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Incorporating Circle Hooks Into Atlantic Pelagic Fisheries: Case Studies from the Commercial Tuna/Swordfish Longline and Recreational Billfish Fisheries

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INCORPORATING CIRCLE HOOKS INTO ATLANTIC PELAGIC FISHERIES: CASE STUDIES FROM THE COMMERCIAL TUNA/SWORDFISH LONGLINE AND RECREATIONAL BILLFISH FISHERIES

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ABSTRACT

An emerging body of literature has demonstrated the benefits of the use of circle hooks relative to standard J-hooks in commercial and recreational fisheries. In the pelagic longline fishery for tunas (*Thunnus* spp.) and swordfish (*Xiphias gladius* Linnaeus, 1758), the use of circle hooks has resulted in greater catch rates of some target species, lower catch rates of some bycatch species, and a higher percentage of many target and bycatch species alive at the time of haulback (gear retrieval). However, a lack of agreement among results of studies conducted in different fisheries and areas, using different baits and rigging techniques, and with different styles and sizes of circle hooks has hindered the adoption of this terminal tackle as a management measure at the international level. Nevertheless, some countries have mandated the use of circle hooks in pelagic longline fisheries to protect bycatch species, and some individual fishers have incorporated circle hooks because they appear to maximize individual profit. In the recreational fishery for billfishes (family Istiophoridae), which is primarily a catch-and-release fishery in the United States, studies have demonstrated that circle hooks result in higher rates of external hooking and post-release survival than standard J-hooks. The use of circle hooks in billfish fisheries has been promoted by the sportfishing industry and is currently required by some nations; however, partnerships promoting active outreach and education with stakeholders in both commercial and recreational fisheries are critical to maximize the use and conservation benefit of this technology.

Circle hooks reduce the incidence of deep hooking, hook induced trauma, and post-release mortality in a variety of freshwater and marine fishes (Cooke and Suski 2004), and their overall benefit to commercial and recreational billfish fisheries was recently reviewed by Serafy et al. (2009). In a few fisheries and in some nations, circle hook use has been mandated to reduce fishing mortality on target species (regulatory discards or catch-and-release fisheries) and/or bycatch species. However, despite the apparent conservation benefits of circle hooks in some fisheries, their use has not been readily adopted in situations where fishers have an option of using circle hooks or other types of terminal tackle. With an emphasis on fisheries in the Atlantic Ocean, we review studies comparing the use of circle hooks and standard J-hooks in (1) the commercial pelagic longline fishery that primarily targets tunas (*Thunnus* spp.) and swordfish (*Xiphias gladius* Linnaeus, 1758) and (2) the offshore recreational fishery for billfishes (family Istiophoridae). We also review challenges and results of efforts to incorporate circle hooks in these fisheries.

Circle Hooks in the Pelagic Longline Fishery

The pelagic longline fishery for tunas and swordfish occurs throughout the world's subtropical and tropical waters. Within the Atlantic Ocean, the primary target species of the pelagic longline fishery are yellowfin tuna, *Thunnus albacares* (Bonnaterre, 1788), bigeye tuna, *Thunnus obesus* (Lowe, 1839), and swordfish. The most recent assessments by the Standing Committee for Research and Statistics (SCRS) of the International Commission for the Conservation of Atlantic Tunas (ICCAT) indicate that current biomass levels of bigeye tuna, yellowfin tuna, and northern and southern stocks of swordfish are at or above levels needed to support maximum sustainable yield (ICCAT 2011). However, stock levels of many non-target species that interact with pelagic longline gear are severely depleted, including sea turtles, some species of pelagic sharks, and istiophorid billfishes. Concerns about the interaction of these bycatch species with pelagic longline gear, most particularly endangered sea turtles, has had a large impact on US domestic fisheries management.

