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In-Water Conventional Tagging Techniques Developed by the Cooperative Tagging Center for Large Highly Migratory Species

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Abstract.—The Cooperative Tagging Center (CTC) of the National Marine Fisheries Service's Southeast Fisheries Science Center operates one of the largest and oldest fish tagging programs of its type in the world. Since 1954, more than 35,000 recreational and commercial fishing constituents have voluntarily participated in the CTC, and this has resulted in tagging more than 245,000 fish of 123 species. Although some tagging activities have been conducted by scientists, most of the tag release and recovery activities were achieved by recreational and commercial fishery constituents. Five large highly migratory species have historically represented the Program's primary target species, including Atlantic bluefin tuna *Thunnus thynnus*, blue marlin *Makaira nigricans*, white marlin *Tetrapturus albidus*, sailfish *Istiophorus platypterus*, and broadbill swordfish *Xiphias gladius*. Tagging equipment and procedures for catching, tagging, and resuscitation of species too large to be brought aboard fishing vessels have evolved and improved considerably over the years. This paper presents a review of the development of the most efficient tagging, handling, and dehooking techniques used on a variety of large highly migratory species in the CTC. In addition, the results of a comparative tag retention study on billfish are presented, comparing stainless steel dart tags used for nearly 30 years with a hydroscopic nylon double-barb dart tag, recently developed in conjunction with The Billfish Foundation. Recommendations are made on the best techniques, procedures, and equipment for in-water tagging of large, highly migratory species.

Introduction

It is difficult to pinpoint the origin of catch-and-release fishing practices for large, highly migratory species in the Atlantic Ocean. An argument can be made that at least one major development in the evolution of these practices for Atlantic pelagics in the U.S. recreational fishery coincided with the initiation of the Cooperative Tagging Center (CTC), pioneered by Frank J. Mather III of Woods Hole Oceanographic Institution (WHOI) in 1954 (Scott et al. 1990). The CTC, known prior to 1995 as the Cooperative Game Fish Tagging Program (CGFTP), has always been a joint research effort by scientists and recreational and commercial fishing constituents. The program was designed to provide basic information on the movements and biology of highly migratory species in the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea, through direct participation of the public in scientific research. Atlantic bluefin tuna *Thunnus thynnus* was the primary target species when the program first started, but after a few years the number of target species was increased to include blue marlin *Makaira nigricans*, white marlin *Tetrapturus albidus*, sailfish *Istiophorus platypterus*, and broadbill swordfish *Xiphias gladius*. Some of the other scombrids currently included in the program are yellowfin tuna *Thunnus albacares*, albacore tuna *T. alalunga*, bigeye tuna *T. obesus*, and blackfin tuna *T. atlanticus*. In 1973, the CGFTP became a cooperative effort between WHOI and the National Marine Fisheries Service (NMFS). With the retirement of Dr. Mather in 1980, the NMFS Southeast Fisheries Science Center (SEFSC) assumed sole responsibility for operation of the program.

Justification for the CTC tagging program has been, from its inception, based on the need for biological data on large, highly migratory species. Tagging meaningful numbers of large oceanic pelagic species without constituent participation, particularly the rare event Istiophorids (Prince and Brown 1991), would be difficult if not impossible to accomplish at a reasonable cost. In addition to gaining biological information, the CTC has resulted in a virtual windfall of positive public relations, as well as the unanticipated development and subsequent popularity of catch-and-release fishing practices (Pepperell 1990). As a result of the initial success of the CTC, the concept of constituent-based marine tagging programs has been widely embraced, as reflected by the development of similar programs in Australia (Pepperell 1990), New Zealand (Murray 1990), and South Africa (van der Elst 1990), as well as programs on large Atlantic sharks (Kohler et al. 1998) and on Pacific Istiophoridae (Squire 1974; Holts and Prescott 2000).

From 1954 to 1999, more than 35,000 recreational and commercial fishermen have participated in the CTC and tagged more than 245,000 fish representing 123 species (Table 1; Scott et al. 1990; Ortiz et al. 1999). At present, about 10,000 persons are listed as active participants in the CTC. Program participants reside not only in the USA, but also in Canada, Mexico, South America, West Africa, Brazil, and numerous Caribbean island nations as well. Historical recapture rates since 1954 (Table 1) have ranged from almost 12% for Atlantic bluefin tuna to less than 1% for blue marlin. Data generated by the program are widely used by a variety of state and federal fisheries agencies, as well as international fisheries organizations. For example, since the International Commission for the Conservation of Atlantic Tunas (ICCAT) started conducting stock assessments of highly migratory species in the mid-1970s, the commission has relied heavily upon the CTC database as a primary source of information concerning movement patterns, defining management units, and detailing aspects of growth and biology of these species (Miyake 1990; Jones and Prince 1998).

Many of the CTC target species are too large to be brought on board for tagging. Therefore, one of the major challenges during the early stages of the program was developing in-water tagging techniques that could be used easily, safely, and effectively, by volunteer fishermen and scientists. Over the past four decades, the techniques have evolved and improvements made to reduce the hazards of tagging the larger tunas and billfishes (Scott et al. 1990; Ortiz et al. 1999).

This paper reviews the development of efficient tag and release in the CTC for large, highly migratory species. The techniques described for in-water tagging reflect the development of improved fish-handling procedures used at boatside, as well as describing tagging equipment and methods for catching, tagging, dehooking, and resuscitation. In addition, results are presented on the performance of individual taggers and from a study conducted on billfish that compared tag retention of a stainless steel dart tag with that of a hydroscopic nylon double-barb dart tag. The overall objective of this paper is to provide an overview, guidance, and recommendations on the best equipment, techniques, and procedures for a successful constituent-based program for in-water tagging of large, highly migratory species.

Table 1. Release and recapture statistics for the major target species of the Cooperative Tagging Center, 1954-1999. The category "all species" is composed of 123 different species, including major and minor target species (Istiophoridae, Xiphiidae, Scombridae), as well as many inshore non-target species that have been opportunistically tagged over the years by Program participants (Scott et al. 1990).

	Number of fish		
Species	*Releases*	*Recaptures*	*Percent recaptured*
Blue marlin	23,528	205	0.87
White marlin	31,277	577	1.84
Sailfish	65,065	1,182	1.82
Swordfish	9,983	348	3.49
Bluefin tuna	39,357	4,609	11.71
All species	247,658	10,979	4.43

History of Tag Development

From 1954 to 1981, a stainless steel dart tag designed by Mather (1960, 1963) and manufactured by Floy Tag Manufacturing Company[1] was used almost exclusively by the CTC to tag large, highly migratory species (McFarlane et al. 1990; Figure 1, top). This dart tag (FH 69 series) used a brass sleeve crimped on the end of the monofilament shaft to hold the yellow vinyl tubing (containing the legend) in place. The anchor portion of the tag consisted of a stainless steel barb that was inserted into the dorsal musculature of the fish. The legend contained the word "reward," as well as a unique tag number and the return address of the Miami laboratory (Scott et al. 1990). This tag was modified in 1981, as a result of field observations that noted that many of these tags, especially from recaptured bluefin tuna, were returned with the tubing and its imprinted legend missing (i.e., only the monofilament shaft was projected from the dorsal musculature). It was found that the brass sleeve often corroded completely, allowing the tubing to slip off and be lost. To prevent this known source of shedding, the original design was modified by Floy Tag Company (FH 69S), using a plastic heat shrink sleeve that was slipped over the doubled end of the monofilament to retain the identification tubing. In 1981, the original FH 69 series dart tag was replaced in the CTC by the FH 69S series dart tag (Figure 1, bottom).

