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HAWAIIAN MONK SEAL (*Monachus schauinslandi*)

STOCK DEFINITION AND GEOGRAPHIC RANGE

Hawaiian monk seals are distributed throughout Hawaii 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). 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 extremely rare, suggesting these may be more appropriately designated as separate stocks. Further evaluation of a separate MHI stock will be pursued following genetic stock structure analysis (currently underway) and additional studies of MHI monk seals. In the mean time, the species is managed as a single stock.

POPULATION SIZE

The best estimate of the total population size is 1,252. This estimate is the sum of counts at the six main Northwest Hawaiian Islands subpopulations, an extrapolation of counts at Necker and Nihoa Islands, and counts at the main Hawaiian Islands. Abundance of the main reproductive subpopulations is currently estimated using the number of seals identified at each site, though efforts to develop improved methods are underway (Baker 2004, Baker et al. in review). Individual seals are identified by flipper-tags and applied bleach-marks, and distinctive natural features such as scars and pelage patterns. In 2003, identification efforts were conducted during two- to six-month studies at all main reproductive sites. A total of 1,100 seals (including 180 pups) were observed at the main reproductive subpopulations in 2003 (Johanos and Baker, in press). The estimated probability that known-aged seals are identified during a given field season average over 90% at French Frigate Shoals, Laysan Island, Midway Atoll and Kure atoll; approximately 85% at Lisianski Island, and approximately 80% at Pearl and Hermes Reef (Harting 2002). These probabilities likely represent the potential extent of negative bias in enumerating the subpopulations.

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 1999-2003 were 16.4 (±6.9) at Necker Island and 17.0 (±7.6) at Nihoa Island (Johanos and Ragen 1999; Johanos and Baker 2000, 2001, 2002, 2004, in press). 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 (±SE) of 2.89 (±0.06, NMFS unpubl. data). Resulting estimates (plus the average number of pups known to have been born during 1999-2003) are 48.5 (± 19.9) at Necker Island and 51.7 (± 22.1) at Nihoa Island.

A 2001 aerial survey determined a minimum abundance of 52 seals in the MHI and remains the most recent available estimate (Baker and Johanos 2004). Seals in the MHI include those naturally occurring and any animals remaining from 21 seals translocated from the NWHI in 1994.

Minimum Population Estimate

The total number of seals identified at the six main NWHI reproductive sites is the best estimate of minimum population size at those sites (i.e., 1,100 seals). Minimum population sizes for Necker and Nihoa Islands (based on the formula provided by Wade and Angliss (1997) are 35 and 37, respectively. The minimum abundance estimate for the main Hawaiian Islands based upon the 2001 aerial survey is 52 seals. The minimum population size for the entire stock (species) is the sum of these estimates, or 1,224 seals.

Current Population Trend

The total of mean non-pup beach counts at the six main reproductive NWHI subpopulations in 2003 is approximately 60% lower than in 1958. A log-linear broken-line regression (two lines joined at a break point) is fitted with the break point chosen to minimize the sum of squares error[1]. This method estimates that the total counts declined 4.2% yr^{-1} until 1993, then declined at 1.9% yr^{-1} thereafter (Fig. 1). The broken line regression fit significantly better than a single regression line (p = 0.05). Thus, current population trend is estimated as -1.9 yr^{-1} (95% CI = -3.0% to –0.9 % yr^{-1}).

[1] (B. Venables, s-news website, http://www.biostat.wustl.edu/mailinglists/s_news/200004/msg00212.html)

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Using mean beach counts as a long-term index of total abundance, the current net productivity rate for this species is –0.019 yr^{-1} (see above). Trends in abundance vary considerably among the six main subpopulations. For example, the decline since the mid-1980's (Fig. 1) was largely due to a severe decline at French Frigate Shoals, where non-pup beach counts decreased by 70% from 1989-2003. Populations at Laysan and Lisianski Islands have remained relatively stable since approximately 1990, though the former has tended to increase slightly while the latter has decreased slowly.

