Bycatch Initiative: Eastern Pacific Programme

A vehicle towards sustainable fisheries

Progress report of fishing experiments with modified gear (2004-2007)

25 July 2008

This report was prepared by WWF and IATTC. There are many other partners engaged in the programme, and their support and commitment have made these conservation activities possible. For a complete list of acknowledgments, please refer to page 35 of the report.

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Progress report of fishing experiments with modified gear (2004-2007)

Dated: July 25, 2008

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A full list of program partners by country is provided in Table 1

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1.0 Executive summary

In 2003, WWF started a joint venture project with the Inter-American Tropical Tuna Commission (IATTC) and other partners to save marine turtles from long-line fisheries bycatch in the Eastern Pacific Ocean. Since then, the program has grown to become a region-wide bycatch network and the largest regional artisanal fisheries conservation program in Latin America.

Key initial partners of this program include IATTC, NOAA, Ocean Conservancy, the Western Pacific Regional Fishery Management Council (WPRFMC), the Overseas Fisheries Cooperation Foundation of Japan (OFCF-Japan), and WWF.

The program works under three ruling principles:

1. Nobody wants to harm or kill turtles.
2. Nobody wants to put fishermen out of business.
3. Participation of fishermen and vessels in the program is voluntary.

The method of work is unique as it is testing alternative gear and best practices under "real life" fishing conditions operating in several fisheries, in vessels of different sizes and navigational autonomy, at a regional scale.

Objective

The objective is to reduce the threat to marine turtle populations in the Eastern Pacific Ocean due to bycatch interactions in long-line fishing operations. To achieve this objective, the program is working cooperatively with fishermen, boat owners, governments and other key stakeholders to identify and test means to reduce marine turtle bycatch and reach a massive transformation of the long-line fleets towards the adoption of best fishing practices for sustainable fisheries.

This participatory approach to marine turtle bycatch mitigation has several benefits:

1. It allows direct trials of circle hooks by fishermen.
2. Data collected by observers are entered into the database and as more fishermen join the program and accept an onboard observer, a better understanding about the fishery and the nature of the interaction with marine turtles is gained.
3. As the number of fishermen participating in the program increases, eventual regulations coming from the fishing authority have a better chance of being supported by fishermen.
4. The project provides a practical and current opportunity for fishermen to be part of a major effort to save marine turtles to become key drivers of change. We believe that this "ownership" will lead to the dawn of a new culture of multi-sector collaboration and continuous improvement.
5. Innovative ideas coming from the direct experience of fishermen can greatly contribute to enhancing the performance of bycatch mitigation tools, and in directing the adaption of solutions to particular fishery circumstances.

Results

BCPUE values for the TBS fishery (tuna-billfishes-sharks) from the data set analyzed show overall, significantly larger turtle by-catch rates in J hooks than circle hooks (Wilcoxon Signed-ranks test for matched pairs, $T^- = 37$, $p < 0.02$, $n = 19$). The CPUE values of the TBS fishery indicate overall larger fish catch rates in circle hooks than in J hooks, but this difference was not significant (Wilcoxon Signed-ranks test for matched pairs, $T^- = 88$, $p > 0.1$, $n = 23$).

In the mahi-mahi fishery, BCPUE also followed the same pattern as in the TBS fishery, with significantly lower numbers of turtles caught with circle hooks than J hooks (Wilcoxon Signed-ranks test for matched pairs, $T^- = 101$, $p < 0.02$, $n = 27$). Again, the largest values of by-catch rates come from J hooks. The CPUE values of the mahi-mahi fishery indicate overall, significantly larger fish catch rates in J hooks than in circle hooks (Wilcoxon Signed-ranks test for matched pairs, $T^- = 101$, $p < 0.02$, $n=28$).

There are four possible types of general results from fishing experiments:

a. cases where circle hooks have fewer turtles hooked and lower fish catch rates than J hooks;
b. cases where circle hooks have fewer turtles hooked and higher fish catch rates than J hooks;
c. cases where circle hooks result in more turtles hooked and lower fish catch rates than J hooks; and
d. cases where circle hooks result in more turtles hooked and higher fish catch rates than J hooks.

The mahi-mahi fishery BCPUE and CPUE estimates fall scattered into the four categories of general results or outcome areas, with more of the points (year-port combinations) in the region of fewer turtles hooked, with a particular concentration in the lower fish catch category. Most of the data for the TBS fishery fall within the preferred outcome region of fewer turtles hooked and avoid overfishing (smaller fish catch differences with J hooks).

Further examination of possible factors influencing both bycatch and fish catch rates is needed to refine a prescription of bycatch mitigation tools. This is particularly important for the mahi-mahi artisanal fishery, since mahi-mahi is an important target species and source of income for many fishermen in the Eastern Pacific Ocean.