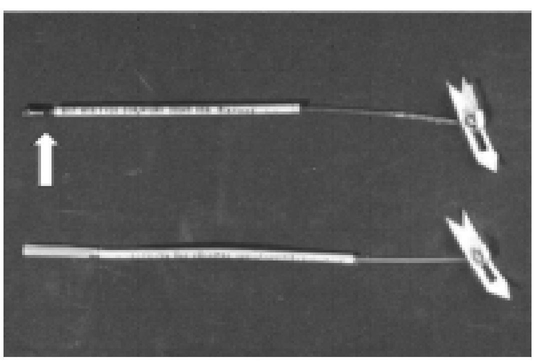


Figure 1. Original stainless steel dart tag (FH 69) with brass crimp (see arrow) securing the legend, used in the Cooperative Tagging Center from 1954 to 1981 (top). Modification of original stainless steel dart (FH 69S), using shrink tubing over doubled monofilament to secure the legend (bottom).

Yamashita and Waldron (1958) modified Mather's dart tag design by using a nylon anchor while tagging skipjack tuna *Katsuwonus pelamis*. They reported significantly higher returns compared with stainless steel dart tags. Hydroscopic nylon dart tags in three different sizes (18, 10, and 6.5 mm in diameter) were first developed by the CTC on an experimental basis and used briefly on bluefin tuna in the middle to late 1970s (Scott et al. 1990). These tags were later miniaturized for use in smaller king mackerel *Scomberomourus cavalla* and red drum *Sciaenops ocellatus* in the 1980s (Fable 1990; Gutherz et al. 1990). Gutherz et al. (1990) first reported encouraging results using a nylon anchor dart tag prototype (E series tag) on red drum at the Fish-Marking Techniques Symposium (Parker et al. 1990) in September 1989. They found that fish tissue (connective tissue and muscle) encapsulated and adhered to the nylon anchor head within a minimum of at least 166 d after placement. In fact, Gutherz et al. (1990) reported that tags so encapsulated were almost impossible to take out by hand and had to be cut out of the fish with a knife.

The findings of Gutherz et al. (1990) motivated The Billfish Foundation (TBF) and the NMFS to jointly develop a larger nylon anchor for a tag that could be used on billfish and other large highly migratory species. A formal agreement between these two agencies to develop the hydroscopic (porous) nylon tag was finalized in late 1990. This agreement also included provisions to increase cooperation between these agencies in running the constituent-based tagging programs. For example, TBF agreed to provide NMFS with electronic copies of the release and recovery database on a regular and timely basis (Peel et al. 1998).

During the initial tag development phase, the design of the two nylon barbs of the anchor was modified to expand outward into the adjacent musculature with backward pressure. This feature resulted in their designation as "intramuscular tags." The anchors of the tags were made in an injection mold with hydroscopic nylon, similar to surgical grade nylon. The intent was to eventually develop an anchoring mechanism that could: be placed easily and properly by fishers using in-water tagging techniques on large, highly migratory species; increase

1. The mention of commercial products or entities does not imply endorsement by the National Marine Fisheries Service or the authors.

the biological compatibility of the tags to encourage the adherence of tissue to the nylon anchor to minimize long term shedding; and increase the short-term retention of the tag, even when accidentally placed in muscle tissue, using an intramuscular anchoring system. Since tag placement on a live fish using in-water tagging techniques is inherently imprecise, the use of intramuscular tags was considered an improvement over the stainless steel dart tag that worked best when carefully placed and anchored between dorsal spine pterygiophores. The stainless steel material used to make the anchor was also relatively soft, pliable, and easily bent when pulling this tag out of the fish. Conversely, the barbs of the nylon anchor were virtually impossible to bend. In addition, hydroscopic nylon is a relatively inert material compared with stainless steel. This feature was thought to be an advantage in reducing the instances of tissue inflammation and necrosis, which were often observed near the stainless steel tag wound site in recaptured fish. Necrotic and inflamed tissue surrounding the anchoring site was thought to contribute to tag shedding.

The Billfish Foundation started distributing an 8-mm diameter hydroscopic nylon anchor dart tag to tagging program participants in late 1990 (Peel et al. 1998). Parallel to the field application of the larger nylon dart tags used on billfish by TBF, a joint double-tagging study on billfish, comparing the tag retention of stainless steel dart tags (hereafter referred to as steel tags or Tag A, Figure 2, top) and the TBF nylon anchor tags (hereafter referred to as nylon tags or Tag B, Figure 2, bottom) was initiated by TBF and NMFS in 1990. By 1995, the CTC adopted the TBF design as the primary tag issued to participants based on three lines of evidence: results testing a miniaturized version of the TBF design on red drum and red snapper held in captivity were very encouraging and indicated superior retention qualities of the double-barb nylon anchor (Jones, in press); the TBF tag recovery rates for billfishes the first four to five years of using the nylon tag were comparable to, or better than, those of the CTC using the steel tag (Peel et al. 1998); and preliminary results of a comparative tagging study, comparing the tag retention of the nylon tag with the steel tag used on billfish (Figure 3) indicated better tag performance and retention qualities of the nylon tag relative to the steel tag (Jones et al. 1996).

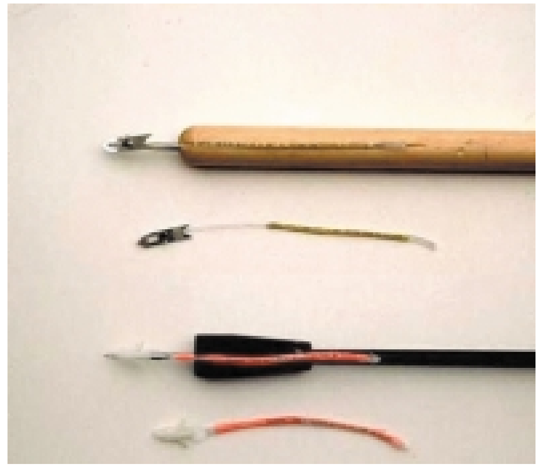


Figure 2. Stainless steel dart tag, Tag A (top) and hydroscopic nylon double-barb dart tag, Tag B (bottom) used in the double-tagging study to evaluate retention of the two tag types on billfishes (1990–1999).

