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Developments (2006-2007) in scientific research on the use of modified fishing gear to reduce longline bycatch of sea turtles

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Developments (2006-2007) in scientific research on the use of modified fishing gear to reduce longline bycatch of sea turtles[2]

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A synthesis of findings from studies in numerous fisheries suggests the following general conclusions with respect to reducing sea turtle bycatch and injury on longline gear:

1) Replacing J hooks and tuna hooks with circle hooks reduces the deep ingestion of hooks by sea turtle species that tend to bite baited hooks (e.g. hard shell sea turtles).
2) In fisheries with bycatch of large (45-65 cm carapace length) loggerhead turtles (*Caretta caretta*) or leatherback turtles (*Dermochelys coriacea*), using large sizes of circle hooks (i.e., wider than 4.9 cm minimum width, e.g. size "18/0") can substantially reduce the bycatch of both species. It appears that larger hook size reduces capture rates of turtles that bite baited hooks (hard shell turtles), and that circle hook shape helps prevent turtles that seldom bite (e.g. leatherbacks) from getting snagged and subsequently entangled.
3) In fisheries with bycatch of smaller turtles, using smaller sizes (e.g. size "16/0") of circle hooks can reduce capture rates of sea turtles when the circle hooks replace other hook styles with smaller widths. Circle hooks tend to be much wider than other hook styles with similar length and gape.
4) Another way to successfully reduce capture rates of sea turtles while continuing to use a relatively small hook is to increase the effective width of the hook by adding a wire appendage.
5) Using fish for bait instead if squid can reduce bycatch of both leatherback and hard shell sea turtles. Use of fish instead of squid bait can also improve swordfish catch, and may be used to offset a decrease in swordfish catch sometimes seen when switching from J to circle hooks.
6) Using monofilament line in place of the more flexible multifilament cordage used in many artisanal fisheries can significantly reduce entanglement of sea turtles.
7) In many (not all) cases, trials of circle hooks compared with traditional hooks have indicated that economically viable catch rates for target species can be maintained.

This report summarizes experimental field trials comparing modified fishing gear to traditional methods in numerous fisheries worldwide where incidental capture of sea turtles is high enough to allow for statistically robust comparative results. Specifically, recent field trials comparing J and circle hooks in shallow set swordfish fisheries in Italy, Brazil, and Uruguay, have shown viable CPUE for target species using circle hooks plus fish bait. And trials in deep set tuna fisheries in the United States and Indonesia have also shown viable CPUE for target species. Additionally, field trials comparing hooks with and without offset and with and without an "appendage" have examined CPUE of both sea turtles and target species in the Eastern Tropical Pacific. With regards to sea

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turtle entanglement, information from recent trials indicates improved performance of monofilament line vs. more flexible multifilament cordage as means to reduce entanglement of hard shelled sea turtles off the coast of Peru.

2005-2007 Circle Hook Experiments

Experimental field trials were conducted to test the effects of circle hooks against a traditional hook, such as a J hook in both commercial and experimental longline fishing vessels. Experiments were conducted in collaboration with fisheries scientists, managers and commercial fishermen in a number of countries, with the research design often guided by NOAA PIFSC staff. Briefly, the results are as such:

Italy: Field trials were conducted in a shallow set swordfish (*Xiphias gladius*) fishery in the Strait of Sicily, Mediterranean Sea. A commercial fishing vessel was used to conduct 20 sets over 5 different trips during 2005 and 2006 whereby a total of 20,000 hooks of fishing effort were used to compare CPUE for target and non-target species. Traditional (control) hooks were J hooks with a 20 degree offset (narrowest width = 34 mm, gape = 26 mm). These were compared to a 16/0 circle hook with a 10 degree offset (narrowest width = 44mm, gape = 27mm, Figure 1). Circle and J hooks alternated along the line for a total of ~ 1,000 baited hooks per set, there were 5 hooks between floats, and the estimated hook depth was between 18-50 m. Frozen mackerel (*Scomber scomber*) was used as bait. Yellow lightsticks were used on every branchline. During the trials, 17 loggerhead turtles were captured, whereby circle hooks accounted for 17.6 % of hooking, while J hooks were responsible for 82.4% (binomial test, p = 0.0006). Of all hooks, 88.2% were caught in the mouth, while 11.8% were swallowed. All swallowed hooks were J types. Size range of the individual turtles caught was 43 to 56cm curved carapace length (CCL), a somewhat smaller size distribution than encountered in the seminal Atlantic experiments (Watson et all 2006), which found that a larger circle was required to effectively reduce turtle captures. No differences were found between number and total weight of target swordfish captured between