Due to interactions of threatened and endangered loggerhead, *Caretta caretta* (Linnaeus, 1758), and leatherback, *Dermochelys coriacea* (Vandelli, 1761), sea turtle populations with pelagic longline gear, the United States closed the Atlantic Northeast Distant (NED) pelagic statistical area, an area of 8.9 million km^2, to the US pelagic longline fishery from 2001 to 2003. An even larger area (all waters north of the equator) was closed to the Hawaii-based US shallow-set swordfish pelagic longline fishery in the central North Pacific from 2002 to 2004 for similar reasons. Both closed areas included international waters, but because the closures were a US management measure, they did not apply to foreign vessels fishing in those areas, nor were there import restrictions on products from these foreign fleets. During the Atlantic closure, Watson et al. (2005) conducted an investigation within the US Atlantic NED pelagic statistical area to determine if there were combinations of hook style/size and bait that would significantly reduce bycatch of sea turtles. They reported that large (size 18/0) circle hooks in combination with Atlantic mackerel (*Scomber scombrus* Linnaeus, 1758) bait significantly reduced interactions with both loggerhead and leatherback sea turtles, with limited impact on target species catch rates. Based on these results, the United States reopened the NED closed area to US Atlantic pelagic longline fishers but currently requires the use of selected bait and hook configurations, specifically whole squid (*Illex* spp.) or Atlantic mackerel with size 18/0 or larger circle hooks with offsets not to exceed 10°. In areas of the Atlantic outside of the NED, US pelagic longline fishers are now required to use circle hooks size 16/0 or greater. Similarly, current regulations for the US Pacific shallow-set swordfish pelagic longline fishery require the use of size 18/0 circle hooks with "mackerel type" bait. There is no mandated hook type in effect at this time for the US Pacific deep-set pelagic longline fishery for tunas; however, this fishery primarily uses size 3.4–3.8 sun tuna and size 11/0–18/0 (mainly 16/0) circle hooks, (D Curran, NOAA Pacific Islands Fishery Science Center, pers comm).

The use of circle hooks can affect catch rates and condition of target species as well as bycatch species. Falterman and Graves (2002) conducted a preliminary study in which 16/0 circle hooks were alternated with similarly-sized 7/0 J-hooks in the Venezuelan live-bait pelagic longline fishery that targets yellowfin tuna. Over six sets, which included 2105 observed hooks, significantly higher catch rates were observed on circle hooks for both the target species and for all species combined. The use of circle hooks also resulted in greater survival at the time of haulback (gear retrieval) for yellowfin tuna and for all species combined, and fish caught on circle hooks had a higher rate of external hooking locations than those caught on J-hooks. The results from this controlled study conducted from one vessel over a short time frame were nonetheless consistent with those of Hoey (1996) who analyzed fishery observer data from 75 J-hook and 122 circle hook sets in the live-bait pelagic longline fishery in the Gulf of Mexico (the use of live bait in the US domestic Gulf of Mexico pelagic longline fishery was prohibited in 2000). Relative to J-hook sets, Hoey (1996) found that circle hook sets had higher catch rates and increased survival at haulback over all species.

Other comparative studies of circle hooks and J-hooks on pelagic longline gear deployed in the western Atlantic have also noted differences in the performance of circle hooks and J-hooks relative to catch rates, survival, and looking location. Kerstetter and Graves (2006) alternated 16/0 non-offset circle hooks and 9/0 10° offset J-hooks on each of 85 sets (30,600 observed hooks) in the US coastal pelagic longline fishery that targets tunas and swordfish. They reported an increase in tuna catch rates with circle hooks in the fall (tuna directed) fishery and a decrease in swordfish catch rates in the spring (swordfish directed) fishery, though differences were not statistically significant. The percentage of swordfish alive at haulback was similar between circle hooks and J-hooks, while a greater fraction of tuna caught on circle hooks were alive at haulback, but the difference was not significant. However, there was a significant increase in the frequency of external hooking locations with circle hooks for all species combined.

Similar trends were recently reported by Pacheco et al. (2011) who alternated 18/0 non-offset circle hooks and 9/0 10° offset J-hooks on 81 sets (50,170 hooks) in the pelagic longline fishery for tuna and swordfish in equatorial waters off Brazil. The use of circle hooks resulted in higher catch rates of tunas (significant for bigeye) and comparable catch rates for swordfish, while no major differences in catch rates were noted for bycatch species with the exception of pelagic rays, which had significantly reduced catch rates with circle hooks. Mortality at haulback was significantly reduced for bigeye tuna, yellowfin tuna, and billfish caught on circle hooks, and the use of circle hooks resulted in higher frequencies of external hooking for almost all target and bycatch species. These results were consistent with those of Diaz (2008) who analyzed fishery observer data from 437 circle hook (mainly sizes 15/0 and 16/0) and 630 J-hook (sizes 7/0–9/0) pelagic longline sets targeting yellowfin tuna in the Gulf of Mexico. No difference was seen between hook types in the catch rate of the target species, and although circle hooks resulted in a lower catch rate for blue marlin, *Makaira nigricans* Lacépède, 1802, and white marlin, *Kajikia albida* (Poey, 1860), the differences were not significant. However, significantly higher survival at haulback was noted for blue marlin and white marlin caught on circle hooks.

