predators (sharks and jacks) (Baker and Johanos 2004). If the monk seal population continues to expand in the MHI, it may bode well for the species' recovery and long-term persistence. In contrast, there are many challenges that may limit the potential for growth in this region. The human population in the MHI is approximately 1.2 million compared to fewer than 100 in the NWHI, so that the potential impact of disturbance in the MHI is great. Also, the same fishing pressure that may have reduced the monk seal's competitors, is a source of injury and mortality. Finally, vessel traffic in the populated islands carries the potential for collision with seals and impacts from oil spills. Thus, issues surrounding monk seals in the main Hawaiian Islands will likely become an increasing focus for management and recovery of this species.

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