

Attempts to reduce shark predation on Hawaiian monk seal pups:  
A comparative study of two potential mitigation techniques

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## JUSTIFICATION

Although it is thought that the current decline of the Hawaiian monk seal population is due to food limitation for juveniles, shark predation is important to consider because pups are especially susceptible when sharks can reach them in very shallow waters near pupping beaches. This shark predation is a threatening source of mortality, but the magnitude of its effect on the population is not known. (NMFS 2007.)

Pupping beaches are an essential component of monk seal development because pups must learn to swim in shallow water that is free of strong currents, waves, and predators (Gerrodette & Gilmartin 1990). If beaches are especially good habitat for giving birth and raising pups, they are likely to be used by many females and over a long period of time. Females may give birth at the same beach every year (Antonelis et al 2006) and although females can give birth at any time of the year, most births occur in March and April (Johnson & Johnson 1980, cited in Antonelis et al 2006).

Shark predation was attributed to tiger sharks until the late 1990s (Gerrodette & Gilmartin 1990) when Galapagos sharks began to kill approximately 18-28 monk seal pups per year in the French Frigate Shoals (Antonelis et al 2006). Since then, gut analyses of tiger and Galapagos sharks have revealed monk seal remains (NMFS 2007) and it has been estimated that up to 30% of an annual seal pup cohort at one site could be taken by shark predation (Antonelis et al 2006). Although the intense pup predation was first seen at a specific site in French Frigate Shoals (Trig Island), the behavior apparently spread to other sites in French Frigate Shoals, which raises a concern of it being adopted at completely new locations (Antonelis et al 2006). This could potentially affect different subpopulations as well as the monk seal population as a whole.

In other parts of the world, shark control programs have been used primarily for the protection of swimmers. The programs in New South Wales and Queensland (Australia) and South Africa were established in 1937, 1962, and 1952, respectively (Dudley 1997). Despite the lack of rigorous monitoring in their early years, these programs are well-established, providing insight to the process of reducing the threat of large sharks. However, there is a fundamental difference between these shark control programs and the following proposed program. While the programs in Australia and South Africa reduce shark encounters by reducing shark numbers, the proposed mitigation seeks to reduce shark predation by reducing their presence. Rather than eliminating sharks, this mitigation will attempt to deter them from monk seal pupping beaches by testing two mechanisms: modified gillnets and shark-proof enclosures.

Predation rate depends on many different factors (Melvin et al 1999) such as site-specific prey density, site-specific predator abundance, accessibility of prey (water depth, beach exposure, channels to shore), ocean conditions, and the time of day. This mitigation would indirectly affect predator abundance by directly reducing accessibility. A key condition of this mitigation is to have a negligible effect on non-target (i.e. non-shark) species. Ideally, we would also like to minimize the effect on the shark population as well. According to these conditions, the following hypotheses create the foundation of this proposal:

$H_{0(A)}$  = The rate of shark predation is not reliant on their site-specific densities (In other words, mitigation efforts to exclude sharks will not reduce predation and are thus not appropriate.)

$H_A$  = By reducing the density of sharks near pupping beaches by reducing the amount of area that is accessible to the predators, shark predation on monk seal pups is appreciably reduced.

$H_{0(B)}$  = The gillnets and shark-proof enclosures will result in similar reductions of shark predation on monk seal pups.

$H_B$  = Shark-proof enclosures will be more effective at directly reducing predation.

$H_{0(C)}$  = The gillnets and shark-proof enclosures will have similar bycatch rates.

$H_C$  = Gillnets will have greater amounts of bycatch (i.e. seabirds, turtles, fishes, cetaceans, as well as sharks and seals.)

## OBJECTIVES

- Evaluate the current predation rate by sharks on monk seal pups at all beaches that are consistently used by female monk seals for pupping during March and April. This would project a baseline predation rate at a time of year when there is maximum prey (i.e. pup) availability.
- Introduce two possible techniques to reduce pup mortality caused by shark predation: gillnets and shark-proof enclosures. These efforts would directly reduce the physical accessibility of pupping beaches to sharks so there is a direct reduction in the number of sharks around pupping beaches. Ultimately, this can reduce the probability of a monk seal pup being preyed on by a shark while it is in the direct vicinity of its birth spot.