The results of studies comparing circle hooks and J-hooks in Atlantic pelagic longline fisheries are not completely consistent (see summary Table 1A,B). Significant differences observed in one study might be noted as a non-significant difference in another investigation, and possibly not detected at all in others. Still, over all of these studies, certain trends are apparent. In several of the studies, the use of circle hooks resulted in higher catch rates of tunas, with little impact on swordfish catch rates. In most studies, circle hooks did not result in lower catch rates of bycatch species,

Table 1. (A) Main comparative field and (B) observer data studies of circle hooks with J-hooks in pelagic longline fisheries targeting tunas (*Thunnus* spp.) and swordfish (*Xiphias gladius*). Note hook codes: "NOS" = non-offset, "OS" = offset, and "OSnr" = offset not reported.

A

Study [# sets / # hooks deployed]	Study location	Main target species	Hook types compared	Main findings
Falterman and Graves (2002) [6 sets / 2,105 hooks]	Southern Caribbean	Yellowfin tuna	7/0 J OSnr, 16/0 circle OS	Significantly higher CPUE for target species and "all fishes" group on circle hooks; no significant differences in survival at haulback for any species.
Watson et al. (2005) [489 sets / 427,382 hooks]	Northwest Atlantic	Swordfish, bigeye tuna	9/0 J OS, 18/0 circle OS, 18/0 circle NOS	Tested comparisons of squid and mackerel bait with J-hook model and OS and NOS circle hooks; for both baits, lower swordfish catches on circle hooks; for bigeye tuna, catches higher on circle hooks, especially with squid bait; billfish catches insufficient for comparison.
Kerstetter and Graves (2006) [39 sets / 14,040 hooks]	Western Atlantic	Yellowfin tuna, bigeye tuna	9/0 J OS, 16/0 circle NOS	Significantly higher CPUE for yellowfin tuna; no significant CPUE difference for other target species or billfishes; no significant differences in survival at haulback for any target species or billfish.
[46 sets / 16,560 hooks]	US Gulf of Mexico/ Caribbean	Swordfish	9/0 J OS, 16/0 circle NOS	No significant CPUE differences for swordfish or any billfish; no significant differences in survival at haulback for any target species or billfish.
Pacheco et al. (2011) [81 sets / 50,170 hooks]	Western Equatorial Atlantic	Yellowfin tuna, bigeye tuna, swordfish	9/0 J OS, 18/0 circle NOS	No significant difference in target catch rate, except for higher catch rate of bigeye tuna on circle hook; no significant differences in billfish catch rates, except for higher catch rate of sailfish on J-hook; significantly higher mortality at haulback on J-hooks for "all tunas" and "all billfish" groups.
Curran and Bigelow (2011) [211 sets / hooks not reported]	Central Pacific	Bigeye tuna, yellowfin tuna	9/0 J OSnr, 18/0 circle OS and NOS combined	No significant difference in target catch rate; significantly higher catch rate for blue marlin and shortbill spearfish; no significant survival differences at haulback for target species or billfishes, other than significantly lower survival for striped marlin on circle hook.

B

Study [# sets / # hooks included]	Study location	Main target species	Hook types compared	Main findings
Hoey (1996) [197 sets / hooks not reported]	US Gulf of Mexico	Yellowfin tuna	Not reported	Circle hook sets had higher catch rates and increased survival at haulback over all species.
Diaz (2008) [1,067 sets / hooks not reported]	US Gulf of Mexico	Yellowfin tuna	7/0-9/0 J OSnr, 13/0-16/0 circle OSnr	No significant CPUE differences for yellowfin tuna; non-significant lower catch rate for billfish on circle hooks; significantly higher survival at haulback for blue and white marlin.

although the hook type did result in a higher frequency of external hooking locations, and increased survival of tuna and bycatch species.