Discussion

After four years of work, the program demonstrates a very positive outcome trend from the circle hooks experiments. For the two long-line artisanal fisheries predominant in the Eastern Pacific, TBS and mahi-mahi, circle hooks reduce bycatch of marine turtles, in accord with the first essential condition of any bycatch solution. Circle hooks also may result in more benign hookings as preliminary suggested by the data of hooking location.

An interesting and very positive finding is that 95% of all turtles caught in long-line experiments, either hooked or entangled, were reported to have been recovered alive by observers. This finding is most encouraging since it is a strong endorsement of the value of proper turtle handling and releasing techniques by fishermen. The data also show that where entanglements constitute a recurrent problem, the use of monofilament to construct the gear could dramatically reduce entanglements.

The second most important condition that circle hooks need to meet as a bycatch solution is to catch fish at a similar rate to the J hooks they are going to replace. Preliminary findings of the experiments indicate that circle hooks do perform as well as J hooks in the TBS fishery.

Results of experiments with circle hooks in the mahi-mahi fishery show a wider range of results in fish catch rates. Here, there are more cases of where circle hooks exhibit lower commercial catch rates than J hooks. The program will continue its research in the mahi-mahi fishery to ascertain the correct fishing condition that will allow commercial catch rates to be maintained whilst simultaneously reducing turtle bycatch

Clearly, there are other challenges to make the transformation of the fleet to circle hooks a reality. These are, among others: a) making circle hooks and other bycatch tools available in local markets at reasonable and competitive prices; b) promoting the institutional adoption of the observer program by local actors to provide sustainability to the program in the medium and long term; c) continue and strengthen the awareness and education of fishermen; d) facilitate the technological adaptation and transformation of the fleet with proper regulatory measures; and e) find and develop potential markets for fish coming from fisheries with circle hooks and turtle-friendly practices.

Therefore, the work of this program will expand from its original fishing experiments focus (which will be continued) to other areas, such as those mentioned above. The intention will remain the same though, that being to ensure that solutions to bycatch can be effectively implemented to save marine turtles and at the same time laying the foundations to move the artisanal long-line fishery in the Eastern Pacific Ocean toward sustainability.

2.0 History and evolution of the program

In 2003 WWF started a joint venture project with the Inter-American Tropical Tuna Commission (IATTC) and other partners to save marine turtles from long-line fisheries bycatch in the Eastern Pacific Ocean (EPO; Figure 1). At the time, Eng. Guillermo Morán, advisor to the fish exporter association of Ecuador (ASOEXPEBLA) and the Sub-Secretary for Fisheries of Ecuador, Ms. Lucia Fernandez De Genna, asked the IATTC to help the Ecuadorian artisanal fishers reduce their bycatch of marine turtles. Dr. Martin Hall, Principal Investigator of the Bycatch Program of IATTC responded to the request from Ecuador. Dr. Hall, Captain Charlie Bergmann and Dr. Yonat Swimmer from NOAA, headed to Ecuador armed with a presentation about circle hooks as tools to reduce marine turtle bycatch from long-line fishing, based on results of experimental fishing conducted by NOAA (Dr. John Watson, Dr. Chris Boggs and others), and a toolbox consisting of circle hooks samples, de-hookers and other relevant equipment. They traveled along the coast of Ecuador talking to fishermen on the importance of saving turtles and improving their fishing practices. Fishermen were also informed about how fisheries contribute to the danger of extinction faced by marine turtles, and how fishermen can contribute to the solution.

The initial project idea relied on the substitution of J hooks with large circle hooks and the training of fishermen in best fishing practices, including proper on-board handling and resuscitation techniques for turtles caught by hooks, or entangled in branch-lines. As with any technological transformation in fisheries, local data on the performance of circle hooks against J hooks had to be collected in order to reassure fishermen, leading to an effective gear exchange program. The fishers were asked to test circle hooks in their own fishing vessels by performing experimental fishing trips and accepting an on-board observer that would collect catch and bycatch information.

This approach to fishing technology transformation proved successful and WWF and IATTC started building a database to compile scientific information to study bycatch interactions between marine turtles and long-line fisheries. Analysis would test the usefulness of circle hooks and other fishing gear modifications to save marine turtles. As the program expanded to other countries in the Eastern Pacific, we began to learn and understand the magnitude of the problem within the context of complex artisanal fisheries.

Current status

After four years of work, the program has grown to become a region-wide bycatch network and is estimated to be the largest regional artisanal fisheries conservation program in Latin America. Key initial partners of this program include IATTC, NOAA, Ocean Conservancy, the Western Pacific Regional Fishery Management Council (WPRFMC), the Overseas Fisheries Cooperation Foundation of Japan (OFCF-Japan), and WWF. These organizations have provided important resources, while OFCF-Japan and NOAA have also provided technical expertise and equipment. The team works under three ruling principles:

1. Nobody wants to harm or kill turtles.
2. Nobody wants to put fishermen out of business.
3. Participation of fishermen and vessels in the program is voluntary.