Tag Recoveries

The primary source of information for the CTC has always been the recovery of tagged fish. For many years, however, promotion of the recovery aspect was a secondary consideration (Scott et al. 1990). As a part of recent efforts to improve the quality and quantity of tag recovery data, tagging kits (Figure 4), which have been issued to CTC participants since the program's inception, are continually modified. Currently these kits include: a zip-lock plastic container for storage of tagging materials; the most recent issue of the NMFS tagging newsletter which summarizes current tagging results and procedures; a CTC brochure explaining the program of tagging procedures; a tag release flag; (5) tag release cards with tags; a fish tag issue "report card" (i.e. inventory card); a stainless steel applicator; if requested, a tagging pole; and most recently, a fluorescent orange recapture (recovery) card. This last item was added because experience with tag recoveries indicated that the majority of the fishing public did not remember the information needed to report a recapture. Fluorescent orange was chosen as the color for the card, allowing it to be located easily when needed. Also, to facilitate reporting, the legend on the dart tag was modified to include a toll-free phone number and the CTC address.

As part of this overall effort to improve tag recovery rates, outreach efforts promoting the use of recovery cards and other tag recovery aspects have been made in the domestic and international media through the CTC tagging newsletter and the ICCAT Tag Recovery Network (Block et al. 2001). Recovery cards, now printed in English and Spanish, have been made available to recreational and commercial fishing constituents at important fishing sites both in the United States and abroad.

To provide an incentive to report a tag recovery, a small monetary reward (US$5) used to be awarded. After 1981, this policy was changed and currently a hat, embroidered with the emblems of the program, is sent to participants reporting recoveries. In addition, ICCAT supports a $500 annual lottery drawing for constituents reporting tag recoveries for the major pelagic species.

Tagging Research

Comparative Tag Retention Study

A comparative double-tagging study was conducted to determine which of two tag types had the best retention qualities when applied by fishery constituents using an in-water approach on large billfish. The null hypothesis to be tested stated that retention of the steel tag (tag A, FH 69S or R series) and the nylon tag (tag B, BF or HM series) was equal (Figure 2). The only difference in design between the two tags was the anchoring mechanism—stainless steel versus hydroscopic nylon. The length and diameters of the streamer portions of the tags, as well as the length of tag applicators that determine depth of anchor penetration, were the same. We recommended that one tag be placed on each side of the billfish.

Comparative Tagging Methods. Double-tagging procedures were developed to minimize factors that might have a differential effect on tag retention. Only experienced commercial and recreational fishery constituents who had previously participated in TBF and CTC billfish tagging programs were allowed to participate in this study (Ortiz et al. 1999). This was done to reduce individual tagger variation and to standardize (to the extent possible) tagging techniques. We opted to use experienced fishery constituents for tagging, instead of scientists or trained technicians, because the new tag was developed for use in the constituent-based CTC and TBF tagging programs (Dugger 1992[2]). In addition, using scientists and trained technicians for tagging was beyond the financial feasibility of this project. We recommended that one tag be placed on each side of the billfish, whenever possible, to avoid physical contact between tags. Tagging on both sides also increased tag visibility and the potential for recoveries. However, tagging on both sides of the fish usually involved longer handling times, and this was not always possible under field conditions. When tagging on the same side of billfish could not be avoided, we recommended that the two tags be inserted far enough apart that the tags could not touch each other (Figure 3).

Tagging kits for the double-tagging study were assembled by NMFS and distributed by TBF. Each tag release card in the kit had steel and nylon tags attached. The alphanumeric tag numbers were printed on each tag release card prior to distribution. The numeric serial numbers for both tag types were matched for each pair of tags, but the steel tag used an R prefix, and the nylon tag used a BF or HM prefix in front of the serial number of the tag legend. Each tag type required a different stainless steel applicator, and several applicators of each type were also supplied to participants. The color of the legend for the steel tags (Tag A) was yellow, while the legend of the nylon tag (Tag B) was orange. Specific instructions for participating in the tagging study were communicated to participants by written instructions, telephone calls, popular media[2], and the CTC newsletter (Jones et al. 1995).

Figure 3. A hydroscopic nylon double-barb dart tag (left) and a stainless steel dart tag (right) used to double tag billfish, such as this blue marlin, to assess the relative retention of the two tag types.

2. Dugger, A. 1992. The Billfish Foundation. Sport Fishing Magazine. 1992. February:47–51. World Publications, Inc., Winter Park, Florida

Statistical Analysis. Data from the double-tagging study were compiled and analyzed at the CTC. A relative tag retention rate (RRR) was calculated as the total number of steel tag returns (defined as fish recaptures with both steel and nylon tags plus fish recaptures with only steel tags) over the total number of nylon tag returns (defined as fish recaptures with both nylon and steel tags plus fish recaptures with only nylon tags). A 2×2 contingency table of tag type (steel and nylon) and tag fate (return or loss) was used to test the null hypothesis that the retention of steel tags was equal to the retention of nylon tags (Snedecor and Cochran 1967). The corresponding chi-square statistic was estimated as

$$X^2 = \sum ij[(f_{ij} - F_{ij})^2 / F_{ij}]$$

for i = 1, 2 (Tag Type) and j = 1, 2 (Tag result; 1 Return, 2 Lost).(1)

where:

f_{ij} = observed number of tag recaptures for steel and nylon tags

F_i = expected - number of tag recaptures for steel and nylon tags

This analysis assumed that there was no difference in tag retention rates among fish species and that immediate shedding after the tagging procedure (Type I tag shedding) was similar for both tag types. It also assumed that there was a sufficient time between release and recapture events, such that the differences in tag retention were mainly due to each tag type's retention qualities.

Individual Tagging Performance

Throughout the years of the program, many of the improvements in tagging equipment, fish handling procedures, and methods of dehooking and resuscitation were developed by captains who were major participants in the CTC (Jones et al. 1995). As a quantitative measure of how these improvements could affect tagging performance, we evaluated tag recapture rates of fish tagged by some of the top individual CTC participants as a proxy for tagger performance. Tags used in this particular fishery were from the CTC as well as from The Billfish Foundation. Individual tag recapture rates were then computed for the top captains in order to provide insight into tagger performance.

Results and Discussion

Comparative Tag Retention Study

A total of 3,038 marlin, sailfish, and swordfish, were double-tagged with the steel (R series) and nylon tags (BF/HM series) from 1990 to 1999 (Table 2). Of these, 1,069 were blue marlin, 947 were sailfish, 590 were swordfish, and 432 were white marlin. More than 50% of the total number of double-tagged billfish were tagged by only seven individuals. During the ten-year duration of the project, 2.8% or 86 billfish (including swordfish) were recaptured; 41 had both tags present; 11 had only steel tags present; and 34 had only nylon tags present (Table 2). The relative tag retention rate (RRR) for each species was 85.7% for blue marlin, 64.7% for white marlin, 57.7% for sailfish, 72.7% for swordfish, and 69.3% for all species combined. Therefore, the improved retention of the nylon tags compared with steel tags for these categories ranged from 14.3% (blue marlin) to 42.3% (sailfish). Assuming all other factors influencing tag retention remained constant between species, steel tags were retained 69.3% as well as nylon tags for all species combined. The chi-square statistic using a 2×2 contingency table for all billfish species combined was highly significant (X^2 = 15.92, P = 0.0001, with 1 df), and the null hypothesis was rejected.