There have been a number of hook comparison studies in pelagic longline fisheries in the Pacific and Indian oceans. Because many pelagic longline vessels in the Pacific and Indian oceans use so-called tuna hooks, which are intermediate in shape in several regards to J-hooks and circle hooks, most of the studies undertaken in these oceans have compared J-hook and tuna hook performance (e.g., Ward et al. 2009, Curran and Bigelow 2011). For those studies that have compared circle hooks and J-hooks in the Pacific and Indian oceans, the results have not been completely consistent with those noted in the Atlantic. Curran and Bigelow (2011) analyzed 211 sets (approximately 420,000 hooks) in which 18/0 circle hooks were alternated with 9/0 J-hooks in the deep-set Hawaiian pelagic longline fishery that targets tunas. They observed an increase in the catch rate of bigeye tuna with circle hooks, although the difference was not significant. Catch rates of blue marlin and shortbill spearfish, *Tetrapturus angustirostris* Tanaka, 1915, were significantly lower on circle hooks, while there was no significant difference for striped marlin, *Kajikia audax* (Philippi, 1887). In contrast to studies in the Atlantic, circle hooks did not result in significantly higher rates of survival of many target and bycatch species. In fact, two istiophorid billfishes, striped marlin and shortbill spearfish, demonstrated significantly higher survival on J-hooks than on circle hooks.

There are likely a host of factors contributing to the disparate results among studies comparing the performance of circle hooks and J-hooks in the pelagic longline fishery. Among these, sample size may be important. Closely controlled studies in which the same vessel fishes circle and J-hooks in a similar manner in a limited geographical area may reveal differences in hook performance, but will also have relatively small numbers of caught animals, thereby limiting the power of the analyses. Such power is especially limited for rare-event bycatch species, such as istiophorid billfishes and sea turtles. The limitation of small sample sizes of these bycatch species can be overcome with larger scale studies that incorporate more vessels, observed sets, and hooks. However, this trade-off also results in an increase in variance due to a greater number of fishing styles, even if the gear configurations are kept consistent. This variance also will increase if the fishing activities occur over a broader geographic area and over multiple seasons. Simply increasing the number of observed hooks without accounting for these sources of variance may obscure subtle signals in hook performance for target and bycatch species.

Differences in hooks, including such factors as size, shape, and degree of offset, may contribute to a lack of agreement among circle and J-hook studies. There is currently no standardization of hook sizes among manufacturers, so the physical dimensions of a size “18/0” circle hook used in one study may be different than those used in another, including the wire diameter. Similarly, there is a great deal of variation in shapes among different models of circle hooks, and these could influence results between studies; the description of “hook with the point turned perpendicular to the shank” from Cooke and Suski (2004) may no longer be sufficient to describe the shapes. The degree of offset of circle hooks and J-hooks also often varies among, and sometimes within, studies. Other factors contributing to contrasting results among studies may include the types and physical sizes of the bait, the manner in which baits are rigged on hooks, the depth of deployment, oceanographic conditions, and

Table 2. Problems facing studies comparing the performance of circle hooks and J-hooks in pelagic longline and recreational billfish fisheries, with recommended solutions to facilitate standardization.

Problem	Within study	Between studies	Suggested solution
Unequal hook sizes	×		Select experimental hooks of similar physical dimensions as the control hooks; report physical dimensions of hooks and include photographs.
		×	Select both control and experimental hooks of similar physical dimensions to hooks currently used within fisheries; report physical dimensions of hooks and include photographs.
Unequal hook offsets	×	×	Use same degree of offset for experimental and control hooks; report method for offset measurement.
Variation in baits	×	×	Use same bait type, size, and rigging protocol for both experimental and control hooks; report bait species, size range, and method of rigging.
Variation in leaders	×	×	Standardize and report leader length, material, and diameter.
Seasonal effects	×	×	When appropriate, conduct experiments across multiple seasons.
Inconsistent hooking location descriptions		×	Use standard descriptions (e.g., Prince et al. 2002, Cooke and Suski 2004, Kerstetter and Graves 2006, Pacheco et al. 2011) for hooking locations.

season. We identify some of these issues and propose solutions to facilitate comparisons among studies (Table 2).