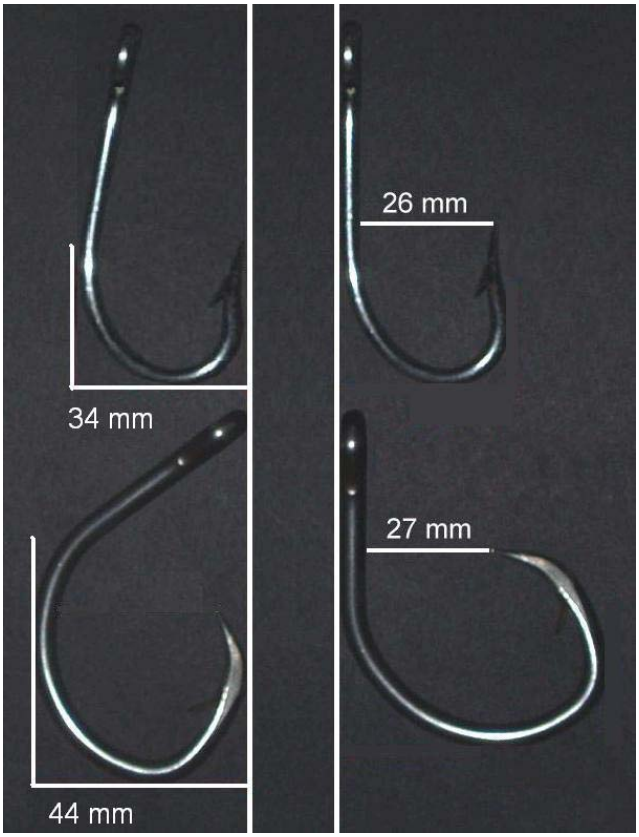


Figure 1. Traditional (control,) J hook (top) and 16/0 circle hook (bottom) tested in the Strait of Sicily. Dimensions show minimum width (left) and gape (right) of hooks.

hook types (48% vs. 52% for circle and J hooks, respectively). Further tests are planned to increase sample sizes for statistical robustness. These results suggest that 16/0 circle hooks maintain viable catch rates of swordfish, reduce the frequency of loggerhead interaction rates when compared to narrower J hooks, and also reduce the severity of injury to turtles as compared to traditional J hooks used in Mediterranean longline fisheries. These preliminary findings support assertions #1, 3, 5 and 7 from the list above.

Brazil: Field trials have been underway to test 18/0 circle hooks with a 10 degree offset (minimum width = 49-52 mm, gape = 25-27 mm) vs. 9/0 J hooks minimum width = 39-40 mm, gape = 27-28 mm) since 2005. A total of 3 fishing trips making experimental field trials were undertaken between Oct. 2006-May 2007. These trials consistently used mackerel bait. Tests in Brazil were not conducted along the entire set, but rather only for a portion of the set, whereby trials were conducted in groups of 500 hooks with J and C hooks alternating along a subset of the line, and only traditional J hooks added to another portion of the line. Here were 5 hooks between floats, so that each hook type occupied all possible positions relative to the floats in equal proportion. Thus far, 36 sets have been conducted, comparing 16,500 hooks (8,250 of each type). Results to date indicate 30 sea turtles caught in total, primarily loggerhead turtles, with a J hooks responsible for 66% of all sea turtles captured (compared to 34% for circle hooks). With regards to severity of injury, J hooks were swallowed 59% of time, whereby circle hooks were swallowed only 13% of time for all species of sea turtles. With regards to hook type effects on target species, capture rates were slightly lower (60 vs. 65) for swordfish on circle hooks as compared to J hooks, yet CPUE was similar for tuna species on each hook type. An analysis of swordfish biomass by hook type suggested similar weights of individuals caught on both J and circle hooks. Future studies are planned to complete the field trials and increase statistical power of the results. Findings to date suggest that use of a large circle hook (18/0) effectively reduced the frequency of loggerhead captures, reduced the frequency of swallowed hooks, and also maintained viable CPUE for target species. These preliminary findings support assertions #1, 2, and 7 from the list above.