Better tag retention of the nylon tag is also supported by a recent report that indicates improvements in the tag recapture rates for each species of billfish in the Billfish Foundation and CTC tagging programs over the last decade (Jones and Prince 1998; Prince et al. 2000). This is highlighted by the recapture rates for Atlantic white marlin in the TBF tagging program, which has achieved recapture rates greater than 2% for the first time since the program started in 1990. No other constituent-based tagging program targeting Istiophoridae throughout the world's oceans have reported recapture rates this high (Murray 1990; Pepperell 1990; Scott et al. 1990; Holts and Prescott 2000; Ortiz et al., in press).

Individual Tagging Performance

A total of 6,421 bluefin tuna were tagged and released off Hatteras, North Carolina, from 1994 to 1999 (Table 3). The biggest single release year for this fishery was 1996, when a total of 2,827 bluefin

Table 2. Comparative tagging study for blue marlin, white marlin, sailfish and swordfish in the North Atlantic using steel tags (FH69S or R series) and nylontags (BF or HM series).The relative retention rate (RRR) is calculated as the numbers of steel tags retained over numbers of nylon tags retained (see text).

	Number of fish		*Number of tags returned*			*Relative retention*
Species	*Double tagged*	*Recaptured*	*Both*	*Steel*	*Nylon*	*rate (%)*
Blue marlin	1,069	26	13	5	8	85.7
White marlin	432	18	10	1	7	64.7
Sailfish	947	29	12	3	14	57.7
Swordfish	590	13	6	2	5	72.7
Total	3,038	86	41	11	34	69.3

Table 3. Tag releases and recaptures of bluefin tuna by the Hatteras, North Carolina recreational fishing fleet, 1994-1999. Tagging agencies include the Cooperative Tagging Center (CTC) and the Billfish Foundation (TBF).

	Number released			*Number recaptured*		
Year	*NMFS*[a]	*TBF*[b]	*Total*	*NMFS*	*TBF*	*Total*
1994	37	9	46			
1995	671	123	794	11	3	14
1996	1,688	1,139	2,827	52	20	72
1997	1,830	599	2,429	89	50	139
1998	187	14	201	22	8	30
1999	124	– c	124	10	– c	10
Total	4,537	1,884	6,421	184	81	265

a. Tagging agency, CTC, NMFS
b. Tagging agency, TBF
c. No data

tuna were tagged and released from this location using both the CTC and TBF tags. The historical bluefin tuna tag recapture rate in the CTC from 1954 to 1999 was about 12% (Table 1), with the majority of these returns being made within the first six years after release. Although 265 bluefin tuna recaptures of the Hatteras releases have been reported through 1999, this represents a recovery rate of only 4.1%. However, these results are expected to improve as the time at liberty for many of these releases increases and allows for additional recoveries. This analysis evaluated the top captains who participated in the Cape Hatteras bluefin tuna fishery (releasing > 400 fish) from 1994 to 1999.

The most substantive contribution to the tag and release effort during this period was made by the seven captains of the Hatteras, North Carolina fishing fleet who accounted for 67% of the total number of releases and a similar percentage of recoveries (Figure 5). The tag recapture percentage for fish released by six of the seven captains was close to or exceeded the 4.1% average from 1994 to 1999 (Figure 6), and the top recapture percentage for an individual captain was 5.7% (Figure 6). One of the outcomes of this intensive effort was the development of innovative tagging equipment and procedures that

Figure 4. Many of the components of the Cooperative Tagging Center kits remained the same since the program started in 1954. However, incentives for return of tag recaptures changed after 1981 from monetary rewards to embroidered hats. In addition, fluorescent orange tag recapture cards were added to the kits in 1992.

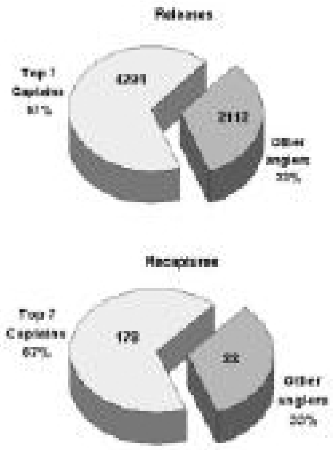


Figure 5. Bluefin tuna tag releases (top) off Hatteras, North Carolina, 1994–1999. Tag recaptures of Hatteras-released bluefin tuna (bottom), 1994–1999.

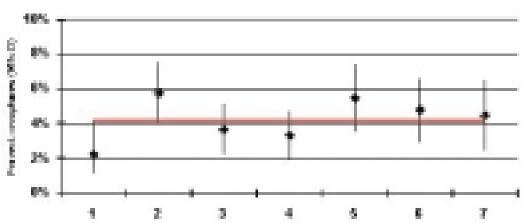


Figure 6. Tagging performance of the top seven captains (releasing > 400 fish) participating in the recreational fishery for bluefin tuna off Hatteras, North Carolina, 1994–1999. The solid horizontal line represents the overall percent recapture rate for all bluefin tuna released off Hatteras, North Carolina, from 1994 to 1999.

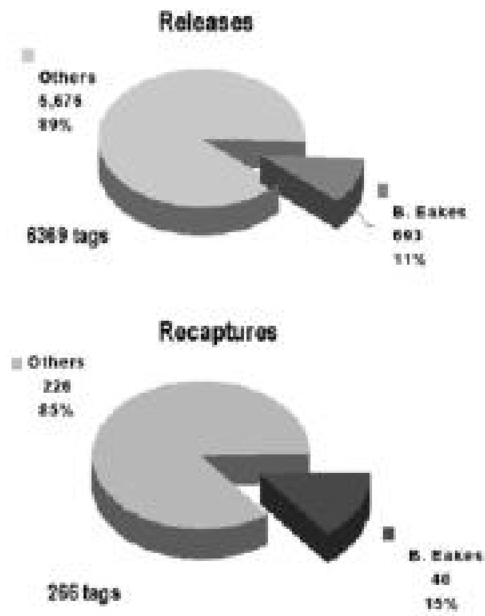


Figure 7. Captain Bob Eakes released 11% of the total number of tagged bluefin tuna off Hatteras, North Carolina. 1994–1999 (top). Fifteen percent of the Hatteras bluefin tuna released by Captain Eakes off Hatteras, North Carolina, were subsequently recaptured (bottom).

