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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 1,272, which is the sum of abundance estimates throughout the species' range (Table 1). In 2014, for the third 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 2014, total enumeration was achieved only at Kure Atoll, and capture-recapture estimates were obtained for Laysan Island and Midway Atoll. At French Frigate Shoals, Lisianski Island and Pearl and Hermes Reef, capture-recapture estimates were either not obtainable or were lower than known minimum abundance. Consequently, only minimum abundance was available for those sites. Counts at Necker and Nihoa Islands are conducted from zero to a few times per year. A new method for estimating non-pup abundance uses the empirical distribution of the ratio of beach counts to total population size at other NWHI subpopulations to correct beach counts at Necker and Nihoa Islands. This method is described in a manuscript currently in preparation (Harting *et al*. in prep.) and the resulting estimates are presented in Table 1. Pups are born over the course of many months and have very different haulout patterns compared to older animals. Therefore, pup production at Necker and Nihoa Islands is estimated as the mean of the total pups observed in the past 5 years, excluding counts occurring early in the pupping season when most have yet to be born. There were no counts conducted at Necker Island in 2014, so two beach counts conducted in 2013 were used to estimate abundance (no change in abundance since 2013 assumed). Three counts were conducted at Nihoa Island in 2014.

In the MHI, NMFS collects information on seal sightings reported throughout the year by a variety of sources, including a volunteer network, the public, and directed NMFS observation effort. In recent years, a small number of surveys of Ni'ihau and nearby Lehua Islands have been conducted through a collaboration between NMFS, Ni'ihau residents and the U.S. Navy. Total MHI monk seal abundance is estimated by adding the number of individually identifiable seals documented in 2014 on all MHI other than Ni'ihau and Lehua to an estimate for these latter two islands based on counts expanded by a haulout correction factor. A recent telemetry study (Wilson *et al*., in prep.) found that MHI monk seals (N=23) spent a greater proportion of time ashore than Harting *et al*. (in prep) estimated for NWHI seals. Therefore, the total non-pup estimate for Ni'ihau and Lehua Islands was the total beach count at those sites (less three individual seals already counted at other MHI) divided by the mean proportion of time hauled out in the MHI (Wilson *et al*., in prep). The total pups observed at Ni'ihau and Lehua Islands were added to obtain the total (Table 1).

Table 1. Total and minimum estimated abundance of Hawaiian monk seals by location in 2014. The estimation method is indicated for each site.

	Total			Minimum			
Location	**Non-pups**	**Pups**	**Total**	**Non-pups**	**Pups**	**Total**	**Method**
French Frigate Shoals	136	38	174	136	38	174	Minimum count
Laysan	188	35	223	181	35	216	Capture-recapture
Lisianski	129	11	140	129	11	140	Minimum count
Pearl and Hermes Reef	119	16	135	119	16	135	Minimum count
Midway	55	8	63	53	8	61	Capture-recapture
Kure	62	13	75	62	13	75	Total enumeration
Necker	63	5	68	50	5	55	Haulout correction
Nihoa	110	9	119	87	9	96	Haulout correction
MHI_(without Ni'ihau/ Lehua)	132	15	147	132	15	147	Minimum count
Ni'ihau/Lehua	108	20	128	86	20	106	Haulout correction
Total	*1102*	*170*	***1272***	*1035*	*170*	***1205***	

Minimum Population Estimate

The total numbers of seals identified at the NWHI subpopulations other than Necker and Nihoa, and in the MHI other than Ni'ihau and Lehua, are the best estimates of minimum population size at those sites. Minimum population sizes for Necker and Nihoa Islands are estimated as the lower 20th percentiles of the non-pup abundance distributions generated using the Harting *et al*. (in prep.) haulout correction, plus the pup estimate. The mean proportion of time non-pups spent hauled out in the MHI was 0.370 (sd = 0.089, CV = 0.241) (Wilson *et al*. in prep.). Minimum abundance at Ni'ihau and Lehua Islands were calculated by applying the formula in Wade and Angliss (1997) to the Ni'ihau and Lehua non-pup estimate with a CV of 0.241, plus the observed pup tally. The minimum abundance estimates for each site and for all sites combined (1,205) are presented in Table 1.

Current Population Trend

In past years, the total stock abundance was not adequately assessed. However, in 2014, a range-wide total abundance estimate was generated using new methods for correcting beach counts at rarely visited sites (Necker, Nihoa and Ni'ihau/Lehua). Maintaining the commitment to conduct future counts at these latter sites will allow for the eventual estimation of total population trend. The following describes trends within different portions of the monk seal's range. The trend in abundance at the six most-studied NWHI subpopulations estimated with a log-linear regression of estimated abundance on year for the past 10 years (2005- 2014) yields a decline of -2.8% yr^{-1} (95% CI = -3.7% to -1.9% yr^{-1}). This rate of decline has been moderating in recent years. 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. Using life table analysis, Baker *et al*. (2011) estimated an intrinsic population growth rate (λ) of 6.5% per year based on data available through 2008. An updated analysis using MHI monk seal data through 2014 yields an estimated growth rate of 5.2% per year. However, the realized growth rate may differ considerably from λ, depending upon the unknown current age and sex structure. Given the uncertainties in these regional trends, it is not known whether the total stock abundance is decreasing, stable or possibly increasing. A reliable conclusion regarding population trend will only be apparent after more annual range-wide abundance estimates have accrued.