Uruguay: To date, a single commercial fishing vessel has conducted surface longline operations comparing the effects of target and non-target CPUE when using 18/0 (10 degree offset) circle hooks vs. J hooks ("Portuguese 9/0" J hooks, no offset). The vessel deployed 66 sets during January through March 2007, comparing ~19,000 hooks of each type (37,968 hooks compared in total). Circle hooks and J hooks were deployed in groups of 96 along the mainline. In total, 29 loggerhead sea turtles were caught, 62% on J hooks and 38% with J hooks. These findings remain preliminary. Further field trials are planned during 2007-2008. To date, however, the data would suggest slightly fewer loggerhead turtles caught using circle hooks, supporting part of assertion #2 from the list above.

Indonesia: As of early spring 2007, field trials were conducted in the tuna fisheries off the coast of Benoa (Bali), Indonesia. Preliminary experiments with a single commercial tuna longline vessel compared CPUE for target and non-target species between size 16/0 circle hooks with rings (minimum width = 43-44 mm) and traditional style tuna hooks with rings (minimum width = 28-30 mm, Fig 2. During a single trip, the commercial

vessel conducted 36 sets. Each set consisted of approximately 1,500 hooks in which the two types of hooks were alternated along the line. There were 5 hooks between floats. Preliminary analysis compared total catch between the two hook types, with 16/0 circle hooks responsible for 53.5% of the total catch with no sea turtle interactions, and tuna hooks responsible for 46.5% of the total catch, including one hooked olive Ridley turtle (*Lepidochelys olivacea*). Circle hooks caught 12% more target fish (e.g., albacore, *Thunnus alalunga;* bluefin tuna, *Thunnus maccoyii;* bigeye tuna, *Thunnus obesus;* and yellowfin tuna *Thunnus albacares*) and resulted in 14.63 % less discards than the traditional tuna hooks. It is important to note that there was great difficulty in convincing Indonesian tuna boat captains to try the circle hooks. With initial results showing an increase in large tuna catch using the16/0 circle hooks as compared with traditional tuna hooks, more vessels have expressed interest in participating in future field trials. This result supports assertion #7 from the list above.

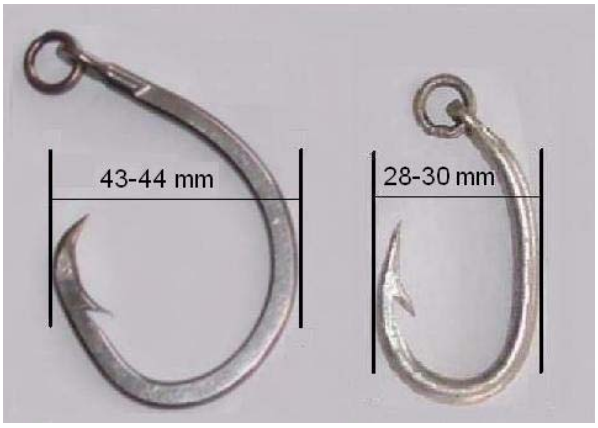


Figure 2. Types of hooks (circle hook on left, tuna hook on right) used in the experiment in Indonesia (dimensions = minimum width, with some variation in hook sizes).

