Bycatch: The Effects of Pelagic Longlining on Pacific Sea Turtle Populations

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Each day the world's human population expands to record size. The ultimate apex predator, humans have put pressure on nearly every ecosystem in the world to provide food and other resources. That pressure not only affects the species that is being hunted, but can sometimes have unintentional effects on other species. In fishing, this type of accidental interaction with non-target species is called "incidental take," with the non-target species becoming "bycatch."

Many populations of marine animals have been negatively impacted as a result of fishing practices which incur large amounts of bycatch. Generally, bycatch species are not of economic value and therefore bycatch incidents have been largely ignored and under reported. However, studies of threatened and endangered marine vertebrates have shown that many already at-risk species face an even greater decrease in survival rates due to incidental take from fisheries (DeFlorio et al. 2005).

One such fishery, pelagic longlining, is responsible for hundreds of thousands of tons of bycatch every year (Lewison et al. 2004b). Longlines target commercially valuable pelagic fish using heavy duty monofilament. A surface longline will have a mainline suspended by floats with weighted vertical lines attached which have baited hooks hung at regular intervals. Longlines can stretch for tens of kilometers (several miles) and are suspended at different depths depending on the location and type of fish being targeted (Deflorio et al. 2005). In the Pacific Ocean, longliners primarily target two species: bigeye tuna (*Thunnus obesus*) and swordfish (*Xiphius gladius*). However, non-target animals accidentally caught on longlines are extensive and include dolphins, whales, seabirds, sharks, and sea turtles, among others (Lewison et al. 2004a).

Such interactions can have potentially devastating effects on species like sea turtles. Of the seven species of sea turtles found in our oceans today, all are considered threatened or endangered, with six listed on the IUCN redlist of endangered species. Two species, the loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) have been identified as being at particular risk of population decline as a result of incidental take by longline pelagic fisheries (Lewison et al. 2004b). In fact, incidental catch by fisheries is considered to be one of the most important causes of anthropogenic mortality for sea turtles (DeFlorio et al 2005).

As with many other marine megafauna, the life history characteristics of sea turtles make their populations particularly vulnerable to collapse. Turtles have a long lifespan and take years to reach sexual maturity. There is a very high rate of mortality among young offspring, and population stability requires a high survival rate for those few individuals which do reach adulthood. Therefore, turtles suffer significant population decline when adult and sub-adult age classes endure higher-than-average mortality: the loss of even a few individuals can have significant effects (Lewison et al. 2004a). Longlines are documented to cause selective mortality among these older age classes in sea turtles (Lewison et al. 2004b).

Like turtles, longliners are found in every ocean in the world. With the banning of high seas driftnets by the United Nations in 1991, many industrialized fisheries turned their efforts to longlining. Boats from 40 nations set approximately 3.8 million hooks on 100,000 miles of longline every day, with more than half of that fishing effort concentrated in the Pacific. In the year 2000, conservative estimates put numbers of global bycatch for loggerheads at over 200,000 and for the critically endangered leatherback at 50,000. Nesting populations of Pacific leatherbacks have experienced a 95% decline in just two decades (Lewison et al. 2004b), leading scientists to speculate that the Pacific leatherback faces imminent extinction in the next ten years (James et al. 2005). Loggerhead turtles showed over an 80% population decline in the same period (Lewison et al. 2004b).

Although these numbers seem to indicate a correlation between longlining and population decline, the actual effects of longlining are difficult to quantify. When analyzing the effects of fisheries bycatch, two things are crucial: determine how many individuals are being removed from the population,

and then determine the effects of this removal (Lewison et. al. 2004a). Data to accurately answer these questions in many cases is simply unavailable. Although the existence of bycatch is acknowledged for all fisheries, the extent and magnitude is sporadically recorded. The most reliable data on bycatch numbers comes from onboard observers (Lewison et al. 2004b). However, out of 40 nations with active longlining fisheries, only 15 have an onboard observer program and of those, only a small percentage of trips are actually required to have an observer onboard (Lewison et al. 2004a). Logbooks kept by ship's crew commonly under-report bycatch, and in most cases there is no reporting at all. In addition, much longline fishing is illegal and even the fishing itself is unreported (Lewison et al. 2004b), making extrapolating data to draw conclusions an even more difficult task.