Figure 8. Circle hooks used in combination with dead natural bait and heavy chumming (i.e., chunk fishing) by the Hatteras fishing fleet targeting bluefin tuna.

were subsequently adopted by the CTC (Jones et al. 1995; Ortiz et al. 1999). For example, tagging innovations certainly contributed to the performance of one of the top captains[3] in the Hatteras fleet, who accounted for 11% of the total number of tag released bluefin tuna (1994–1999), while the recaptures for this captain represented 15% of the total number of recaptures resulting from Hatteras released bluefin tuna (Figure 7). These tagging procedures included: use of circle hooks in combination with dead natural bait to minimize hook injuries (Figure 8); use of a dual applicator tagging pole with parallel and perpendicular applicators for greater accuracy in tag placement (Figures 9 and 10); use of a dehooking tool to remove circle hooks (Figure 11) to minimize

3. Captain Bob Eakes was one of the top tagging participants in the Hatteras fleet. He had the highest bluefin tuna tag recapture percentage of any participant in this fishery (5.7%; Figure 6) and accounted for 11% of all tag released Hatteras bluefin (Figure 7), while about 15% of the recaptures from Hatteras releases were originally tagged by Captain Eakes (Figure7). These included five transAtlantic recoveries. Captain Eakes developed numerous tagging innovations and procedures while participating in the Hatteras bluefin tuna fishery, and many of these procedures were eventually adopted by most of the Hatteras fleet, as well as the CTC.

Figure 9. Dual applicator tagging pole, with a perpendicular as well as parallel applicator, used to improve the accuracy of tag placement into giant bluefin tuna caught off Hatteras, North Carolina (see text).

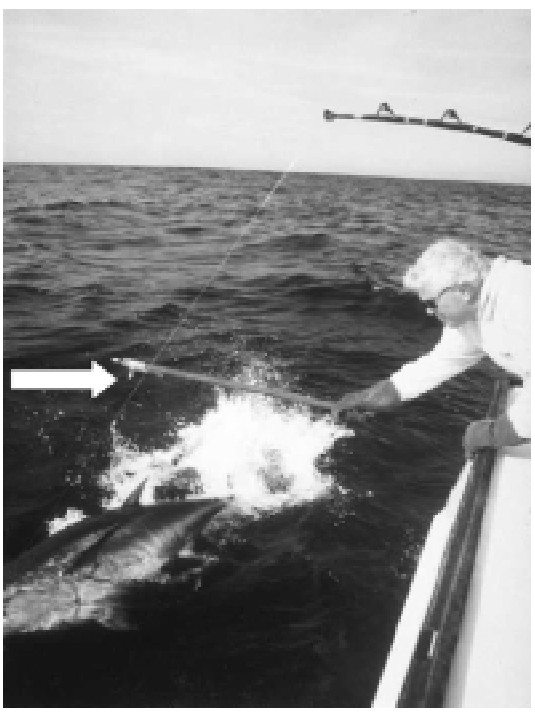


Figure 10. Use of the perpendicular applicator (see white arrow) to tag bluefin tuna when they turn sideways to the boat improves the precision of tag placement.

post release trauma; and use of resuscitation techniques (Figure 12) prior to releasing fish in order to improve the short-term condition of the tagged fish.

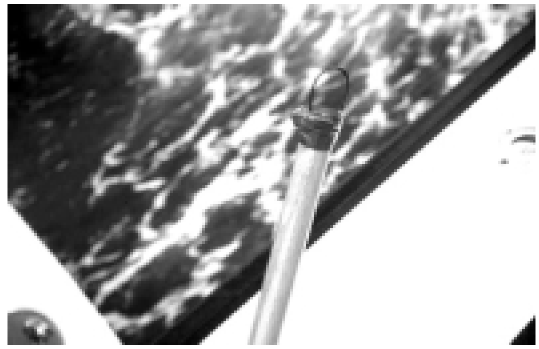


Figure 11. Dehooking device for removing circle hooks from bluefin tuna. The wire loop (see white arrow) is put under the point of the circle hook lodged in the jaw hinge and the hook is pulled through the hook wound; the hook is then cut from the leader, which is pulled back through the wound to release the fish.

Tagging Procedures

It is inherently more difficult to tag a large, active fish in the water than it is to tag a smaller fish that can be controlled aboard a boat where precise placement of the tag can be accomplished. For this reason, development of in-water techniques that can be used easily, safely, and effectively by volunteer recreational and commercial constituents targeting large, highly migratory species has been a challenge. Nevertheless, tagging equipment and procedures for catching, tagging, dehooking, and resuscitation have improved over the past 46 years of the CTC.

Fishing Techniques

The general types of fishing techniques used by participants in the CTC for tagging large, pelagic species include rod and reel trolling with artificial baits, rod and reel trolling with natural live or dead baits, rod and reel still fishing with natural live or dead baits, longline fishing with natural dead or live baits, and purse-seine fishing. Consistent with the theme of promoting the live release of fish tagged in the CTC, we strongly recommend the use of circle hooks as terminal gear (a hook where the point is at a 90-degree angle to the hook shaft), whenever possible. Use of circle hooks is particularly appropriate whenever live or dead bait fishing techniques are used, as with fishing techniques 2, 3, and 4 (above). This recommendation is supported by the most recent research on the use of circle hooks for recreational fishing for billfish and tuna, which indicates this terminal gear promotes the live release of these species by minimizing deep hooking, foul

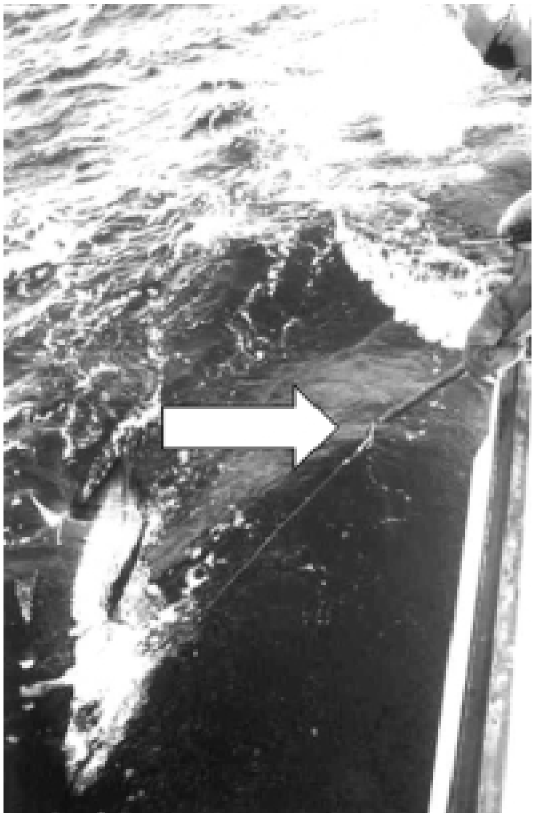


Figure 12. Resuscitation techniques for bluefin tuna caught on circle hooks. A dehooking device (see Figure 11) or a small gaff is used to pull the hook (white arrow) through the hook wound and hold the fish in place during resuscitation. After resuscitation is finished, the hook is cut and the leader is pulled back through the hook wound to release the fish.

hooking, and bleeding (Prince et al; Skomal et al, both this volume). One caveat that needs to be recognized with the use of circle hooks is that any offset of the point of the circle hook greater than about four to six degrees can result in deep hooking rates comparable to "J" hooks (Prince et al., this volume). In addition, reports by Berkeley and Edwards (1997) and Falterman and Graves (this volume) indicate that billfish and tuna caught on circle hooks during longline fishing also have markedly less physical damage associated hook trauma using this terminal gear, in contrast with straight shank or "J" hooks.