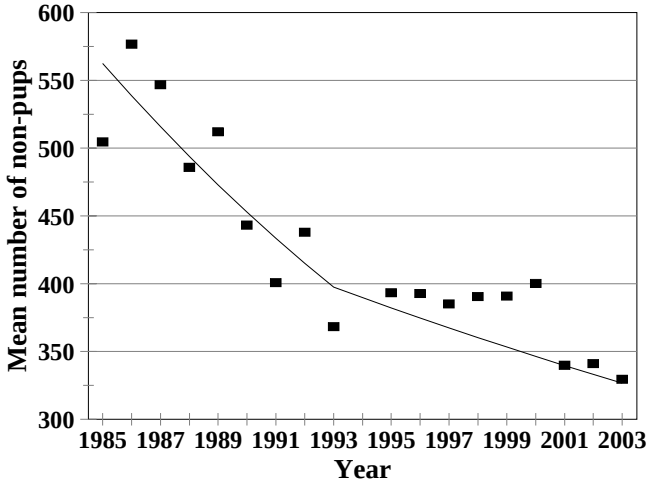

Figure 1. Mean beach counts of Hawaiian monk seals at the six main NWHI subpopulations, 1985-2003.

Until recently, the three westernmost subpopulations, Kure, Midway and Pearl and Hermes Reef exhibited substantial growth. The subpopulation at Kure Atoll grew at an average rate of 5% yr^{-1} from 1983 to 2000 (loglinear regression of beach counts; R^2 = 0.85, p<0.001), due largely to decreased human disturbance and introduced females. However, since 2000, counts at Kure have declined coinciding with very low survival of the 2000-2002 cohorts from weaning to age 1 yr (15% to 22%). The subpopulation at Pearl and Hermes Reef increased after the mid-1970s. The average growth rate from 1983-2000 was 6%yr^{-1} (loglinear regression of beach counts; R^2 = 0.84, P<0.001), and prior to 1999, growth rates of up to 7%yr^{-1} were observed. This is the highest estimate of the maximum net productivity rate (R_{max}) observed for this species. Growth of this subpopulation has slowed recently and early survival has declined. Recovery of the small subpopulation at Midway Atoll appears to have slowed or stopped, also accompanied by relatively poor juvenile survival. These demographic trends at the western end of the NWHI do not bode well for recovery, especially if recent low juvenile survival rates become chronic. While the MHI monk seal population may be on the rise (Baker and Johanos 2004), this remains unconfirmed and abundance appears to be too low to strongly influence current total stock trends.

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 reduced 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 1.9% yr^{-1} on average for the past decade. Thus, for unknown reasons, the stock's dynamics do not conform to the underlying model for calculating PBR. The prescribed PBR calculation for this stock would be the minimum population size (1,224) times one half the maximum net growth rate (½ of 7%) times a recovery factor of 0.1 (for an endangered species, Wade and Angliss 1997), which yields 4.3 monk seals per year. However, given the stock's current status and trend, the intended standard for determining PBR, i.e., recovery to MNPL, will not be achieved in the foreseeable future if a take of 4.3 seals a year is realized. It also appears unlikely that some non-zero level of removal below 4.3 animals could explain the lack of recovery of this stock. Given this unique set of circumstances, 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 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.

Fishery Information

Fishery interactions with monk seals include: operations/gear conflict, seal consumption of discarded fish, 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. Since 1976, four known fishery-related monk seal deaths have included the following (NMFS unpubl. data): one seal drowned in a nearshore gillnet off Kauai (1976), another seal died from entanglement in the bridle rope of lobster trap near Necker Island (1986), another died from entanglement in an illegally set gill net off Oahu (1994), and one ingested a fish hook and likely drowned off Kauai (1995). A total of 31 seals have been observed with embedded fish hooks from 1982 to 2003. The hooks were not always recovered and it was not possible to attribute each hooking event to a specific fishery. Among hooks that could be identified, sources included nearshore fisheries (esp. for *Caranx* sp. in the MHI) in State of Hawaii waters, bottomfish (handline) and longline fisheries in State and Federal waters (NMFS unpubl. data). A recent Biological Opinion summarized hookings and entanglements (NMFS 2002). The majority of these deaths and injuries have been observed incidental to land-based research or other activities. Monk seal/fisheries interactions are not monitored in a manner such that the rate of fisheries-related injury or mortality can be assessed .