Each of these organizations have made important contributions to the program and helped fishermen to improve their technologies and reduce marine turtle bycatch. IATTC is providing key scientific and technical guidance, based on their significant experience in solving the tuna-dolphin bycatch problem in the tuna purse-seine fishery, as well as inspiration in making sure the program maintains the best technical level possible.

NOAA has provided circle hooks for the initial trials, funding and technical and scientific support and advice. The Western Pacific Regional Fisheries Management Council (WPRFMC) and OFCF-Japan have been crucial in building the model program in Ecuador in collaboration with IATTC and local partners, and also in providing funding and expertise. OFCF-Japan has also expanded its contribution to the program to include Panama, working in co-ordination with IATTC offices in this country and WWF.

The contribution of WWF is to provide a structure to what is today one of the largest participatory fisheries conservation programs in the region. WWF has engaged with its regional network capacity to provide technical, administrative, funding and logistic support in order to integrate and coordinate the program across the region.

The program is a leading example of transforming fisheries through collaboration, in line with global WWF priorities. WWF offices in Latin America, including WWF-Colombia, WWF-Peru, WWF-Central America and WWF-Mexico, embraced the program and helped to build working relationships with the key actors of the fishery.

This initiative is now a robust, multi-sector program that seeks bycatch mitigation and sustainable fisheries with fishermen organizations, individual fishing companies and captains, fishing authorities, academic and training institutions, fish buyers, fish exporters, and local NGOs. Now, the program works in eight countries: Peru, Ecuador, Colombia, Panama, Costa Rica, Guatemala, El Salvador and Mexico (Table 1).

The project is developing activities in eight countries. Nicaragua is expected to join the program in 2008. In every country, the program has established a voluntary observer program to test circle hooks in experimental fishing lines during routine commercial fishing trips. Captains take an observer onboard and all fishing trip data are collected, along with experimental results. Data are subject to quality control, and entered into a database, which is managed by IATTC, who also provide scientific and technical guidance. In addition to this, the IATTC supports national teams and technical meetings are periodically conducted to improve the technical performance of the problem, "debug" errors and plan further experiments.

The approach of this program is unique as it is testing alternative gear and best practices under "real life" fishing conditions operating in several fisheries, in vessels of different sizes and navigational autonomy, at a regional scale. However, this poses enormous logistical challenges to the rigorous application of the experimental design, the maintenance of comparable experiments at good quality standards, and forces the program to adapt to the different fishery contexts across the region.

Table 1 Participating organizations in the program.

Country	**Fishermen Organization**	**Fishing authority/Government**	**Academic/NGOs**	**International support**
Mexico	Oaxaca fishermen Coops.	-INP (Instituto Nacional de Pesc) -CONAPESCA (Comisión Nacional de Acuicultura y Pesca) -PROFEPA (Procuraduría – Federal de Protección del Ambiente)	-WWF/Mexico -Defenders of Wildlife CMT (Centro –Mexicano de la Tortuga) -Universidad Autónoma de Sinaloa	-IATTC -NOAA
Guatemala	APASJO (Asociación de Pescadores del Puerto de San José) ASOCHAMP (Asociación de Pescadores de Champerico) FENAPESCA (Federación Nacional de Pescadores) Boat owners and captains	UNIPESCA (Unidad de Pesca y Acuicultura)	-WWF/Central America -PROBIOMA (Profesionales en Biodiversidad y Medio Ambiente)	-IATTC -OSPESCA (Organización del Sector Pesquero y Acuícola del Istmo Centroamericano) -NOAA
El Salvador	Fishermen Coops. Charles Pinto Tiburon Pinto Export Inc.	CENDEPESCA (Centro Nacional de Desarrollo Pesquero) CCCN-Pesca (Consejo Consultivo Científico Nacional de Pesca y Acuicultura)	WWF/Central America	IATTC OSPESCA (Organización del Sector Pesquero y Acuícola del Istmo Centroamericano) NOAA
Nicaragua	Individual fishermen Federación de Pescadores Artesanales de Nicaragua	ADPESCA (Administración Nacional de Pesca y Acuicultura)	-WWF/Central America -Flora & Fauna	-IATTC -OSPESCA (Organización del Sector Pesquero y Acuícola del Istmo Centroamericano)

