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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 1,324 (95% confidence interval 1,263-1,430; CV = 0.03), (Table 1, Baker *et al.* 2016, Johanos 2017a,b,c). In 2015, NWHI field camp durations were longest in duration since 2011, with the exception of Midway Atoll. This allowed for more thorough demographic studies. In 2016, new approaches were developed to estimate Hawaiian monk seal abundance, both range-wide and at individual subpopulations (Baker *et al.* 2016, Harting *et al.* 2017). In brief, methods for abundance estimation vary by site and year depending on the type and quantity of data available. Total enumeration is the favored method, but requires sufficient field presence to convincingly identify all the seals present, which is typically not achieved at most sites (Baker *et al.* 2006). When total enumeration is not possible, capture-recapture estimates (using Program CAPTURE) are conducted (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), total non-pup abundance is estimated using pre-existing information on the relationship between proportion of the population identified and field effort hours expended (referred to as discover curve analysis). At rarely visited sites (Necker, Nihoa, Niihau and Lehua Islands) where data are insufficient to use any of the above methods, beach counts are corrected for the proportion of seals at sea. At all sites, pups are tallied. Finally, site-specific abundance estimates and their uncertainty are combined using Monte Carlo methods to obtain a range-wide abundance estimate distribution. All the above methods are described or referenced in Baker *et al.* (2016) and Harting *et al.* 2017). Note that because some of the abundance estimation methods utilize empirical distributions which are updated as new data accrue, previous years' estimates can change slightly when recalculated using these updated distributions.

In 2015, total enumeration was achieved only at Kure Atoll, and a capture-recapture estimate was obtained for French Frigate Shoals. At Laysan Island, Lisianski Island, Pearl and Hermes Reef, and Midway Atoll abundance estimates were obtained using discovery curve analysis. Counts at Necker and Nihoa Islands are conducted from zero to a few times per year. 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 or 2015, 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 2015.

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 US Navy. Total MHI monk seal abundance is estimated by adding the number of individually identifiable seals documented in 2015 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.* 2017) found that MHI monk seals (N=23) spent a greater proportion of time ashore than Harting *et al.* 2017) 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 individual seals already counted at other MHI) divided by the mean proportion of time hauled out in the MHI (Wilson *et al.* 2017). 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 2015. The estimation method is indicated for each site. Methods used include DC: discovery curve analysis, Enum: total enumeration; CR: capture-recapture; CC: counts corrected for the proportion of seals at sea; Min: minimum tally. Median values are presented. Note that the median range-wide abundance is not equal to the total of the individual sites' medians, because the median of sums may differ from the sum of medians for non-symmetrical distributions.

	Total			**Minimum**			
Location	**Non-pups**	**Pups**	**Total**	**Non-pups**	**Pups**	**Total**	**Method**
French Frigate Shoals	148	45	193	143	45	188	CR
Laysan	209	35	244	208	35	243	DC
Lisianski	133	18	151	133	18	151	DC
Pearl and Hermes Reef	118	27	145	118	27	145	DC
Midway	53	11	64	48	11	59	DC
Kure	78	12	90	78	12	90	Enum
Necker	59	5	64	49	5	54	CC
Nihoa	108	9	117	91	9	100	CC
MHI_(without Ni'ihau/ Lehua)	130	15	145	130	15	145	Min
Ni'ihau/Lehua	81	21	102	65	21	86	CC
Total	*1126*	*198*	***1324***	***1063***	*198*	***1261***	

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, Nihoa, Ni'ihau, and Lehua Islands are estimated as the lower 20^{th} percentiles of the non-pup abundance distributions generated using haulout corrections as described above, plus the pup estimates. The minimum abundance estimates for each site and for all sites combined (1,261) are presented in Table 1.

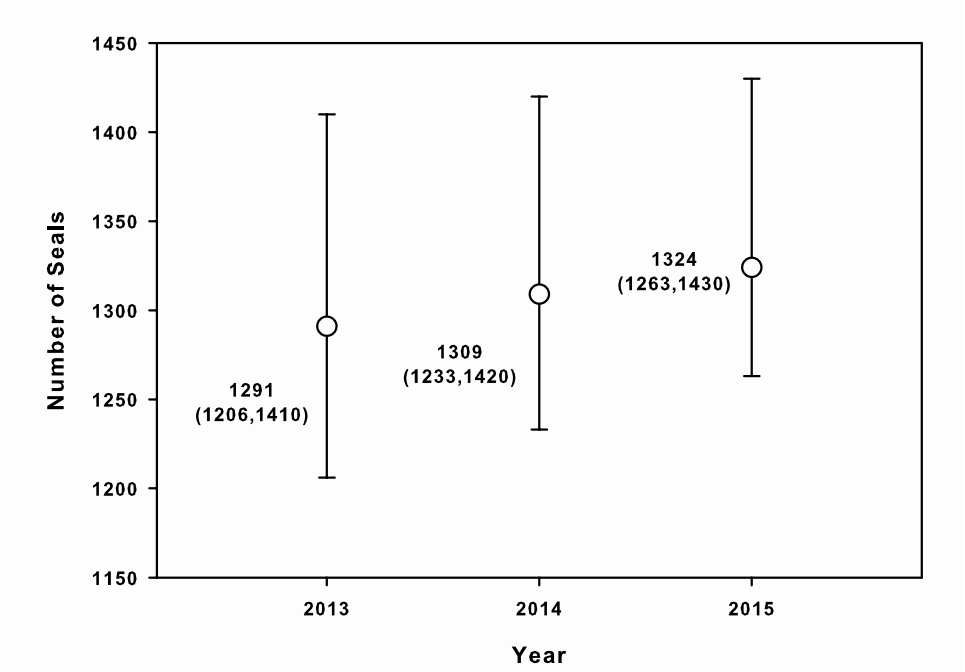
Current Population Trend

Range-wide abundance estimates are available only from 2013 to 2015 (Figure 1). While these estimates remain somewhat negatively-biased for reasons explained in Baker *et al.* (2016), they provided a much more comprehensive assessment of status and trends than has been previously available. The abundance estimates from 2013 to 2015 are encouraging—the point estimate for 2014 is higher than for 2013, and 2015 is even higher. The confidence intervals for all years largely overlap one another. Thus, it is not currently possible to unequivocally conclude whether the current trend is declining, stable, or 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

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 (Johanos 2017a). Consistent with this value, a life table analysis representing a time when the MHI monk seal population was apparently expanding, yielded an estimated intrinsic population growth rate of 1.07 (Baker *et al.* 2011).