Several fisheries have potential to interact with Hawaiian monk seals. The NWHI lobster fishery was closed in 2000 due to uncertainty in the estimates of biomass, and the fishery remains closed to date. 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 the longline fishery have been confirmed. Since 1991, there have been no observed or reported interactions of this fishery with monk seals.

The NWHI bottomfish handline fishery has been reported to interact with monk seals. This fishery occurred at low levels (< 50 t per year) until 1977, steadily increased to 460 metric tons in 1987, then dropped to 284 metric tons in 1988, and varied from 95-201 metric tons per year from 1989-2003 (Kawamoto 1995; Kawamoto, pers. comm.). The number of vessels peaked at 28 in 1987, then varied from 9 to 17 in 1988 through 2003 (Kawamoto 1995; Kawamoto, pers. comm.). 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, though a MMPA Negligible Impact Determination is currently being prepared. An EIS for the bottomfish fishery management plan is also being prepared. 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 with 33% coverage and no monk seal interactions during that quarter. 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, rarely 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, Parrish et al. 2000). Fatty acid signature analysis is incomplete regarding the importance of commercial bottomfish in the monk seal diet, but this methodology continues to be pursued.

There have also been interactions between nearshore fisheries and monk seals in both the NWHI and the MHI. At least three seals were hooked at Kure Atoll before the U.S. Coast Guard vacated the atoll in 1993. In the main Hawaiian Islands (MHI), one seal was found dead in a nearshore (non-recreational) gillnet in 1994 and a second seal was found dead in 1995 with a hook lodged in its esophagus. A total of 20 seals have been observed with embedded hooks in the MHI during 1990-2003. 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 hookings have occurred since 2000, and a seal was entangled in an actively fished nearshore gillnet off Oahu in 2002 (NMFS unpubl. data). The MHI bottomfish handline fishery also has potential to interact with monk seals, though no mortalities or serious injuries have been attributed to the fishery (Table 1).

Episodic interest in the harvest of precious coral in the NWHI represents a potential for future interactions with monk seals, as some seals forage at precious gold coral beds occurring over 500m in depth (Parrish et al.,

2002). As a result, the Western Pacific Regional Fisheries Management Council recommended regulations to suspend or set to zero annual quotas for gold coral harvest at specific locations until data on impacts of such harvests become available.

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 Mortality/ Serious Injury	Estimated Mortality/ Serious Injury	Mean Takes (CV)
NWHI Lobster	1999 2000-present	data collector[1] fishery closed	83%	0	n/a	n/a
Pelagic Longline[2]	1999 2000 2001 2002 2003	observer observer observer observer observer	3.3% 10.4% 22.5% 24.6% 22.2%	0 0 0 0 0	0 0 0 0 0	0 (0)
NWHI Bottomfish	1999-2002 2003[3]	logbook observer	n/a 33%	n/a 0	n/a 0	0 (0)
MHI Bottomfish[4]	1999 2000 2001 2002 2003	n/a	none	0 0 0 0 0	n/a	n/a
Nearshore[4]	1999 2000 2001 2002 2003	n/a	none	0 1 1 1 2	n/a	n/a

Fishery Mortality Rate

Data are unavailable to fully assess interaction with some fisheries in Hawaii, therefore, total fishery mortality and serious injury cannot be considered to be insignificant and approaching a rate of zero. Monk seals also die from entanglement in fishing gear and other debris (likely originating from various countries), and NMFS along with partner agencies, is pursuing a program to mitigate entanglement (see below).

Direct fishery interactions with monk seals remain to be thoroughly evaluated and the information above represents only observed interactions. Without further study, an accurate estimate cannot be determined. Indirect interactions (i.e., involving competition for prey or consumption of discards) remain the 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 238 cases of seals entangled in fishing gear or other debris have been observed through 2003 (Henderson 2001; NMFS, unpubl. data), including seven documented mortalities resulting from entanglement in fisheries 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 Hawaiian 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 there are no commercial trawl fisheries in Hawaii.