Costa Rica	-CNIP (Cámara Nacional de La industria Palangrera) -Cámara de Pescadores Artesanales de Puntarenas -CANEP (Cámara Nacional de Exportadores de Productos Pesqueros) -Federación Nacional de Organizaciones Pesqueras -Several Fishing companies	INCOPESCA (Instituto Costarricense de Pesca y Acuicultura)	-WWF/Centroamerica -CBCR (Colegio de Biólogos de Costa Rica)	-IATTC -OSPESCA (Organización del Sector Pesquero y Acuícola del Istmo Centroamericano) -NOAA
Panama	-IMPSA (Industrias del Mar Pacífico S.A.) -Capt. Guillermo Bernal (Adangelis B FV)	ARAP (Autoridad de Recursos Acuáticos de Panamá)	-WWF/Central America	-IATTC -OFCF-Japan (Overseas Fisheries Cooperation Foundation of Japan) -NOAA
Colombia	-Tumaco artisanal fishermen -Charambirá artisanal fishermen -Papayal artisanal fishermen	-INCODER (instituto Colombiano de Desarrollo Rural) -Parque Nacional Natural Gorgona	-WWF/Colombia	-IATTC -NOAA
Ecuador	-ASOEXPEBLA (Asociación de Exportadores de Pesca Blanca) -Cámara de Pesquería del Ecuador -PROBECUADOR -FENACOPEC (Federación Nacional de Cooperativas Pesqueras del Ecuador)	SRP (Sub-Secretaría de Recursos Pesqueros del Ecuador)	-WWF/LAC -ESPOL (Escuela Politécnica del Litoral) -Jatun Sacha	-IATTC -OFCF-Japan (Overseas Fisheries Cooperation Foundation of Japan) -WPRFMC (Western Pacific Regional Fisheries Management Council) -NOAA -Ocean Conservancy
Peru	-FIUPAP (Frente Integrado Unido de Pescadores Artesanales del Perú) -Federación Nacional de Pescadores	-IMARPE (Instituto del Mar del Perú) -PRODUCE (Ministerio de la Producción)	-WWF/Perú -CEP-Paita (Centro de Entrenamiento Pesquero de Paita)	-IATTC -NOAA

3.0 Conservation relevance

The mortality of marine turtles when they are by-caught in long-line fishing is, among others, one of the major factors affecting their population survival. In the Eastern Pacific Ocean (EPO), Leatherback turtles (*Dermochelys coriacea*) and Loggerhead turtles (*Caretta caretta*) are the species of most concern because of their critical population condition (Sarti *et al.* 1996, 2000, 2002; Limpus and Limpus 2003; Kamezaki *et al.* 2003; Spotila *et al.* 2000). The Eastern Pacific Leatherback turtles are critically endangered, and could disappear entirely within a decade, if the main threats are not abated effectively and soon. Bycatch of marine turtles must be reduced in order to minimize fishing related mortality and to increase the chances of survival of these marine reptiles.

Solutions to marine turtle bycatch problems must be beneficial to both marine turtles and fishermen. Industrial and artisanal fleets targeting tuna, billfishes, sharks, mahi-mahi (*Coryphaena hippurus*), and other large pelagic fishes, sustain important economies along the Pacific coast of Latin America, where thousands of families depend on fishing resources for their food security, income, and livelihood. Surface long-line fishing for large pelagic species, and bottom long-line fishing (targeting snappers, groupers, catfish and other coastal finfish), are very popular fishing gears and are most commonly used with baited J-shaped hooks.

Bycatch interactions

There are two basic types of bycatch interactions of marine turtles with long-lines: a) hookings and b) entanglements.

a. Hookings

Baited long-line hooks attract swimming turtles close to the fishing gear. When the turtle bites at the bait, the hook can become lodged in the beak, tongue, or throat. Hookings in the beak or tongue cause injuries that normally are not fatal. However, if the hooking is in the throat it can cause serious or even fatal injuries when hooked turtles are pulled during line recovering operations, or when cutting the line fishermen leave part of the line in the hook. The line can actually cause more serious injuries than the hook and eventually kill the turtle (Maryluz Parga, Personal Communication 2007). Other hookings occur in the fins or tail, but even if the injury is not serious the turtle may drown if it cannot reach the surface to breathe.

b. Entanglements

Turtles can also be caught when swimming near the long-line gear. If for example, the turtle is attracted (for any reason) to a float, it can become entangled with the float's line when "playing" with and around the float. If the gear is subsequently lost or it sinks, the turtle will also sink and can drown if not retrieved and released in time.

Post-hooking/entanglement mortality

Another important factor affecting turtles incidentally caught in long-lines is the retrieval of the gear and manipulation of turtles by fishermen. Improper handling of hooked or entangled turtles can further injure them, or reduce their survival chances when released. Therefore, any technical solution to marine turtle bycatch must be matched with proper education, awareness and training of captains, crew and boat owners, so the fishing operation can be adapted to implement fishing gear modifications and adopt adequate fishing practices, especially with regard to gear retrieval, and turtle handling and release techniques.