Fish Handling

Handling large, highly migratory species at boat-side is one of the most difficult parts of the tagging process; therefore, the decision to tag or not should be left to the discretion of the captain. For very large tuna and billfish, two deckhands are normally used, one to control the fish using the leader and the other to tag (Figure 13). One of the primary considerations is whether the fish is "played down" to a point where it is subdued near the boat. As a rule of thumb, tagging green fish (i.e., fish that are very active or wild when brought near the boat) is not recommended and can be very dangerous to the crew and the fish itself, as well as risking damage to the boat. The more active the fish, the more difficult it is to place the tag in the correct target location (Figure 14). Very experienced crews do attempt to tag fish that are not completely subdued, and the decision to proceed should always be made by experienced captains familiar with their crew's abilities to tag properly. The entire tagging process, including fish handling, becomes increasingly more difficult in rough seas, and this should also be considered when deciding to tag. One of the recent innovations that can improve billfish handling at boat-side is the use of a tool called a snooter (Figure 15). This tool is composed of a plastic polyvinyl chloride (PVC) pipe with a rope running inside that leads to a multistrand stainless steel wire loop. The loop is placed over the upper bill of the billfish, pulled tight, and the fish is secured by tying off the rope on a cleat of the boat. The snooter allows the fish to be secured while submerged in the water during the tagging process, eliminating the need for a crew member to hold the bill of the fish, which can be very dangerous.

Figure 13. Two crew members tagging a large blue marlin, one handles the leader and brings the fish alongside the boat and the other inserts the tag.

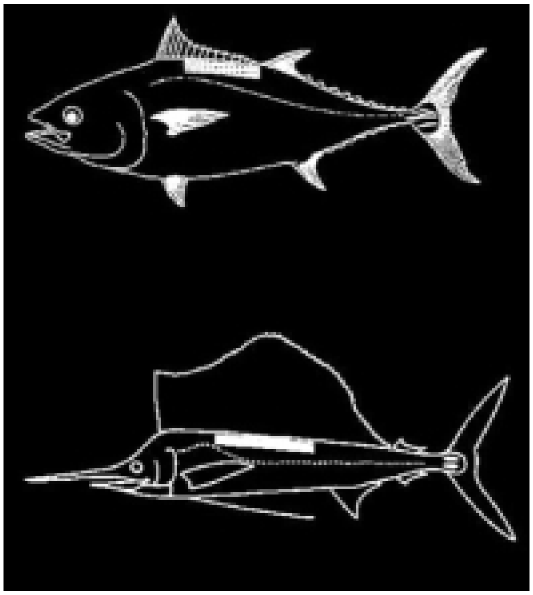


Figure 14. Target area (rectangles) for tagging tuna (top) and billfish (bottom) recommended by the Cooperative Tagging Center. Tags should be placed above the lateral line, away from the head and other vital organs along the dorsal musculature.

Figure 15. A "snooter" used to control a billfish at boatside during the tagging process. The snooter is made of a plastic PVC pipe and has a rope running through it connected to a wire loop. When pulled tight, the upper bill (see white arrow) is secured and the snooter rope is tied to a cleat.

Tagging Procedure and Equipment

The results of the comparative tagging study indicate that, when applied by fishery constituents, the nylon tag facilitates better retention compared with the steel tag (Table 2). Therefore, we recommend the use of the nylon tag for constituent-based tagging programs that apply in-water tagging techniques targeting large, highly-migratory species. The biological compatibility of the hydroscopic nylon material and the unique design of the double barbs, which promote intramuscular anchoring, likely contributed to the improved rates of retention observed in the double-tagging study. This is particularly true in situations where in-water tagging is dictated by the large size of the fish and often results in imprecise tag placement, as compared with in-boat tagging where precise tag placement is easily accomplished.

One of the most important factors in tagging large, highly migratory species involves proper tag placement in the desired target area (Figure 14). For both billfish and tuna, the tag should be placed in the dorsal musculature, above the lateral line and away from the head, gills plates, eyes, and other vital organs. This tag position will promote rapid healing of the tag wound and minimize the chance for serious injury. The target area advertised in the early part of the CTC was closer to the head than the current target area. However, over time, we have found that a target area starting just posterior to the gill plates was risky due to possible movement of the fish, which sometimes resulted in tags being lodged inappropriately (Figure 16). The preferred way for inserting the tag into the fish is to take a downward or dorsal tag placement approach over the

Figure 16. Poorly placed tags, such as this one in the cranium (white arrow), are likely to account for a large proportion of tag shedding.

fish's back (Figure 13). The tag should be placed as close to the dorsal spines as possible. Tags should be placed away from the head at a distance equal to at least one half the length of the pectoral fins. We recognize that dorsal tag placement over the back of the fish cannot always be accomplished because many fish, particularly tuna, turn sideways when brought alongside the boat (Figure 10). This also happens periodically with billfish. The dual-applicator tagging pole (Figure 9) promotes improved tag placement in these situations, due to the added flexibility of being able to insert the tag with a hammering motion using the perpendicular applicator (Figure 10). By equipping the tagging pole with dual applicator pins (parallel and perpendicular), the tagger has the flexibility to make last minute adjustments in the way the tag is placed in the fish, depending on the position of the fish at boat-side.

The dorsal tag placement approach avoids the dense concentration of highly vascularized red muscle tissue adjacent to the lateral line. This area should be avoided in order to minimize hemorrhaging and promote healing of the tag wound. In most species of billfish and tuna, there is little, if any, red muscle tissue along the back next to the dorsal spines. *Poor tag placement can kill fish*, particularly if vital organs are damaged (Figure 17). Sublethal effects of poor tag placement can result in less than optimum tagging results, which contribute, at best, to tag shedding or infection (Figures 16 and 18), or, at worst, to mortality (Figures 17). As a general rule of thumb, it is better to slow down the tagging process and wait for the fish to be subdued at boat-side to ensure proper placement of the tag in the target area.

When inserting the tag, the depth of tag placement is determined by the length of the stainless steel applicator that extends beyond the tagging pole. After 1997, the stainless steel applicator issued by the CTC was increased from two to three inches for both the TBF and CTC tagging programs to allow for deeper tag placement. We *strongly* encourage the use of this longer applicator, even in the smallest sailfish, which are still large enough to accommodate a 3-in deep placement of the tag.