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[1] Fishery participants voluntarily hosted technicians to collect biological data, including protected species interactions. Because this was not conducted as an official observer program, mortality and serious injury rates were not estimated.

[2] Until 2000, interactions with protected species were assessed using Federal logbooks and observers (4-5% coverage). Since 2001, the observer program has maintained over 20% coverage of the Hawaii-based longline fleet.

[3] Observer coverage began in fourth quarter of 2003. Data for that quarter provided.

[4] Data for MHI bottomfish and nearshore fishery are based upon incidental observations (i.e., hooked seals). Following the method employed in a draft Negligible Impact Determination for the bottomfish fishery, 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.

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. During 1996-2003 debris survey and removal efforts, over 470,000 kg of derelict net and other debris were removed from the coral reef habitat in the NWHI (Donohue et al. 2000, Donohue et al. 2001; J. Asher, pers. comm).

Other Mortality

Since 1982, 23 seals died during rehabilitation efforts; additionally, two died in captivity, two died when captured for translocation, one was euthanized (an aggressive male known to cause mortality), three died during captive research and three died during field research (Baker and Johanos, 2002).

In 1986, a weaned pup died at East Island, French Frigate Shoals, after becoming entangled in wire left when the U.S. Coast Guard abandoned the island three decades earlier. In 1991, a seal died after becoming trapped behind an eroding seawall on Tern Island, French Frigate Shoals. The only documented case of illegal killing of an Hawaiian monk seal occurred when a resident of Kauai killed an adult female in 1989.

Other sources of mortality that may impede recovery include single and multiple-male aggression (mobbing), shark predation, and disease/parasitism. Multiple-male aggression is thought to be related to an imbalance in adult sex ratios, with males outnumbering females. When several males attempt to mount and mate with an adult female or immature animal of either sex, injury or death of the attacked seal often results. This 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 only five seals are thought to have died from multiple-male aggression at this site since their removal (1995-2003).

Attacks by single adult males have resulted in several monk seal mortalities. This was most notable at French Frigate Shoals in 1997, where at least 8 pups died as a result of adult male aggression. 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 have 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 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 in cooperation with the USFWS, which manages French Frigate Shoals as part of the Hawaiian Islands National Wildlife Refuge.

An Unusual Mortality Event (UME) contingency plan has recently been published for the monk seal (Yochem et al. 2004). 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 main Hawaiian Islands and potentially spread to the core population in the NWHI. Recent diagnoses (R. Braun, pers. comm.) confirm that in 2003 and 2004, two deaths of free-ranging monk seals are attributable to diseases not previously found in the species: leptospirosis and toxoplasmosis. 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

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. The substantial decline at French Frigate Shoals is likely related to lack of available prey and subsequent emaciation and starvation. Two leading hypotheses to explain the lack of prey are 1) the local population reached its carrying capacity in the 1970s and 1980s, diminishing its own food supply, and 2) carrying capacity was simultaneously reduced by changes in oceanographic conditions and a subsequent decline in productivity (Polovina et al. 1994; Craig and Ragen 1999). Similarly, recently observed poor juvenile survival rates suggest that prey availability may be limiting recovery of other NWHI subpopulations.

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 2004*a,b*; Stewart and Yochem 2004 *a,b,c*). Preliminary studies to describe the foraging habitat of monk seals in the MHI were begun in 2004.

Tern Island is the site of a U.S. Fish and Wildlife 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. 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 I. sea wall in 2004 to reduce entrapment hazards and protect the island shoreline. The USFWS considers this a high priority project to complete, and is pursuing funding to that end. A recent review suggests that significant loss of terrestrial habitat has occurred at French Frigate Shoals, where pupping and resting islets have shrunk or virtually disappeared (Antonelis et al. in press). This is a subject of considerable interest and is under further investigation.

There are indications that monk seal abundance is increasing in the main Hawaiian Islands (Baker and Johanos 2004). Further, the excellent condition of pups weaned on these islands suggests that there may be ample prey resources available. If the monk seal population does 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 less than 100 in the NWHI, so that the potential impact of disturbance in the MHI is great. As noted above, the hooking of monk seals by fishermen in the MHI is another 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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