4.0 The challenge: long-line fleets fishing in the Eastern Pacific Ocean

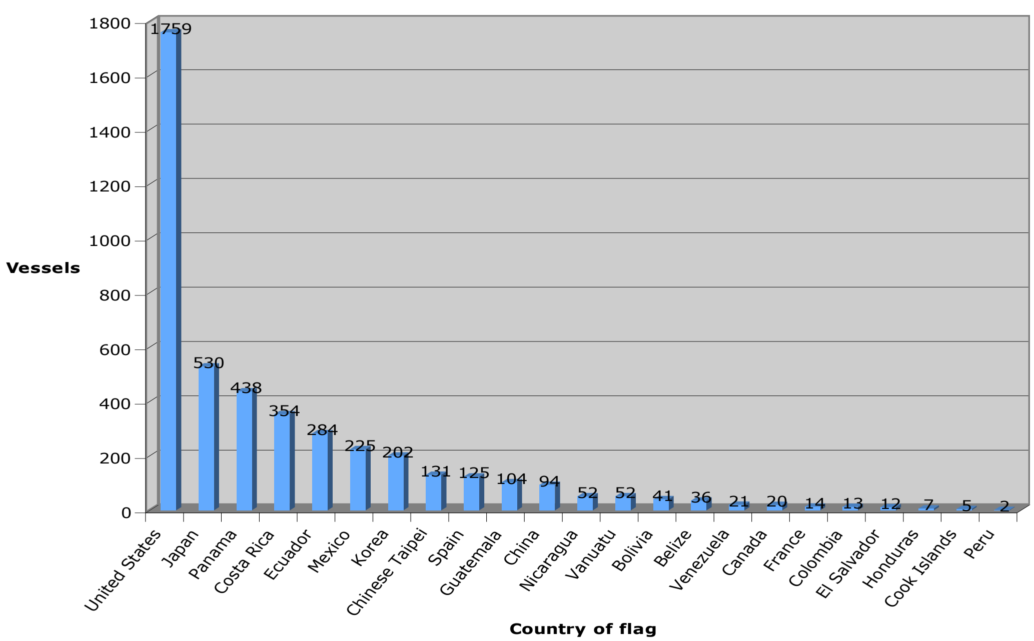
As of the beginning of 2008, there are 4521 tuna vessels operating in the EPO, according to the data of the IATTC's Vessel Register (Figure 1). There are 255 purse-seiners (Figure 2), 2,564 long-liners (Figure 3), 856 trollers, 147 poll & line vessels, 36 gill-netters, 373 multipurpose vessels, 12 hand-liners, 6 harpooners, 192 recreational vessels, 2 of non-specified gear, and 83 vessels of unknown gear (Figure 4).

Despite long-liners representing around 56% of all fishing vessels in the Vessel Register of the tuna commission, the majority of the tuna and tuna-like catches are taken by the purse-seine fleet (around 86% in 2005). In the tuna fishery, marine turtle bycatch is mainly caused by long-line vessels. Current observers' data in the purse-seine tuna fishery shows very little marine turtle bycatch.

Data from IATTC show that 1,290 long-line vessels authorized to fish in the EPO are longer than 24 m, but no precise estimates exist for the number of smaller long-liners. This is due in part to the resolution on Illegal, Unreported and Unregulated (IUU) fishing (Resolution C-05-07) which applies to any fishing vessel greater than 24 m. Nonetheless, some countries have reported to IATTC vessels under 24 m in length. Distant Water Long-line fleets from Japan, Korea, Chinese Taipei, and China constitute 74% of the large long-line vessels.