While there are many factors that may contribute to differences in results among studies comparing the performance of circle hooks and J-hooks in the pelagic longline fishery, the lack of consistent results across studies has not provided scientific advisory committees of the tuna regional fishery management organizations (RFMOs) strong evidence to recommend incorporation of circle hook technology as a management measure for target or bycatch species. Further confounding this issue is the reality that species (e.g., istiophorid billfish) targeted by one nation may be considered bycatch by another nation. In addition, longer term ecosystem simulations of Pacific longline fisheries demonstrate the importance of understanding the effects of circle hooks and J-hooks on both catch rates and survival rates of target and bycatch species, as subtle differences can lead to profound changes in the populations of tunas, billfishes, sharks, and their prey (Kaplan et al. 2007).

The ambivalence to enact management measures incorporating circle hooks at the international level stands in stark contrast to measures implemented at the domestic level; however, the adoption of circle hooks by a commercial fishery does not always require a management measure, nor even a government agency to promote the use of circle hooks. Based on scientific evidence from their fisheries, the United States and Canada implemented management measures requiring pelagic longline fishermen to use large circle hooks with fish baits to reduce interactions with sea turtles. But fishers are keen observers, and a strong profit motive provides an incentive beyond regulation to incorporate technologies that increase overall efficiency. For example, circle hooks were rapidly adopted in the Pacific halibut bottom longline fishery when it was demonstrated that they had much greater catch rates than J-hooks (Trumble et al. 2002). When alternating circle and J-hooks in the Venezuelan live bait pelagic longline fishery, Falterman and Graves (2002) demonstrated a much higher catch rate and survival of yellowfin tuna on circle hooks, thus increasing the number and quality of the target species. Based solely on the first sets of that research, word of the higher target species catch rate and survival on circle hooks rapidly spread through the fleet, and several vessels immediately reconfigured their terminal gear from J-hooks to circle hooks. A similar experience occurred during study of circle hook and J-hook performance in the pelagic longline fishery operating off northeast Brazil. Results from the early cruises indicated higher catch rates and survival of target species caught on circle hooks, and this information was quickly passed around the fishery. Shortly after, boxes of size 18/0 circle hooks that were stored on shore were "appropriated" by other vessels that switched their terminal gear from J-hooks to circle hooks. While these conversions were motivated by differences in target species catch rates and survival, there were potential benefits for bycatch species as well.

The importance of having the fishers directly observe the advantages of circle hooks in their fishery cannot be overstated, an observation that underscores the value of outreach activities and collaborative gear research. Certain techniques must be modified with the use of any new technology as well, which will often take additional time and experimentation. For example, the use of large circle hooks in the US Atlantic swordfish fishery required the adoption of a slower and more cautious haulback (gear retrieval) technique to avoid ripping the hooks out of the relatively-fragile swordfish mouth structures as the leaders were brought to the surface. Using the old method of hauling the gear quickly, catch rates for swordfish with circle hooks appeared low; with the new technique, catch rates are reportedly similar to those with J-hooks. However, without consistent monitoring of the fishery and notation of such changes, the early conclusion on catch rates could be counter to the actual results. More importantly for management, without agreement among studies of hook performance in pelagic longline fisheries, it is likely that incorporation of circle hook technology into the global pelagic longline fisheries will not come from RFMOs. Rather, it will result from either domestic management measures requiring the use of circle hooks to protect bycatch species or from outreach activities that provide fishermen with an opportunity to observe the benefits and drawbacks of the technology in their particular fisheries.