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

Using current minimum population size (1,205), R_{max} (0.07) and a recovery factor (F_r) for ESA endangered stocks (0.1), would yield a Potential Biological Removal (PBR) of 4.2. However, 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 undergone a prolonged decline in abundance. Thus, past reports have concluded that the stock's dynamics do not conform to the underlying model for calculating PBR such that PBR for the Hawaiian monk seal has been undetermined. Given what appears to be an easing of the decline in the NWHI and continued growth in the MHI, this situation may have changed. If future monitoring reveals that the population is exhibiting positive growth, a valid PBR could be determined.

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 2).

Table 2. Intentional and potentially intentional killings of MHI monk seals, and anthropogenic mortalities not associated with fishing gear since 2010.

Year	Age/sex	Island	Cause of Death	Comments
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
2014	Adult male	Oahu	Suspected trauma	Intent unconfirmed
	Pup female	Kauai	Skull fracture, blunt force trauma	Likely intentional
	Pup male	Kauai	Dog attack/bite wounds	4 other seals injured during this event

In July 2014, single or multiple dogs on Kauai attacked and injured at least five monk seals, one of which, a nursing pup, died from its wounds. The other four injured seals all recovered, one of which was a female nursing pup that required subsequent treatment for a bite-caused abscess. Four months later this same pup was killed on Kauai when its skull was crushed, likely by a human using a rock that was found nearby. An adult male on Oahu also died from what appeared to be trauma in 2014, but the carcass was too decomposed to draw conclusions about the cause of death. 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).

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 2014, 14 seal hookings were documented, 13 of which either were captured and had the hooks removed,

or the hooks detached without intervention. A yearling male seal was found dead as result of hooking and the necropsy revealed that a 'J' hook had perforated the esophagus and part of one lung, causing pneumothorax and acute death. The remaining 13 hookings were all classified as non-serious injuries, although 9 of these would have been deemed serious had they not been mitigated. 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 (NMFS unpubl. data). 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 3). 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.

Table 3. 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. Percent observer coverage for the deep and shallow-set components, respectively, of the pelagic longline fishery, are shown. Total non-serious injuries are presented as well as, in parentheses, the number of those injuries that would have been deemed serious had they not been mitigated (*e.g.*, by de-hooking or disentangling). 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. Nearshore fisheries injuries and mortalities include 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.

Fishery Name	Year	Data Type	% Obs. coverage	Observed/Reported Mortality/Serious Injury	Estimated Mortality/ Serious Injury	Non-serious (Mitigated serious)	Mean Takes (CV)
Pelagic Longline	2010 2011 2012 2013 2014	observer observer observer observer observer	21.1% & 100% 20.3% & 100% 20.4% & 100% 20.4% & 100% 20.8% & 100%	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 (0)
MHI Bottomfish	2010 2011 2012 2013 2014	Incidental observations of seals	none	0 0 0 0 0	n/a	0 0 0 0 0	n/a
Nearshore	2010 2011 2012 2013 2014	Incidental observations of seals	none	1 0 4 0 1	n/a	11(2) 9 (3) 12 (5) 15 (6) 14 (9)	≥ 1.2
Minimum total annual takes							≥ 1.2

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 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 are 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.

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 347 cases of monk seals entangled in fishing gear or other debris have been observed from 1982 to 2014 (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-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 through 2014, six monk seal mortalities have been directly caused by protozoal infections, most often by *Toxoplasma gondii*, 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). A testament to the effectiveness of past actions to improve survival, Harting *et al.* (2014) demonstrated that approximately one-third of the monk seal population alive in 2012 was made up of seals that either had been intervened with to mitigate life-threatening situations, or were descendants of such seals. In 2014, NMFS produced a final Programmatic Environmental Impact Statement (PEIS) on current and future anticipated research and enhancement activities, and issued a permit

covering the activities described in the PEIS preferred alternative (http://www.nmfs.noaa.gov/pr/permits/eis/hawaiianmonksealeis.htm). A major habitat issue involves loss of terrestrial habitat at French Frigate Shoals, where some 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 ample prey resource availability, 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 and as endangered under the Endangered Species Act. The species is well below its optimum sustainable population 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 (2010-2014) was at least ≥2.8 animals, including fishery-related mortality in nearshore gillnets and hook-and-line gear (≥1.2/yr, Table 3), and intentional killings and other human-caused mortalities (≥1.6/yr, Table 2).

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