Revised 12/31/2015

HAWAIIAN MONK SEAL (*Neomonachus schauinslandi*)

STOCK DEFINITION AND GEOGRAPHIC RANGE

Hawaiian monk seals are distributed throughout the Northwestern Hawaiian Islands (NWHI), with subpopulations at French Frigate Shoals, Laysan Island, Lisianski Island, Pearl and Hermes Reef, Midway Atoll, Kure Atoll, and Necker and Nihoa Islands. They also occur throughout the main Hawaiian Islands (MHI). Genetic variation among monk seals is extremely low and may reflect a long-term history at low population levels and more recent human influences (Kretzmann *et al*. 1997, 2001, Schultz *et al*. 2009). Though monk seal subpopulations often exhibit asynchronous variation in demographic parameters (such as abundance trends and survival rates), they are connected by animal movement throughout the species' range (Johanos *et al*. 2013). Genetic analysis (Schultz *et al*. 2011) indicates the species is a single panmictic population. The Hawaiian monk seal is therefore considered a single stock. Scheel et al. (2014) established a new genus, *Neomonachus*, comprising the Caribbean and Hawaiian monk seals, based upon molecular and skull morphology evidence.

POPULATION SIZE

The best estimate of the total population size is 1,112. This estimate is the sum of estimated abundance at the six main Northwestern Hawaiian Islands subpopulations, an extrapolation of counts at Necker and Nihoa Islands, and an estimate of minimum abundance in the main Hawaiian Islands. In 2013, for the second consecutive year, NWHI field camps were shorter in duration relative to historic field effort levels. The low effort at some sites certainly resulted in negatively-biased abundance estimates and a degradation of the long-term monk seal demographic database. The number of individual seals identified is used as the population estimate at NWHI sites where total enumeration is achieved, according to the criteria established by Baker *et al*. (2006). Where total enumeration is not achieved, capture-recapture estimates from Program CAPTURE are used (Baker 2004; Otis *et al*. 1978, Rexstad & Burnham 1991, White *et al*. 1982). When no reliable estimator is obtainable in Program CAPTURE (i.e., the model selection criterion is < 0.75, following Otis *et al*. 1978), the total number of seals identified is the best available estimate. Sometimes capture-recapture estimates are less than the known minimum abundance (Baker 2004), and in these cases, the total number of seals actually identified is used. In 2013, total enumeration was not achieved for any subpopulation, and capture-recapture estimates were either not obtainable or were lower than known minimum abundance. Consequently, only minimum abundance was available for French Frigate Shoals, Laysan Island, Lisianski Island, Pearl and Hermes Reef, Midway Atoll and Kure Atoll. Abundance at these six NWHI subpopulations was estimated to be 781 (including 104 pups). Counts at Necker and Nihoa Islands are conducted from zero to a few times per 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 2009 and 2013 was 15.9 ± 5.6 at Necker Island and 32.3 ± 5.7 at Nihoa Island. The relationship between mean counts and total abundance at the reproductive sites indicates that total abundance can be estimated by multiplying the mean count by a correction factor of 2.89. Resulting estimates (plus the average number of pups known to have been born during - 2009-2013) are 50.0 ± 16.2 at Necker Island and 102.1 ± 16.5 at Nihoa Island.

Complete, systematic surveys for monk seals in the MHI were conducted in 2000 and 2001 (Baker and Johanos 2004). NMFS continues to collect information on seal sightings reported by a variety of sources, including a volunteer network, the public, and directed NMFS observation effort. The total number of individually identifiable seals documented in 2013 was 179, the current best minimum abundance estimate for the MHI.

Minimum Population Estimate

The total number of seals (781) 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 38.3 and 89.3, respectively. The minimum abundance estimate for the MHI in 2013 is 179 seals. The minimum population size for the entire species is the sum of these estimates, or 1,088 seals.

Current Population Trend

The total stock population trend cannot be assessed currently, because logistical factors vary such that total abundance estimates are not being obtained throughout the species' range. For example, total abundance is estimated at the six most-studied NWHI subpopulations. However, rare visits to Necker and Nihoa Islands do not allow for

either total population enumeration nor capture-recapture estimates. Only a minimum abundance tally is available for the MHI, and this is suspected to be negatively-biased because very little data are available from Ni'ihau, the single island where the largest concentration of seals likely occurs.