Figure 1. Range-wide abundance of Hawaiian monk seals (from Baker *et al.* 2016). Medians and 95% confidence limits are shown.



POTENTIAL BIOLOGICAL REMOVAL

Past reports have concluded that Hawaiian monk seal stock dynamics did not conform to the underlying model for calculating PBR such that PBR for the Hawaiian monk seal has been undetermined. That conclusion was based on the fact that the stock was declining despite being well below OSP (Optimum Sustainable Population level). The trend since 2013 (Figure 1) does not indicate the stock has continued to decline, so that PBR may be determined. Using current minimum population size (1,261), R_{max} (0.07) and a recovery factor (F_r) for ESA endangered stocks (0.1), yields a Potential Biological Removal (PBR) of 4.4.

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 an ongoing and serious concern (Table 2).

Table 2. Intentional and potentially intentional killings of MHI monk seals, and anthropogenic mortalities not associated with fishing gear since 2011 (Johanos 2015d).

Year	Age/sex	Island	Cause of Death	Comments
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
2015	Juvenile male	Kauai	Probable boat strike	
	Adult male	Laysan	Research handling	Accidental, specific cause undetermined

In September 2015, an adult male monk seal died during health assessment research. Nothing was identified in the subsequent necropsy to suggest an underlying health concern that contributed to the seal's death. Histopathology of all major organs identified incidental age-related findings in multiple organs but none that would have predisposed this seal to mortality or contributed to cause of death. Thus, this mortality was deemed solely due to research capture and handling. In the past 10 years (2006-2015) one monk seal died as a result of enhancement activities (in 2006) and two died during research (in 2007 and the adult male described above 2015) (Johanos 2015d).

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 (Gobush *et al.* 2016). There are no fisheries operating in or near the NWHI. In 2015, 11 seal hookings were documented (Henderson 2017a). Among these were two serious injuries and one mortality. The latter was a weaned female pup who ingested a hook. The hook was surgically removed but the pup succumbed to post-surgical complications. The remaining 8 hookings were classified as non-serious injuries, although 2 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 (Henderson 2017a). 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	% Obs.	Observed/Reported	Estimated	Non-serious	Mean

		Type	coverage	Mortality/Serious Injury	Mortality/ Serious Injury	(Mitigated serious)	Takes (CV)
Pelagic Longline	2011 2012 2013 2014 2015	observer observer observer observer observer	20.3% & 100% 20.4% & 100% 20.4% & 100% 20.8% & 100% 20.6% & 100%	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 (0)
MHI Bottomfish	2011 2012 2013 2014 2015	Incidental observations of seals	none	0 0 0 0 0	n/a	0 0 0 0 0	n/a
Nearshore	2011 2012 2013 2014 2015	Incidental observations of seals	none	0 4 0 1 3	n/a	9 (3) 12 (5) 15 (6) 13 (9) 8 (2)	≥1.6
Minimum total annual takes							≥ 1.6

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).

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 361 cases of seals entangled in fishing gear or other debris have been observed from 1982 to 2015 (Henderson 2001; Henderson 2017b). Nine documented deaths resulted from entanglement in marine debris (Henderson 1990, 2001; Henderson 2017b). 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

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 *Toxoplasma gondii*, a protozoal parasite shed in the feces of cats, is of growing concern. A case definition for toxoplasmosis and other protozoal-related mortalities was developed and retrospectively applied to 306 cases of monk seal mortality from 1982-2015 (Barbieri *et al.* 2016). Eight monk seal mortalities (and 1 suspect mortality) have been directly attributed to toxoplasmosis from 2001 to 2015. The number of mortalities from

this pathogen are likely underrepresented, given that more seals disappear each year than are found dead and examined. Furthermore, *T. gondii* can be transmitted vertically from dam to fetus, and failed pregnancies are difficult to detect in wild, free-ranging animals. Unlike threats such as hook ingestion or malnutrition, which can often be mitigated through rehabilitation, options for treating seals with toxoplasmosis are severely restricted. The accumulating number of monk seal deaths from toxoplasmosis in recent years is a growing concern given the increasing geographic overlap between humans, cats, and Hawaiian monk seals in the MHI. 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 has limited 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. 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 juvenile survival rates are favorable in the MHI (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). Yet, 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, such that anthropogenic threats in the MHI are considerable. Intentional killing of seals 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. Vessel traffic in the populated islands includes risk of collision with seals and impacts from oil spills. A mortality in 2015 was deemed most likely due to boat strike. Finally, as noted above, toxoplasmosis is now recognized as a serious anthropogenic threat to seals in the MHI.

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. Therefore, the Hawaiian monk seal is a strategic stock. The species is well below its optimum sustainable population and has not recovered from past declines. Annual human-caused mortality for the most recent 5-year period (2011-2015) was at least 3.4 animals, including fishery-related mortality in nearshore gillnets and hook-and-line gear (>=1.6/yr, Table 3), intentional killings and other human-caused mortalities (>=1.8/yr, Table 2).

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