Hawaii—Gilman et al (2006b) previously reported results of sea turtle capture rates and CPUE of target species (e.g. swordfish) before and after regulations to reduce sea turtle bycatch were required in the Hawaii longline fishery targeting swordfish. These regulations required the use of size 18/0 circle hooks, fish bait, turtle release methods, and 100 percent observer coverage, and other measures. Before these regulations the fishery used predominantly 9/0 J hooks baited with squid (*Illex*). Comparisons were made using data from the Hawaii longline observer program before regulations took effect (1994-2002) and the period post-regulations (2004-2006). Capture rates of combined turtle species, leatherback, and loggerhead turtles significantly declined (by 89%, 85% and 90%, respectively) after the regulations went into effect.. A more recent analysis of data incorporating first quarter fishing effort during 2007 found similar results (Gilman and Kobayashi 2007) and also reported that since the introduction of the regulations, there has been a highly significant reduction in the proportion of turtles that swallowed hooks into the esophagus or deeper and a highly significant increase in the proportion of caught turtles that were released after removal of all fishing line, likely increasing turtles' probability of surviving the interaction. During the pre-regulation period, 53% (111 of 211) of caught sea turtles were deeply hooked, while only 12% (6 of 51) were deeply hooked in the post-regulations period. The proportion of hooked turtles released with terminal tackle attached declined from 60% to 26% in the post-regulations period. Additionally, an analysis of CPUE of target species before and after sea turtle regulations indicated an increased rate of swordfish capture (up 16%) after regulations. Combined tuna species and combined mahimahi (*Coryphaena hippurus*), opah (*Lampris guttatus*), and wahoo (*Acanthocybium solandri*) catch rates significantly declined (by

50% and 34%, respectively). However, with the increased catch rate for the target species (swordfish) the fishery remained economically viable. The shark catch rate significantly declined (by 36%), highlighting the potential for the use of fish instead of squid for bait to reduce shark bycatch These results support assertions # 1, 2, 5, and 7 from the list above.

A very large experiment comparing size 18/0 circle hooks with an equal number of tuna hooks (minimum width 31-37 mm) was undertaken by 19 vessels in the Hawaii longline fishery targeting bigeye tuna in 2006. This study was large enough for a statistically powerful analysis of the effects of using large circle hooks in tuna longline fishing. Preliminary results from testing 546,808 hooks in this study show that bigeye tuna CPUE with large circle hooks is at least as good as with the tuna hooks (Boggs 2006), and shark catches were not higher with the circle hooks. This result supports assertion #7 from the list above.

Bait Experiments

Spain: Field trials were conducted to test the effects of bait type (fish vs. squid) on commercial longline vessels in a shallow set swordfish fishery in the Alboran Sea in the Mediterranean. Preliminary results of 15 sets suggest that use of mackerel bait can effectively reduce incidental capture of loggerhead sea turtles as compared to squid bait. Trials were conducted using J hooks (33-36 mm minimum width) and alternating segments of bait types in segments of 45 hooks each, for a total of 810 hooks per set (and 5 hooks between floats). Green light sticks were placed near every hook. Preliminary results found a total of 38 loggerhead turtles caught, 27 (71%) on squid vs. 11 (29%) on mackerel bait. There were no significant differences found between the numbers of individuals, or the weights of target species (swordfish) between the 2 bait types. These findings confirm Watson et al. (2005) results that fish bait alone has the potential to significantly reduce sea turtle capture rates, supporting assertion #5 from the list above.

Offset Hook Experiments

Boggs (2006) previously described the potential importance of a hook offset with regards to CPUE of both sea turtles and target species. The offset involves the angle at which the point of the hook is bent away from the plane containing the remainder of the hook (Figure 2). An offset hook is often preferred by fishermen, to make certain styles of baiting easier (putting the hook through the bait several times) or to increase gut hooking of target species, especially swordfish. Offset hooks are not a bycatch mitigation tool, but rather a convenience for fishermen that may not increase capture rate or injury to sea turtles. The original longline turtle bycatch experiments (Bolten and Bjorndal 2002, 2003, Watson et