In addition, relatively little is known about the behavior of sea turtles while in their pelagic habitat. As adults, turtles will often find foraging grounds near land masses, and adult female turtles will travel thousands of miles to the beaches where they were born to lay their eggs. Hatchlings emerge several months later and enter the sea on their own. However, during the years in between hatchling and adulthood, which vary depending on the turtle species, the turtles "disappear" and their habits are virtually unknown.

This lack of comprehensive knowledge has hampered conservation efforts to save the sea turtles (Lewison et al. 2004a, James et al. 2005). Recent studies have focused on strengthening scientific data in these areas. For instance, turtle biologists have long hypothesized that juvenile turtles spend much of their developmental years associating with oceanic fronts. In the Pacific, these fronts occur when warmer water from a subtropical ocean gyre meets cold water from a subartic ocean gyre, causing a weak downwelling. These fronts are characterized by rich chlorophyll density caused by the abundance of phytoplankton in the cold water. Predators are attracted to the rich convergence of the phytoplankton, and a complete pelagic food web develops at these sites. Jellyfish, such as the wind sailor, *Vellela vellela*, are among the first predators, and also among the staple foods of loggerhead turtles (Polovina et al. 2000) and leatherbacks (Lewison et al. 2004b), giving rise to the theory that oceanic fronts can provided an abundance of resources for turtles in their pelagic stages.

Studies support this theory. Stomach analyses of 55 juvenile and sub-adult loggerheads drowned in driftnets in 1993 showed that all of the prey consumed by the turtles were species found at these convergent fronts (Polovina et al. 2000), one indication that the juvenile turtles are feeding at those sites. More recent advances in technology have allowed researchers to track turtles in the wide open ocean using satellite transponders. Studies that tracked loggerhead turtles and olive ridley turtles for months at a time in the Pacific confirmed that those species did in fact migrate along ocean fronts (Polovina et al. 2000). A single loggerhead tracked in 2001 spent over three months following the edge of an oceanic front (Polovina et al. 2004).

Determining the nature of the turtle's pelagic habitat can be crucial in finding ways to limit turtle interactions with longlines. For instance, satellite tracking studies that recorded the depths of turtles' dives found that loggerheads spent 90% of their time at depths of less than 40m (Polovina et al. 2004). This would explain why although fishing effort for tuna in the Pacific is up to six times greater than fishing effort for swordfish, swordfish longliners have bycatch ten times that of tuna (Lewison et al. 2004b). The longlines for tuna are known as "deep-set" because they are weighted to depths below 100m, while the swordfish lines are "shallow-set" at less than 100m (Polovina et al. 2004), where turtles are much more likely to encounter them.

Another factor that needs to be considered is *how* the turtles are interacting with the longlines. A study of loggerheads in the Ionian Sea showed that of 200 turtles caught in longlines, 87% were hooked, while 13% were entangled (Deflorio et al. 2005). This is a definite indication that the bait is a primary attractant for the turtle, and that the turtles were caught when trying to feed. However, this did not hold true for all species or all areas. A study of leatherbacks off the Atlantic Coast of Canada found that 95% of those turtles caught by fixed gear longlines (a specific type of longline set in shallower coastal waters and attached to the bottom) were entangled, not hooked. A fifth of these turtles drowned (James et al. 2005). These are important distinctions to make when discussing conservation efforts as type of interaction can have major implications: snared or hooked turtles may be discovered before they drown and released, but often with hooks embedded deeply in their mouth or digestive system, or with fishing line entangling a limb which may become severed. The implications of these post-hooking scenarios are simply not known (James et al. 2005).