- Determine whether the gillnet or shark-proof enclosure is a more favorable mitigation technique for reducing shark predation on monk seal pups. This comparison will be based on the minimization of pup mortality by shark predation, as well as bycatch and shark mortality.

## METHODS

### *Preliminary investigations*

Six reproductive subpopulations have been identified at Midway Atoll, Kure Atoll, French Frigate Shoals, Pearl and Hermes Reef, Lisianski Island, and Laysan Island (Antonelis et al 2006). The subpopulations will serve as replicate units and each unit will have three sites to incorporate either a gillnet or an enclosure, or to serve as a control. For example, Midway Atoll would host this experiment well because Eastern Island is considered to be suitable for pupping, and several beaches on Spit Island are consistently used for pupping as well (Mangel 2003). While Green Island has been identified in Kure Atoll and Tern Island is important in the French Frigate Shoals (Gerrodette & Gilmartin 1990), multiple pupping beaches must be identified for each subpopulation. Thus, prior to conducting this investigation, key beaches must be identified for Lisianski Island, Laysan Island, Pearl and Hermes Reef, and more beaches should be found at Kure Atoll and Tern Island.

After a sufficient number of sites are identified, a baseline evaluation of monk seal abundance will be carried out in order to determine site-specific numbers. More specifically, this estimate will be of monk seal cohorts (i.e. pups of the year) on the beach during the months of March and April.

Likewise, a site-specific evaluation of shark abundance is necessary in order to scale the results as a percentage of the original values. While sharks may display site fidelity, they do not occupy the beaches like monk seals do, so shark abundance can be evaluated in terms of “sightings” when they occur 10-100m from shore and “encounters” when they occur within 10m of the shore (adapted from Melvin et al 1999). Again, these estimates will be done during the months of March and April.

In order to quantify shark predation and combine data from all the sites, the measure of shark predation should be relative to the site-specific predator abundance as well as the site-specific prey abundance. Although all attempts of predation may not result in complete or immediate mortality, they will all be counted as predation since the attempt posed a potential threat to a pup. Thus, shark predation will be evaluated as the number of attempts per average shark encounter per average pup abundance. A baseline rate of shark predation must be accounted for at each site in order to scale the results as a percentage of the original rate (Dudley 1997).

Lastly, since one of the conditions of this investigation is the avoidance of bycatch, it is necessary to establish baseline estimates of site-specific abundances of fishes, turtles, seabirds, and cetaceans. These estimates will also be done in March and April, and they will be quantified as “sightings” within 100m of the shore at the pupping sites.

Although these baseline measurements will be taken, there will also be a control site (i.e. beach) at each location (i.e. atoll/reef/island) in order to account for broader environmental changes that may occur over the course of the investigation.

### *Experimental Design*

The following experiment utilizing gillnets and shark-proof enclosures will be carried out in the year after the baseline evaluations have been taken. The previously discussed shark control programs (Australia and South Africa) utilized gillnets to remove sharks from the area and as a result, the programs also dealt with high bycatch incidence. After reviewing their designs as well as fisheries bycatch avoidance measures, the following mechanisms are proposed for the experimental gillnet.

- By using subsurface floater lines to keep the top of the net 0.5 m below the water level, turtle bycatch can be minimized since green sea turtles are often caught in the very upper portion of gillnets (Gribble et al 1998).
- Cetacean bycatch could be minimized by using nylon mesh with barium sulphate, which increases the properties of sound reflection and essentially makes the net more detectable and gives cetaceans a greater amount of time and distance to react to it (SMM 2003).
- Nets with dull-colored mesh have greater catch efficiency for sharks and it has been shown that they can detect highly reflective mesh colors (Wallace 1972, cited in Dudley 1997), so in order to repel them and prevent their entanglement, brightly color mesh will be used.

The gillnets will be set parallel to the shoreline and far out enough to allow swimming room for pups and they will be maintained as necessary. Despite these measures to reduce incidental take of bycatch, it is extremely likely that the gillnets will have some

effect on the fauna surrounding the pupping beaches. Therefore, shark-proof enclosures are also being tested in order to evaluate their utility for the situation.

Shark-proof enclosures are distinctly different from gillnets because their mesh size will be much smaller and they will completely surround the pupping site in a semi-circle. As with gillnets, the area they enclose will be determined by the amount of space that the pups need in the water near the pupping beach.