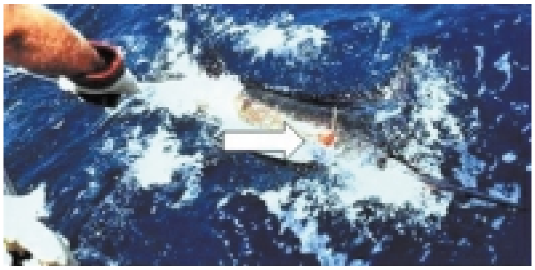


Figure 17. Poor placement of tags, such as this one near the edge of the operculum in a white marlin, can result in mortality, particularly if vital organs are damaged. Note the bleeding from the tag wound (see white arrow).

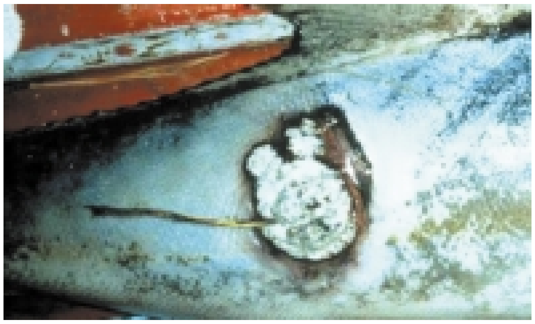


Figure 18. Serious infections that do not result in mortality can result from poor tag placement. This fish was recovered after several months and the wound was caused by the placement of the tag below the lateral line, in the vicinity of the caudal portion of the peritoneal cavity.

Figure 19. Measures of length can usually be obtained with a fiberglass tape, as illustrated here with a blue marlin.

Measuring Fish Length

Prior to release, if possible, we recommend measuring the length of the fish (Figure 19). One approach used by CTC participants is to use a fiberglass tape to measure lower jaw fork length for billfish or fork length for tuna. The fish must be calm at boat-side as, even under these circumstances, getting an accurate measurement is difficult. Some participants have developed customized measuring tapes or ropes with a clip at one end to go over the leader and rest at the jaw hinge. A tennis ball is often fixed to the other end and trails along the fish's back towards the tail. Several markings are usually made on the tape to correspond to the maximum length standards for each species of Atlantic billfish or tuna. This method does not always result in an exact measure of length and usually necessitates some extrapolation to compensate for the length lost by starting the measurement at the jaw hinge, instead of at the tip of the lower jaw. However, this approach is usually better than guessing.

Dehooking

For the first 40 years of the CTC, most participants were advised not to remove the hook from the fish. Instead, the instructions suggested that priority should be given to keeping the tagging event short and cutting the leader as close as possible to the fish. The Hatteras fishery for bluefin tuna provided an opportunity to observe and examine about 100 tag recaptures, particularly wounds that resulted from hooks left in fish. Observations of these returns indicated that removing hooks is preferable, if circumstances permit, since approximately 25% of the hooks remained in the fish more than a year after release, and hook wounds and related infections were commonplace. In addition to the dehooking tool developed for circle hooks (Figure 11), other commercially available dehookers (Figure 20) developed for "J" hooks have been reported to be effective by CTC participants and the manufacturers and should be used whenever possible.

Resuscitation

Resuscitation is normally considered only when a fish is too weak from the fight to swim away from alongside the boat under its own power. Failure to resuscitate a weak fish can result in mortality from exhaustion or predation by sharks. The techniques for resuscitation of tuna and billfish differ somewhat because billfish have an extended upper bill, which serves as a "handle" during resuscitation, while tuna do not. The resuscitation techniques for bluefin tuna are recommended for tuna caught on circle hooks (Figure 12). If tuna are caught on "J" hooks, resuscitation may require the crew to simply keep the hook(s) in place until the fish regains strength. There are several different approaches for resuscitation of billfish. Some captains have their crew lean over the gunnel and hold onto the upper bill with the head of the fish submerged, while towing the fish slowly at two to three knots until they observe the fish has regained strength. This approach is very difficult to apply during rough sea conditions and can be quite dangerous. A preferred approach for resuscitation of billfish is to use a heavy fishing outfit (130-lb gear) with 1,000-lb test nylon cord as the terminal leader. The cord is tied to the upper bill with a slip knot, and the fish is towed ahead slowly at two to three knots (about 40–50 yards or 36–46 m) behind the boat until the angle of the line decreases from about 160 degrees to 45 degrees (Figure 21). As the fish regains strength and is able to maintain its body position in the water column, the angle of the line will decrease. When the fish has regained its strength, the fish is led back close to the boat, the slipknot is pulled, and the fish is released. This approach to resuscitation provides the crew with a more objective basis for deciding when the fish is ready to be released and is much safer than having a crew member lean over the gunnel and hold the upper bill with the head submerged. Use of a snooter is another option for resuscitation of billfish that avoids the problem of having a crew member hold the upper bill during resuscitation (Figure 15).

Figure 20. Commercially available de-hookers are very effective in removing "J" hooks from large highly migratory species.

Tag Release Card

An essential element to the success of any tagging program is that participants conscientiously fill out tag release cards promptly after the tagging event. When participants do not take the time to properly complete and return the release cards, release data will be unavailable. This problem compromises the recapture data and negatively impacts the program.

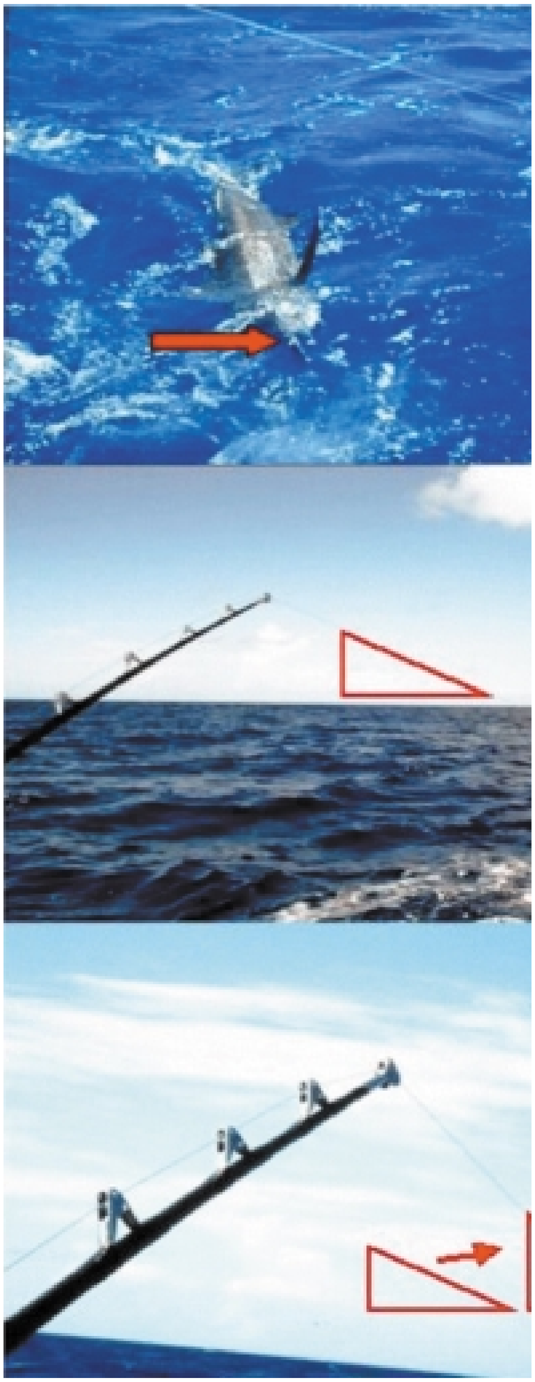


Figure 21. One way of resuscitating billfish is by tying 1,000 pound nylon cord to the upper bill with a slip knot (see white arrows, top) and then towing the fish slowly (2–3 knots) until the angle of the line decreases from about 160 degrees (middle red triangle) to about 45 degrees (bottom red triangle), which indicates the fish has recovered (see text).