U.S. based fisheries are monitored by the National Marine Fisheries Service (NMFS), a division of the National Oceanic and Atmospheric Administration (NOAA). In 2001, the Hawaiian based longline fishery was ordered closed, based on data collected

by the NMFS that showed that the incidental take of endangered species by pelagic longliners exceeded that allowed by the Endangered Species Act (NMFS Report on Technical Gear Workshop, 2001).

Although several studies cited pelagic longline fishing as the number one threat to leatherbacks in the Pacific (James et al. 2005, Lewison et al. 2004b), the longline fishery was reopened in Northern Hawaiian waters in 2004. The fisheries management authority, NMFS, initiated new restrictions and guidelines intended to reduce bycatch of turtles and other species. One of these new guidelines included requiring trained observers on 100% of the swordfish longliners and 25% of the tuna longliners, to carefully monitor bycatch. Another requirement was that swordfish longlines use only the newly developed circle hooks, rather than the traditional "J" style hooks (NMFS Small Entity Compliance Guide, 2004).

Some scientists question the re-opening of the fisheries. Few studies on the effect of the circle hook on bycatch have been completed. One study conducted in longline fisheries around the Azores found there was no significant difference in the number of turtles caught by each hook type. The circle hooks were more likely to embed in the mouths of the turtles rather than the throat, which may help reduce mortality after hooking (NMFS Report on Technical Gear Workshop, 2001). However, because of the lack of data regarding post-hooking recovery and behavior, it is unknown if these hooks can be considered an effective conservation tool.

Although many studies indicate that a moratorium on pelagic longlining is the only measure which could produce significant results in halting declines of sea turtle populations (James et al. 2005), this seems unlikely. Pelagic longlining accounts for 85% of the world's swordfish and 60% of the bigeye and albacore tunas and the high consumer demand cannot be met by other fishing methods (Lewison et al. 2004b).

Conservation efforts instead are focusing on ways to reduce turtle interactions with longlines. One of the satellite tracking studies showed that juvenile loggerheads foraging in the Pacific traveled most frequently along fronts with a sea surface temperature (SST) of 17°C, and secondarily along fronts with SST of 20°C. Further research found a correlation between sea surface temperatures at these levels and high incidence of accidental take with turtles. Based on these results, the study concluded that requiring longliners to cease fishing efforts when surface temperature approaches these limits may help reduce incidental take of sea turtles in the Pacific (Polovina et al. 2000). Another study involved dying squid, a commonly used bait. Researchers found that green turtles (*Chelonia mydas*) virtually ignored the bait when it was dyed blue, although the target fish showed no difference in preference. Studies to test this theory on loggerheads are underway (NMFS Report on Technical Gear, 2004). Such studies may lead to a better outlook for the turtles.

Still, efforts made solely by the United States to reduce bycatch in only U.S. based fisheries may not have a very large overall impact, as the problem simply cannot be addressed by regional or national efforts (James et al 2005). In fact, U.S. based fisheries account for less than 3% of all pelagic longlining in the Pacific (NMFS Report on Technical Gear Workshop, 2001). Japan and Taiwan together are responsible for more than half the Pacific longline fishing effort, while no other nation claims more than 7% (Lewison et al. 2004b). Because turtles travel across oceans, through the waters and onto the shores of many different countries, a truly international conservation effort would be required to have lasting consequences. Scientists are pushing the U.S. to take a leading role in conservation efforts here, then encourage other countries to do the same. The United Nations has been presented with reports calling for international regulation of longlining, as with the high seas driftnets.

As loggerhead and leatherback populations continue to decline in the Pacific, it remains to be seen what effects the loss of these links in the food web may cause to marine ecosystems. Studies to improve scientific knowledge of the turtles' life cycles, to find alternative technology for fishing, and to reduce turtle interactions with longlines are underway. With nesting beaches being destroyed, new diseases plaguing sea turtles, and pressure from fisheries, much remains to be done to ensure the future of sea turtles in our oceans.

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