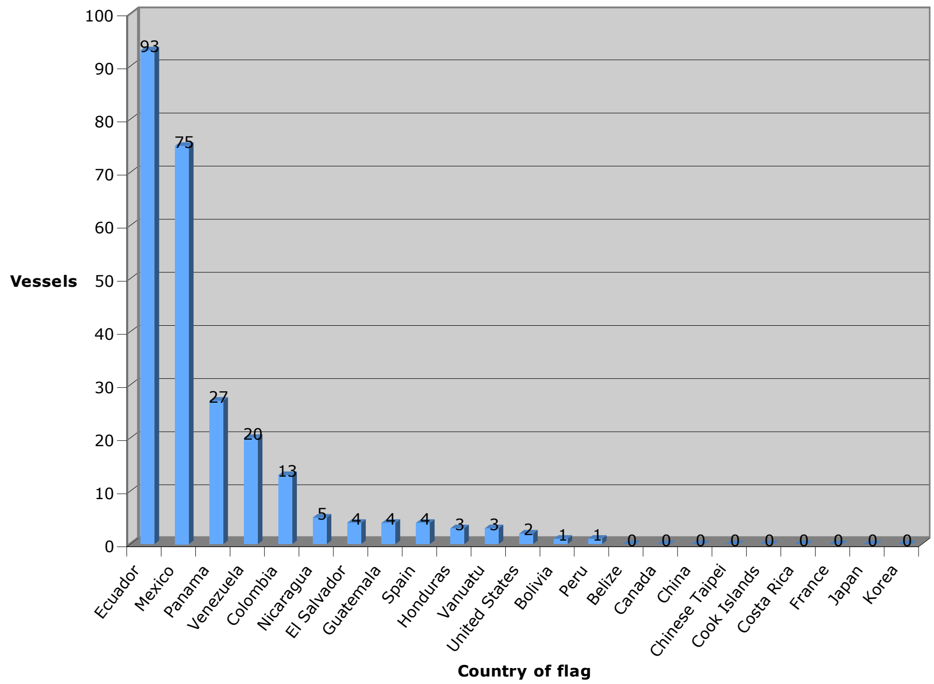
In Latin America, an artisanal long-line fleet is also fishing on tuna and tuna-like species with in-board engine vessels and outboard skiffs. Industrial and artisanal fleets are probably interacting with marine turtles in different ways, as the characteristics of the long-line gear and related equipment vary across the different fisheries and technological capabilities of the fleet. No precise accounts of the number of artisanal long-line vessels are available. Conservative estimations of the artisanal long-line fleet range anywhere between 10,000 to 16,000 small vessels in the region. The number of hooks deployed by the artisanal fleet, therefore, may well be in a similar order of magnitude to those of the industrial fleet. The relative contribution of the artisanal fleet to the overall bycatch of marine turtles in the EPO is therefore likely to be significant.

Figure 1
Composition of the tuna fishing fleet operating in the EPO by country of flag



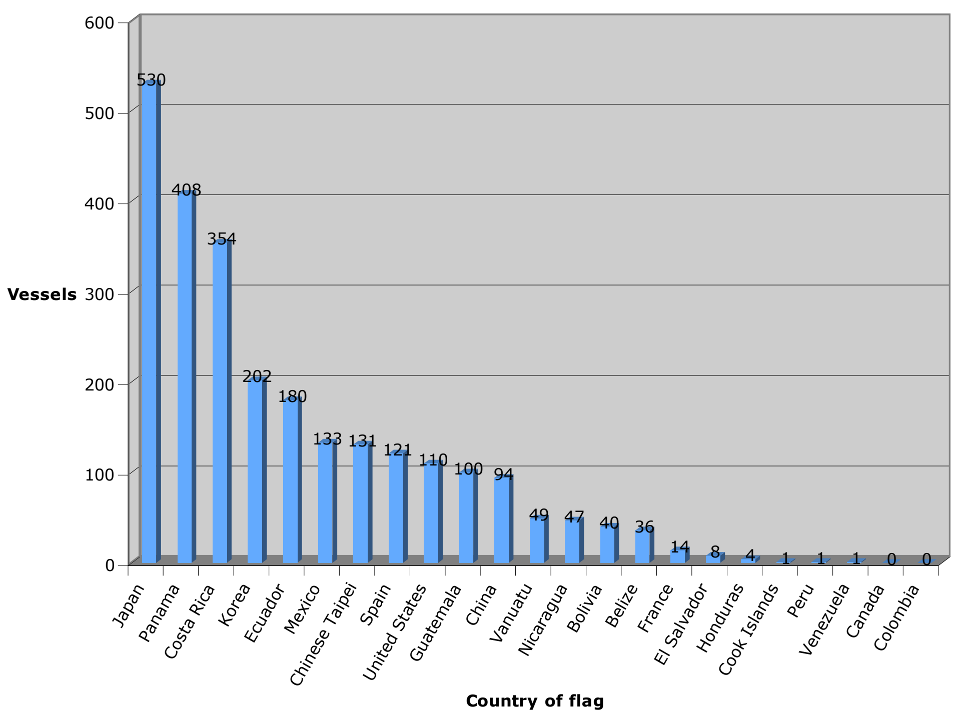
Source: IATTC Regional Vessel Register (2008). 4521 tuna vessels from all gears are pooled in the figure: purse seiners, long-liners, trollers, pole & line, gillnet, multi-purpose, hand-line, harpoon, recreational and other gears.