The following describes trends within different portions of the monk seal's range. The trend in total abundance at the six most-studied NWHI subpopulations estimated with a log-linear regression of estimated abundance on year for the past 10 years (2004-2013) yields a decline of -3.4% yr^{-1} (95% CI = -4.3% to -2.4% yr^{-1}). Sporadic beach counts at Necker and Nihoa Islands suggest either stability or some positive growth over the past decade. The MHI monk seal population appears to be increasing with an intrinsic population growth rate (λ) estimated at 6.5% per year based on simulation modeling (Baker *et al*. 2011). However, the realized growth rate may differ considerably from λ, depending upon the unknown current age and sex structure. While these sites have historically comprised a small fraction of the total species abundance, the decline of the six main NWHI subpopulations, coupled with apparent growth at Nihoa and the MHI may mean that these latter three sites now substantially influence the total abundance trend. The MHI, Necker and Nihoa Islands estimates, uncertain as they are, comprised 30% of the stock's estimated total abundance in 2013. NMFS is developing a method for estimating total abundance (and its uncertainty) at Necker and Nihoa Islands using beach counts. Efforts to obtain regular, high-quality data on Ni'ihau are ongoing.

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% annually 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.

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, on average, declined 3.4% a year since 2004 at the six most-studied NWHI, which comprise some 70% of total abundance. 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 20th century (Rice 1960), most subpopulations again declined. This second decline has not been fully explained, but long-term trends at several sites appear to have been driven both by variable oceanic productivity (represented by the Pacific Decadal Oscillation) and by human disturbance (Baker *et al*. 2012, 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. Intentional killing of seals in the MHI is a relatively new and alarming issue (Table 1).

It is extremely unlikely that all carcasses of intentionally killed monk seals are discovered and reported. Studies of the recovery rates of carcasses for other marine mammal species have shown that the probability of detecting and documenting most deaths (whether from human or natural causes) is quite low (Peltier *et al*. 2012; Williams *et al*. 2011; Perrin *et al*. 2011; Punt and Wade 2010).

Table 1. Intentional and potentially intentional killings of Hawaiian monk seals in the MHI since 2009. No such killings were observed in 2013.

Year	Age/sex	Island	Cause of Death	Comments
2009	Subadult male	Kauai	Gunshot wound	
	Adult female	Kauai	Gunshot wound	Pregnant
	Adult male	Molokai	Gunshot wound	
2010	Juvenile female	Kauai	Multiple skull fractures, blunt force trauma	Intent unconfirmed
2011	Adult male	Molokai	Skull fracture, blunt force trauma	Intent unconfirmed
	Juvenile female	Molokai	Skull fracture, blunt force trauma	Intent unconfirmed
2012	Juvenile male	Kauai	Gunshot wound	
	Subadult male	Kauai	Skull fracture	Intent unconfirmed

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. Fishery interactions are a serious concern in the MHI, especially involving nearshore fisheries managed by the State of Hawaii. In 2013, 14 seals were observed hooked, all of which either were captured and had the hooks removed, or the hooks detached without intervention. One juvenile female seal was observed with a fishing spear embedded in the skin and fat of her forehead. The seal was captured and the spear removed. These hookings and the spearing case were all classified as non-serious injuries, although 7 of these would have been deemed serious had they not been mitigated by human intervention. Several incidents involved hooks used to catch ulua (jacks, *Caranx* spp.). Nearshore gillnets became a more common source of mortality in the 2000s, with three seals confirmed dead in these gillnets (2006, 2007, and 2010), and one additional seal in 2010 may have also died in similar circumstances but the carcass was not recovered. No gillnet-related mortality or injuries have been documented since 2010. Most reported hookings and gillnet entanglements have occurred since 2000. The MHI monk seal population appears to have been increasing in abundance during this period (Baker *et al*. 2011). No mortality or serious injuries have been attributed to the MHI bottomfish handline fishery (Table 1). Published studies on monk seal prey selection based upon scat/spew analysis and video from seal-mounted cameras revealed 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). Quantitative fatty acid signature analysis (QFASA) results support previous studies illustrating that monk seals consume a wide range of species (Iverson *et al*. 2011). 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 individual seals. These results highlight the need to better understand potential ecological interactions with the MHI bottomfish handline fishery.

There are no fisheries operating in or near the NWHI. In the past, interactions between the Hawaii-based domestic pelagic longline fishery and monk seals were documented (Nitta and Henderson 1993). 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 the swordfish or tuna components of the longline fishery have been observed.

Fishery Mortality Rate

Total fishery mortality and serious injury is not considered to be insignificant and approaching a rate of zero. Monk seals are being hooked and entangled in the MHI at a rate that has not been reliably assessed but is certainly greater than zero. The information above represents only reported direct interactions, and without directed 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 sources outside of Hawaii), 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 a topic of ongoing investigation.