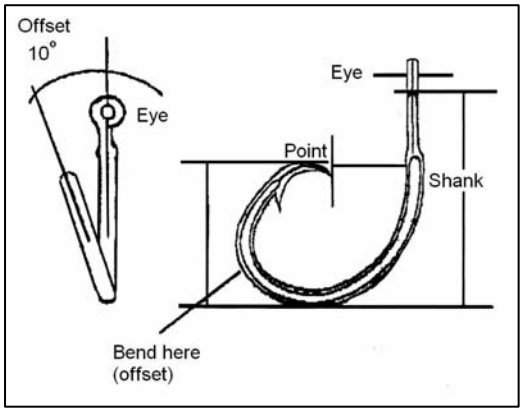


Figure 3. Mechanical drawing of an offset circle hook showing the location of the bend and the angle that defines the degree of offset.

al., 2005) used circle hooks with little (10 degree) or no offset. Although not well designed to test the difference in turtle bycatch rates between offset and non-offset hooks, these studies indicated no significant differences in turtle captures due to offset points. In 2004, testing in the Azores specifically designed to detect any effect of a 10 degree offset in size 18/0 circle hooks found no effect (Alan Bolten, personal communication, 2005). However, due to some uncertainties in the reports of the Azores experiments and the small sample sizes, the effect of the offset was still uncertain, and further experiments were initiated in order to help resolve the issue.

Costa Rica: Tests to determine impact of a 10 degree offset size on a 16/0 circle hook compared to the same size hook with no offset was initiated in a Costa Rica longline fishery for mahimahi . A single commercial longliner was contracted to conduct experiments from 2004-2006. Offset and non-offset 14/0 circle hooks were alternated along the mainline and an average of 816 baited hooks were deployed per set. To standardize analysis of data, only sets with squid baits were compared, resulting in a total of 6 trips with 42 sets that deployed a total of 33,876 hooks. Rates of sea turtle capture was high (over 700 individual turtles), yet all were released alive and most hookings were considered "lightly-hooked" with nearly 100% of line removed, suggesting high rates of survivorship post-release. Olive ridley turtles were the predominate species of sea turtle captured, followed by green turtles (*Chelonia mydas*). There were no differences in the frequency of capture of sea turtles between circle hooks with and without a 10˚ offset. Additionally, there were no significant differences between CPUE of target species, mahimahi, between hook types. While this study does not rule out the potential impact of greater hook offsets on turtle and target species CPUE, no differences were found when comparing a 10 degree offset for olive ridley turtles. Additionally, this experiment is interesting given the relatively high CPUE of olive ridley turtles with a circle hook size 14/0. Given that this is the hook traditionally used in this fishery, there are no comparative results from this particular study regarding the impacts of a non-circle hook with regards to frequency of sea turtle interactions and location of hooking relative to other sizes or types of hooks (but see also Largacha et al. 2005, IATTC 2006, and Hall et al. 2006, http://www.wpcouncil.org/protected/Documents/).

Appendage Hook Experiments

Experiments in several fisheries for smaller target species, especially mahimahi have shown reduced target species CPUE with size 16/0 circle hooks (Largacha et al. 2005, IATTC 2006). The importance of hook width in reducing hook ingestion, as shown in U.S. fishery experiments (Watson et al 2005) suggested a strategy of adding to hook width with a wire appendage, while keeping a smaller hook shape and gape. A study of such hooks in a New Zealand fishery for snapper showed a reduction in hook swallowing and bycatch of undersize fish (Barnes et al. 2004), and so these hooks (Figure 4) are now being tested in fisheries with high rates of turtle bycatch (Hall et al, 2006).

Figure 4. Illustration of a circle hook with a wire appendage.

Costa Rica: Tests to determine the effects of a 16/0 circle hook with and without an "appendage" were initiated in a Costa Rica longline fishery for sharks and mahimahi

during 2007. Baited hooks with and without an appendage alternated along the mainline during 3 trips, comparing a total of 24,343 hooks (12,515 appendage hooks, 12,828 hooks without an appendage). To date, 307 olive ridley turtles have been captured, ~29% on hooks with the appendage, and ~69% on hooks without an appendage (a few percent were entangled or hook type was not determined). The results to date support assertion #4 from list on page 1.