Circle Hook Use in the Recreational Billfish Fishery

In addition to their incorporation into some pelagic longline fisheries, circle hooks have also been increasingly used in pelagic recreational fisheries, most notably those for istiophorid billfishes. Billfishes are targeted by recreational anglers throughout the world's tropical and subtropical waters, and while the fishing mortality from the recreational fishery is low relative to that of the pelagic longline and directed artisanal fisheries, it is not inconsequential (Cramer 2004, Kerstetter and Graves 2006). In the Atlantic Ocean, the recreational billfish fishery primarily targets blue marlin, white marlin, and sailfish, *Istiophorus platypterus* (Shaw in Shaw and Nodder, 1792). The Atlantic-wide stocks of blue marlin and white marlin are considered overfished, while sailfish are considered to be overfished in the eastern Atlantic and fully fished, if not overfished, in the western Atlantic (ICCAT 2011). ICCAT has implemented management measures requiring live release of blue marlin and white marlin from pelagic longline gear, and restricted the US recreational fishery to an annual limit of 250 blue marlin and white marlin combined. To maintain landings of blue and white marlin below the ICCAT limit, the US National Marine Fisheries Service has implemented relatively large minimum sizes of 99 in (approximately 2.51 m) lower jaw fork length (LJFL) for blue marlin and 66 in (approximately 1.68 m) LJFL for white marlin. In addition to these management measures, over the past 40 yrs there has been an increasing trend to release billfish after capture in many areas (Graefe and Ditton 1997). This change in angler ethics, in conjunction with the implementation of large minimum sizes, has resulted in a US recreational Atlantic billfish fishery that is primarily catch-and-release.

Several different fishing techniques are used in the recreational fishery to catch istiophorid billfishes, including high speed trolling with artificial lures or artificial lure/natural bait combinations, slower trolling of live or dead natural baits, and pitching of live or dead baits from a stationary vessel (Holland et al. 1990, Graves et al. 2002, Domeier et al. 2003, Horodysky and Graves 2005, Graves and Horodysky 2008). In the high-speed troll fishery, the billfish usually hooks itself as it attacks a lure or bait/lure combination (Graves et al. 2002). However, in the slow troll and pitch fisheries, the angler removes tension from the line for 5–10 s as the billfish attacks the bait, then applies tension to the line to set the hook (Mather et al. 1975). This procedure, known as a dropback, allows the billfish to engulf the static bait before feeling tension on the line, increasing the probability that the bait will be well into the mouth before the hook is set. Dropbacks thus increase the chance that the fish will be hooked deeply (Prince et al. 2002, 2007). A general lack of standardization in fishing techniques (i.e., presence or absence and duration of dropbacks, trolling speed, etc.), hook types and sizes, and baits (or lures) and their rigging complicate meta-analyses of studies comparing hook performance and post-release survival in recreational billfish fisheries (Table 2).

As previously noted, circle hooks reduce the incidence of deep hooking in several recreational fisheries (Cooke and Suski 2004), and efforts were made during the 1990s to develop techniques to use circle hooks in recreational billfish fisheries, particularly the sailfish fishery along the Pacific coast of Central America. Prince et al. (2002) analyzed the performance of circle hooks and J-hooks in that fishery and clearly demonstrated that circle hooks resulted in lower rates of deep (internal) hooking and bleeding, differences that were expected to result in lower rates of post-release mortality (Prince et al. 2002).

The development of pop-up satellite archival tag (PSAT) technology in the late 1990s provided an improved means to assess billfish post-release survival (Graves et al. 2002). Domeier et al. (2003) deployed 61 PSATs to evaluate post-release survival of striped marlin caught on pitched live baits rigged with circle hooks and J-hooks. While the J-hooks had significantly higher probabilities of internal hooking locations and causing bleeding from the gill cavity, the level of post-release survival between fish caught on the two hook types was not significantly different. In contrast, Horodysky and Graves (2005) used PSATs to estimate post-release mortality of 40 white marlin caught on trolled natural baits rigged with circle hooks or J-hooks and found highly significant differences in post-release mortality between fish caught on the two hook types. Relative to circle hooks, J-hooks resulted in significantly higher rates of internal hooking locations and bleeding. Furthermore, analysis of the PSAT data indicated that seven of 20 (35%) white marlin caught on J-hooks died within 10 d of release, while no mortalities were inferred for white marlin caught on circle hooks. Further analyses of three different models of circle hooks commonly used in the white marlin fishery that vary in overall shape and offset (no offset or minor offset) revealed no major differences in hooking location, bleeding, or post-release mortality among fish caught on the different circle hook models. On the basis of 59 PSATs, the overall post-release mortality of white marlin caught on natural baits rigged with circle hooks was estimated to be 1.7% (Graves and Horodysky 2008).