Table 2. Summary of mortality, serious and non-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[1]	Observed/Reported Mortality/Serious Injury	Estimated Mortality/ Serious Injury	Non-serious (Mitigated serious)[2]	Mean Takes (CV)
Pelagic Longline	2009 2010 2011 2012 2013	observer observer observer observer observer	20.6% & 100% 21.1% & 100% 20.3% & 100% 20.4% & 100% 20.4% & 100%	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 (0)
MHI Bottomfish[3]	2009 2010 2011 2012 2013	Incidental observations of seals	none	0 0 0 0 0	n/a	0 0 0 0 0	n/a
Nearshore[4]	2009 2010 2011 2012 2013	Incidental observations of seals	none	0 1 0 4 0	n/a	12(3) 11(2) 9 (3) 12 (5) 15 (6)	≥1.0
Minimum total annual takes							≥ 1.0

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 339 cases of seals entangled in fishing gear or other debris have been observed from 1982 to 2013 (Henderson 2001; NMFS, unpubl. data). Nine documented deaths resulted 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%, respectively, 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), despite the fact that 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 seals are disentangled 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, Dameron *et al*. 2007).

Other Mortality

In the past 10 years (2004-2013) two monk seals died during enhancement activities (in 2005 and 2006) and one died during research in 2007 (NMFS unpubl. data).

Sources of mortality that impede recovery include food limitation (see Habitat Issues), single and multiple-

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

[2] Total non-serious injuries documented. In parentheses, number of injuries that would have been deemed serious had they not been mitigated (e.g., by de-hooking or disentangling.

[3] Data for MHI bottomfish and nearshore fisheries are based upon incidental observations (i.e., hooked seals and those entangled in active gear). 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.

[4] Includes seals entangled/drowned in nearshore gillnets and hooked/entangled in hook-and-line gear, recognizing that it is not possible to determine whether the nets or hook-and-line gear involved were being used for commercial purposes.

male intra-species aggression (mobbing), shark predation, and disease/parasitism. Male seal aggression has caused episodes of mortality and injury. Past interventions to remove aggressive males greatly mitigated, but have not eliminated, this source of mortality (Johanos *et al*. 2010). Galapagos shark predation on monk seal pups has been a chronic and significant source of mortality at French Frigate Shoals since the late 1990s, despite mitigation efforts by NMFS (Gobush 2010). Infectious disease effects on monk seal demographic trends are low relative to other stressors. However, land-to-sea transfer of pathogens has been increasingly evident since the early 2000's: six monk seal mortalities have been directly caused by toxoplasmosis, a protozoal parasite that is shed in the feces of cats. Furthermore, the consequences of a disease outbreak introduced from livestock, feral animals, pets or other carrier wildlife may be catastrophic to the immunologically naïve monk seal population. Key disease threats include West Nile virus, morbillivirus and influenza.

Habitat Issues

Poor juvenile survival rates and variability in the relationship between weaning size and survival suggest that prey availability is limiting recovery of NWHI monk seals (Baker and Thompson 2007, Baker *et al*. 2007, Baker 2008). Multiple strategies for improving juvenile survival, including translocation and captive care are being implemented (Baker and Littnan 2008, Baker *et al*. 2013, Norris 2013). NMFS has produced a draft Programmatic Environmental Impact Statement on current and future anticipated research and enhancement activities[1]. 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 *et al*. 2006, Reynolds *et al*. 2012).

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). Cahoon (2011) and Cahoon *et al*. (2013) described diet and foraging behavior of MHI monk seals, and found no striking difference in prey selection between the NWHI and MHI.

Remains of the seawall at Tern Island, French Frigate Shoals, is an entrapment hazard for seals. 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 increasing in the main Hawaiian Islands (Baker *et al*. 2011). Further, the excellent condition of pups weaned on these islands suggests that there are 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 1.4 million compared to fewer than 100 in the NWHI, so that the potential impact of disturbance in the MHI is great. Intentional killing of seals (noted above) is a very serious concern. 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. The causes of two recent non-serious injuries (in 2010 and 2011) to seals were attributed to boat propellers. Thus, issues surrounding monk seals in the main Hawaiian Islands will likely become an increasing focus for management and recovery of this species.

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 optimum sustainable population (OSP) and has not recovered from past declines. Therefore, the Hawaiian monk seal is a strategic stock. Annual human-caused mortality for the most recent 5-year period (2009-2013) was at least 2.6 animals, including fishery-related mortality in nearshore gillnets and hook-and-line gear (>=1/yr, Table 2), shooting-related deaths (>=0.8/yr), and blunt-force trauma deaths of unknown origin (>=0.8/yr, Table 1).

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