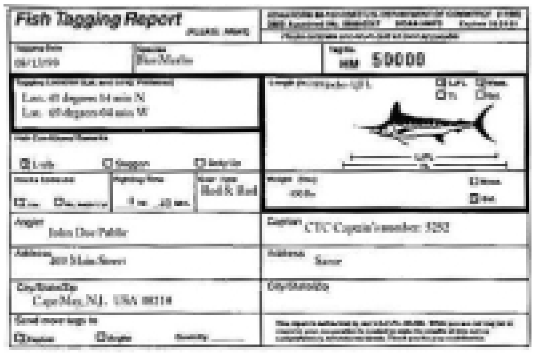
When fishing is good, there is often not enough time to completely fill out the release cards immediately after the fish is tagged and released. In this situation, we suggest that, at a minimum, the date, species, estimated size, and location be filled out immediately. These critical components of the release card are highlighted in bold print on the card (Figure 22), while the remaining information can be completed at a later time.

A major problem associated with missing release cards arises when a participant who was issued tags with specific identification numbers gives these tags to someone else. This practice should be avoided as it hinders the program's ability to match tags to individuals. To make the tagging program work, it is necessary to properly fill out the tag release card (Figure 22) and return it to the CTC as soon as possible, preferably within a week of release, since many tagged fish are recaptured during their first month at large. We also encourage participants to keep an independent log or file of personal tagging activities to ensure CTC records reflect each tagging participant's records.

Reporting Recaptures

The primary source of information for the CTC has always been the recovery of tagged fish. However, throughout the history of the CTC, the program has been known among participants and the press as a "tag and release" activity. Unfortunately, this reference has had the effect of reducing the focus on activities relative to recovery of tagged fish. Starting in the late 1980s, a number of steps were taken to highlight the critical program activity of reporting recaptured fish. Increasing the recapture rate for Istiophoridae (less than 2%; Table 1) is particularly important because of the relatively low recapture rates for this species group, not only in the CTC, but also world-wide (Miyake 1990; Murray 1990; Pepperell 1990; van der Elst 1990).

Since recapturing a tagged fish is a rare event, all fish brought alongside the boat should be examined on *both* sides to see if a tag is present. It is not always easy to recognize a tagged fish, since marine growth often covers the legend, and as the fish grows, the length of the legend extending outside the fish is reduced over time (Figure 23). The CTC database has many instances where fishers have tagged a fish and released it, only to notice another tag on the other



Fish Tagging Report

HM 50000

Figure 22. Current tag release card issued to participants in the Cooperative Tagging Center.

Figure 23. This tag-recaptured blue marlin had been at large for more than seven years. The tag legend is difficult to see because it is covered by green algae and the growth of the fish has reduced the length of the legend extending outside the fish.

side of the fish as it swam away. Recaptured fish should be reported to the CTC or a local fisheries conservation agency as soon as possible.

Recommendations

Tag Release Activities

Conditions and opportunities for using in-water tagging techniques can vary depending on numerous factors, including weather, species, and circumstances involving individual fish. The following general recommendations should be considered when using in-water tagging techniques on large, highly migratory species:

(1) Use circle hooks whenever possible (i.e., while using dead or live bait), as this terminal gear minimizes deep hooking, foul hooking, and bleeding. Thus, circle hooks reduce the physical trauma related to hook damage and promote the live release of tagged fish. Use of circle hooks on lures is not recommended at this time, due to incomplete information;

(2) Only attempt to tag fish that are calm or subdued at boat-side. If the fish is still active, slow down the tagging activity and wait until the fish is subdued before attempting to insert the tag in the target area. Speed tagging lends itself to inaccurate tag placement, increases the potential of injuring the fish as well as the crew, or can cause damage to the vessel. For these reasons, we discourage speed tagging;

(3) When possible, use a snooter on billfish, as this tool increases the control over the fish and reduces the injury hazards to the crew;

(4) Attempt to measure the length of the fish when circumstances permit, as measured size is always better than estimated size;

(5) Use a dual applicator tagging stick to increase the flexibility of the angle of tag entry and promote accurate tag placement. This is particularly important when tagging tuna and billfish that often turn sideways when they are brought alongside the boat;

(6) Use appropriate hydroscopic nylon double-barb dart tags, as these tags have significantly higher retention rates compared with stainless steel dart tags, when applied by recreational and commercial constituents using in-water tagging techniques on large, highly migratory species;

(7) Remove hooks whenever possible. Use of a dehooker can facilitate quick and easy de-hooking;

(8) Resuscitate all fish that show an inability to maintain their body position in the water due to exhaustion from the fight. Resuscitation methods can differ between tuna and billfish. A snooter can be helpful in resuscitating billfish; and

(9) Fill out fish tagging report cards immediately and mail them back to the appropriate tagging agency as soon as possible.

Tag Recapture Activities

The following recommendations for tag recovery should be adopted by all fishers, even those that do not participate in the tagging portion of the program:

(1) Examine the dorsal musculature on both sides of each fish caught to see if a tag is present;

(2) If the fish is going to be taken legally, cut the old tag off. Measure and record the length and weight of the fish. If the fish is to be released, lean over the side of the boat, cut the old tag off and re-tag the fish so it can be rereleased. In this case, try to measure the length of the fish before release. Tags that look old can indicate that the fish has been at large for a long time, and long-term recaptures are particularly valuable;

(3) Record the recovery information, including species, latitude and longitude of the recapture site, date, method of fishing, and size of fish on the CTC fluorescent orange tag recapture card; and

(4) Report tag recovery information to the appropriate fisheries agency as soon as possible. Contact information is printed on the tags. You can get additional Atlantic tagging information for large pelagic species from the following web-sites: Southeast Fisheries Science Center [http://www.sefsc.noaa.gov/], Atlantic States Marine Fisheries Commission [http://fwie.fw.vt.edu/tagging], The Billfish Foundation [http://www.billfishfoundation.org], and the International Commission for the Conservation of Atlantic Tunas [http:// www.iccat.es].

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