The gillnets and enclosures will be set up with sufficient time for observations to begin in March. Pup, shark, and bycatch abundance will be quantified, as well as predation rates, until the end of April. At the end of the experimental period, the gillnets and enclosures will be removed from the sites.

## RESULTS

Since sites are likely to have different baseline shark abundance, pup density, and thus, rates of predation, the effects of mitigation will be evaluated as the percentage change in predation from the initial baseline rate of each site. It is very likely that the two techniques will both reduce shark predation rates, but it is also likely that the magnitude of their effects will be different. Thus, the experimental results will be compared with the baseline measurements of shark abundance and predation rates. The control data will be incorporated if it is evident that the whole location experienced a change in pup and/or shark abundance, or shark predation rate.

The shark abundance and predation at gillnet and enclosure sites will be compared with the pre-mitigation abundance and predation rates for that same site. The gillnet and enclosure sites' predation rates will also be compared to each other. This is possible

because the predation rates are scaled to account for inherently different shark and pup abundances at each site.

By comparing pre- and post-experimental shark encounter data, we can evaluate whether the two techniques affected the frequency of sharks occurring within 10 m of the shoreline. Likewise, by comparing pre- and post-experimental shark sightings, we can determine whether the effect of the techniques occurred on a larger scale, anywhere from 10 to 100 m from the shoreline. If shark mortality is high in the gillnets, it will be necessary to evaluate the situation from a shark conservation standpoint: is the rate of gillnet mortality exceeding the limit for sustainable mortality?

In other words, we would need to know whether the gillnet mortality can be positively balanced by natural recruitment rates (Hall 1998). This concern is also applicable for other populations of bycatch species and essentially, anything that gets caught in either net. It would be ideal to have some initial understanding of each species' population status so that it is clear for each species what the boundary is between negligible effect and unsustainable removal.

Lastly, the experimental data will be evaluated in terms of the effects on the monk seals. Positive results would be indicated by higher-than-baseline cohort survival at the end of the two-month testing period. This would be a direct result of a reduction in pup mortality due to shark predation.

## CONTRIBUTIONS

Ultimately, this investigation will provide a comparison of two potential techniques by which conservation managers can reduce shark predation on monk seal pups. Gillnets

and shark-proof enclosures will be helpful because monk seal pups will be afforded more safety from sharks while they are developing their swimming skills. Additionally, over a long period of time, the subpopulations or even the whole monk seal population may benefit from greater numbers of juveniles surviving to adulthood and reproductive age.

In comparing the two different techniques, it becomes obvious that there is a cost-benefit balance between the use of gillnets and shark-proof enclosures. The latter are likely to be less detrimental to biological components of the ecosystem because the enclosures could have less bycatch and potentially be more successful in reducing shark predation. However, enclosures are more difficult logistically and they could have a greater effect on the habitat (i.e. small-scale hydrodynamic effect and sand shifting). It will be essential to account for all aspects of how the two mitigation techniques affect the ecosystem, and it will likely be difficult to determine what effects “balance” each other.

Similarly, managers may encounter an issue of species prioritization. This would be more applicable for the gillnet results, since this technique will probably result in more bycatch. Since the results are analyzed as separate effects for monk seals, sharks, and bycatch species, there is an inherent complication that arises (Hall 1998). Managers will have to decide whether the protection of monk seal pups is worth the potential mitigation effects on other components of the ecosystem. The bycatch that are of greatest concern are those species that have inherently slow population growth rates, due to long life-spans and late maturity (Heppell et al 2005). Thus, they will have to determine whether the incidental mortality of  $v$  number of fishes,  $w$  number of cetaceans,  $x$  number of turtles,  $y$  number of seabirds, and  $z$  number of sharks is sustainable and acceptable. It is also likely that they will have to justify these decisions to funders and the general public as well.

Over time, the implementation of either of these mitigation efforts could lead to an increase in early survival rates of monk seal pup cohorts. The results for this proposed investigation will provide information about whether gillnets or shark-proof enclosures are better suited for the mitigation of shark predation, assuming the conditions of minimal net-driven mortality. This investigation will also lend insight for the appropriate scale of the mitigation effort, whether they be gillnets or enclosures; perhaps the mitigation is only necessary for a few months out of the whole year, and perhaps it is only useful at a few breeding sites in different subpopulations.

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