In a study of circle hook and J-hook hooking locations in Atlantic istiophorid billfishes, Graves and Horodysky (2010) noted significant decreases in the frequency of internal hooking locations for white marlin, sailfish, and blue marlin caught on trolled natural baits rigged with circle hooks. However, the magnitude of the difference in internal hooking locations between fish caught on circle hooks and J-hooks was much greater for white marlin and sailfish than it was for blue marlin. This difference was also reflected in an analysis of post-release survival using PSATs. Post-release mortality of 30 blue marlin caught on trolled artificial lure/natural bait combinations rigged with J-hooks was 6.7%, while no mortalities were noted for 29 blue marlin caught on natural baits rigged with circle hooks.

These studies demonstrate that relative to J-hooks, circle hooks result in lower frequencies of internal hooking, trauma, and post-release mortality of billfish caught on trolled or pitched natural baits in the recreational fishery. These results have led to the promotion of circle hooks in the recreational fishing industry, and have influenced domestic legislation. Several catch-and-release billfish tournaments began promoting circle hooks a decade ago, many offering workshops on how to rig natural baits with circle hooks. Shortly thereafter, many of these tournaments required the use of circle hooks. In 2008, the US National Marine Fisheries Service implemented a management measure requiring the use of non-offset circle hooks with natural baits in all Atlantic billfish tournaments. Although billfish tournaments only account for a fraction of recreational billfish fishing effort, it was felt that to prepare for fishing tournaments, billfish anglers would use circle hooks on a regular basis, modifying rigging and fishing styles to maximize their performance in tournaments.

Despite the apparent conservation benefits of the use of circle hooks in the recreational billfish fishery, there has been reluctance by many anglers to adopt the technology. A major concern has been the perception of reduced catch rates on circle hooks. However, in those studies that have attempted to quantify hookup success and/or angling success, the two hook types have performed equally well (Prince et al. 2002, 2007, Domeier et al. 2003, Serafy et al. 2009). Learning to properly rig baits with circle hooks and adopt fishing practices that maximize hookups with this gear type takes time, and during this transition it is likely that angling success may drop. Over the past 10 yrs, we have had the opportunity to fish with many expert anglers, several of whom were strong J-hook advocates and would not consider using circle hooks. However, after exposing these individuals to captains and crews that fish circle hooks regularly, almost all of these J-hook stalwarts have since become strong advocates for circle hooks. In fact, some of the "converted" have written articles in the popular literature extolling the benefits of circle hooks in the recreational billfish fishery.

Conclusions

Several studies have shown circle hooks to have benefits to target and bycatch species in both the commercial pelagic longline fishery and recreational billfish fishery, but voluntary adoption of circle hooks by these fisheries has not been overwhelming. In the pelagic longline fishery, conflicting results among studies conducted under varying locations, seasons, and experimental protocols have hindered the development of regulations requiring the use of circle hooks at the RFMO level. While more evidence supporting the use of circle hooks in these fisheries may emerge, obtaining large sample sizes under controlled conditions to adequately test for subtle differences remains a major challenge. Lacking action at the level of the RFMOs, use of circle hooks in the pelagic longline fishery will either be mandated by countries to protect bycatch species or voluntarily adopted by individual fishermen who see a gain in economic efficiency with the terminal tackle. Within the recreational billfish fishery, the scientific basis for conservation benefits of circle hooks is much clearer, and some countries have mandated complete or partial usage in the fishery (Prince et al. 2002, Cooke and Suski 2004). Nevertheless, regulations requiring circle hooks are rare for recreational fisheries, and anglers have a choice of using circle hooks or J-hooks throughout much of the range of Atlantic istiophorids. In those cases, the decision to use or not use circle hooks involves weighing individual perceptions of angling success, personal experience, and billfish post-release survival.

The support and cooperation of stakeholders is critical to the biological, economic, and social success of fisheries management and regulation (Hilborn 2008, Irwin et al. 2011), and such is the case with the use of circle hooks. Based on our experiences in the pelagic longline and the recreational billfish fisheries, the most effective means of transferring the technology to date has not been through management measures that are difficult to enforce, but through direct outreach to the fishers in their fishing operations. Thus, the expansion of mechanisms to engage recreational and commercial stakeholders in circle hook education, outreach, as well as partnership-based structured decision making processes (Irwin et al. 2011) has great potential to enhance effective and efficient incorporation of the technology. This will also increase compliance with management measures and ultimately increase the conservation benefits of circle hook use in pelagic fisheries.

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