Figure 2
Purse seine fleet in the EPO



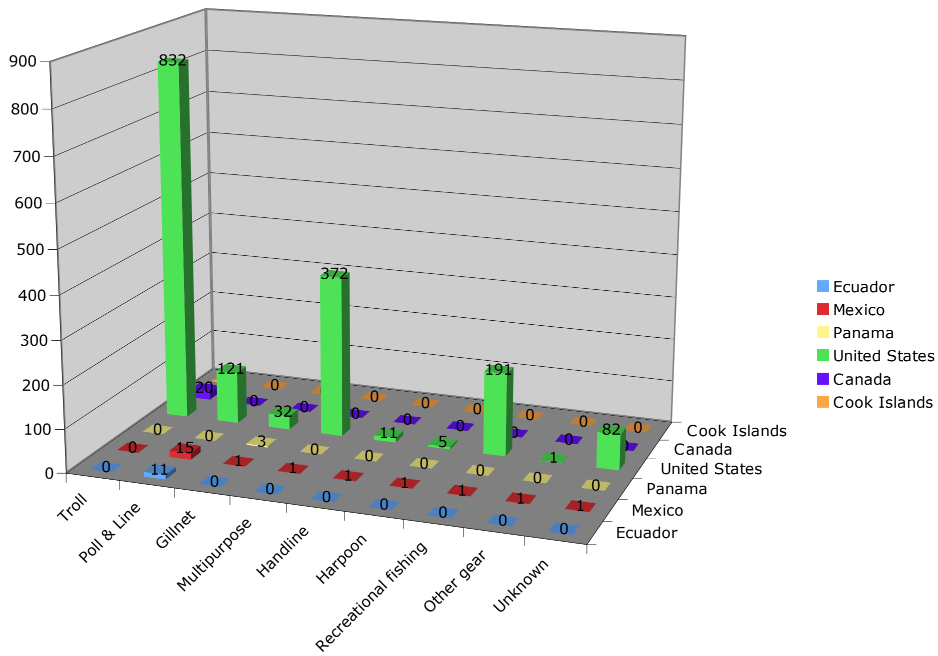
Source: IATTC Regional Vessel Register (2008)

Figure 3
Tuna long-line fleet in the EPO



Source: IATTC Regional Vessel Register (2008)

Figure 4
Tuna fleets other than longliners and purse-seiners by gear in the EPO



Source: IATTC Regional Vessel Register (2008)

5.0 General approach to solve the bycatch of marine turtles

According to Martin Hall (pers. com. 2008), in order to reduce the bycatch of non-target species, it is necessary to reduce at least one of its components. Bycatch can be expressed as a function of the fishing effort and the bycatch per unit effort of a particular gear:

Bycatch = effort x BCPUE

In long-line fishing, effort is the total number of hooks fishing in a given time period, while BCPUE is the bycatch per unit effort, usually measured as a rate such as the number of non-target individuals caught per thousand hooks.

Means to reduce effort may include regulatory limits or bans, market incentives and gear changes, while means to reduce BCPUE may include some of these factors, but also technological and operational changes, changes in fishing practices through awareness, education and training, and regulatory limits to total bycatch.

However, bycatch does not necessarily translate into mortality, though. For example, an incidentally caught specimen (such as marine turtles) is often still alive when the gear is retrieved and when correctly handled, can be released without causing further injuries that could compromise its survival. For this reason, bycatch mortality reduction strategies can address two fronts: avoiding the interaction between the gear and the non-target species altogether, and reducing the harm inflicted by the gear to the specimen when an interaction does occur. Both avenues are pursued under this program.

6.0 Program objective and proposed solution

The objective of this program is to reduce the threat to marine turtle populations in the Eastern Pacific Ocean due to bycatch interactions in long-line fishing operations. To achieve this objective, the program is working cooperatively with fishermen, boat owners, governments and other key stakeholders to identify and test means to reduce marine turtle bycatch, and reach a massive transformation of the long-line fleets towards the adoption of best fishing practices for sustainable fisheries.

The expected result of this transformation is an overall reduction of long-line fishing related marine turtle mortalities in the Eastern Pacific Ocean caused by long-line fishing. Key elements of this are the use of proper fishing gear and the education of captains and crew in best fishing practices so they can reduce interactions and know how to handle and release hooked or entangled turtles and return them to the sea.

This program provides fishermen with the opportunity to test circle hooks during their own fishing trips by incorporating an experimental hook design into their long-lines. Thanks to the on-board observer program critical information regarding fishing trip and results of the hook experiments are collected.

This participatory approach to marine turtle bycatch mitigation has several benefits:

1. It allows direct trials of circle hooks by fishermen. In this way, after returning to port and meeting their peers following an experimental fishing trip, collaborating captains and crew can inform other captains and fishermen about the new technology. This is what we call fishermen-to-fishermen convincing, an important cultural aspect of the process of technology appropriation.
2. Data collected by observers are checked for errors, edited and entered into the database. Consequently, as more fishermen join the program and accept an onboard observer, this participatory project is building a critical mass of information about the performance of the fishery and the nature of the interaction with marine turtles. This will allow managers, fishermen and their organizations to make educated decisions about the regulatory measures that may be needed to improve the fishery and further reduce bycatch interactions.
3. As the number of fishermen participating in the program increases, and thus more fishermen gain experience in being part of marine conservation, eventual regulations coming from the fishing authority have a better chance of being supported by fishermen. This is critical for artisanal fisheries in developing countries where capacity and resources for surveillance and enforcement of regulations are poor.
4. The project provides a practical and current opportunity for fishermen to be part of a major effort to save marine turtles to become key drivers of change. This is a novel experience for them, as true custodians of marine resources, and distinguishes them from the traditional, negative way they are usually portrayed. We believe that this “ownership” will lead to the dawn of a new culture of multi-sector collaboration and continuous improvement. This is essential for a long-term program and for fishermen’s commitment to sustainable fisheries.
5. Innovative ideas coming from the direct experience of fishermen can greatly contribute to enhancing the performance of bycatch mitigation tools, and in directing the adaption of solutions to particular fishery circumstances.