Entanglement Studies: Tests of Line type to reduce entanglement of hard-shelled sea turtles.

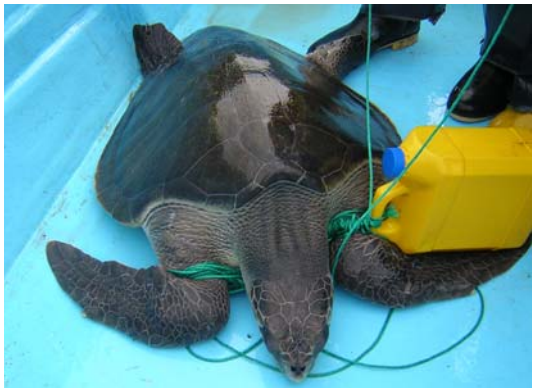
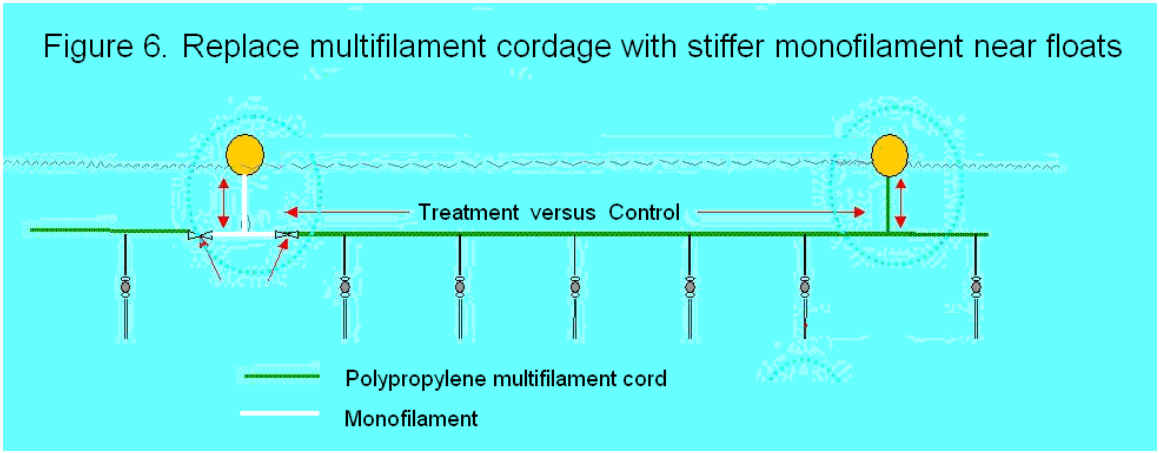


Figure 5. Olive ridley sea turtle entangled in a polypropylene multifilament line next to a float (plastic jug). This gear is typical of that used in artisanal longline fisheries in Latin America.

During the past year, fisheries scientists and managers have worked with artisanal fisheries in the Eastern Tropical Pacific to test the effect of line type (e.g. very flexible polypropylene multifilament cordage vs. nylon monofilament) with regards to entanglements of hard-shelled sea turtles (Fig.5), which occurs much more frequently than hookings in many of these fisheries. Although replacing traditional polypropylene was shown to effectively reduce the frequency of sea turtle interactions, fishers were reluctant to adopt the line for the entire length of the mainline due to concerns regarding storage space for the stiffer, less compressible monofilament. Therefore, tests were conducted in which only the portion (ca.1 m) of line on each side of the float was replaced with monofilament, and polypropylene cordage was used for the majority of the line (Fig.6). This method also has shown promise in significantly reducing rates of sea turtle entanglements (see the 7th ISC Plenary Documents, Annex 7, p. 13-14 at http://isc.ac.affrc.go.jp/). This research supports assertion #6 from the list above, and more work is planned for areas with high rates of sea turtle entanglement.



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