7.0 The experiments and observer program

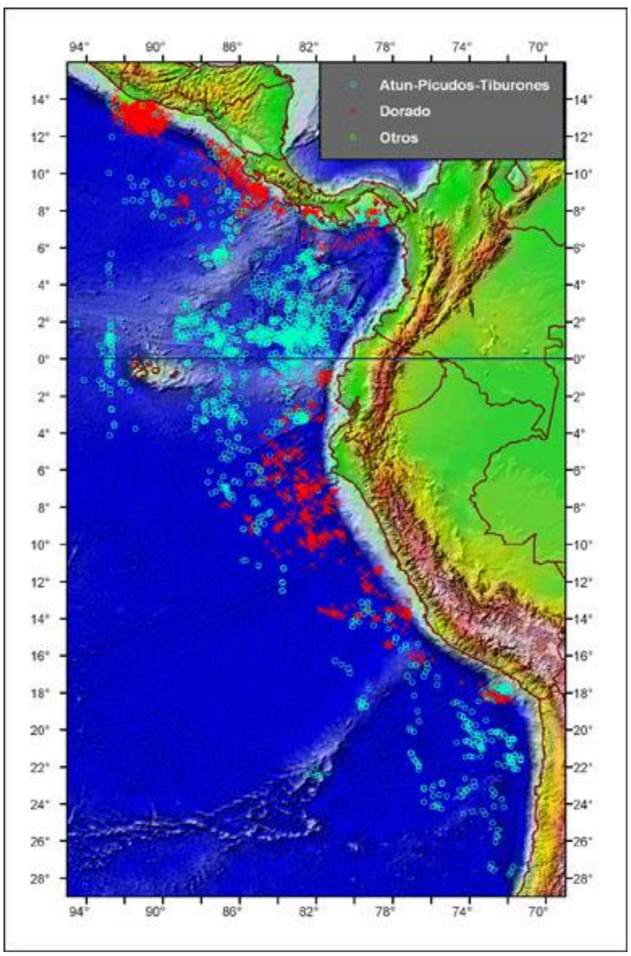
Experiments with circle hooks have been conducted in surface long-line fisheries and bottom long-line fisheries under this program since 2003. Surface long-line fisheries target large pelagic fish including several species of tuna, billfishes, sharks, and mahi-mahi (Table 2). Bottom long-line fisheries target snappers, groupers, catfish, and other coastal and bottom dwelling species.

These fisheries are distinct and can be grouped as:

a. Tuna-Billfish-Shark (TBS): use larger hooks, deeper long-line sets, from inshore to offshore and usually more oceanic.
b. Mahi-mahi: smaller hooks, shallower long-line sets with more hooks and more coastal.
c. Bottom: smaller lines, smaller hooks, and very coastal.

In Latin America, TBS fishing is usually more oceanic than the mahi-mahi fishery, although there are important exceptions, such as Panama. Here, long-line fishing occurs closer to the coast than in other countries. Mexico provides another example, where in some areas such as Puerto Angel, the tuna “corrida” (migration) comes very close to the coast during certain times of the year. The program has conducted experiments with on-board observers in each of these three fisheries. Results from the bottom long-line fishery are not included in this report since it will be part of a separate analysis in the future.

Table 2 shows the current level of activity of the observer program from 2003 to 2007. After the start of the Ecuador observer program, other countries joined the initiative with different levels of sampling effort, according to funding availability and as working relationships with partners progressed.



All experimental fishing trips (observed trips) were conducted aboard on commercial fishing vessels under normal fishing conditions, with the only differences being the experimental design in the gear utilized and the presence of the on-board observer. In four years, the program has conducted experiments in 1,420 fishing trips with 305 artisanal fishing vessels, and generated a total sample of 2,396,413 observed hooks (Figure 5).

Figure 5 Position of observed experimental long-line sets in the Eastern Pacific Ocean

6,305 long-line sets have been observed in 1,420 TBS and mahi-mahi fishing trips. Positions of sets in the map are from the artisanal fishing vessels of Guatemala, El Salvador, Costa Rica, Panama, Ecuador and Peru from 2003 to 2007. Samples from Mexico and Colombia are not shown in the map (see explanation on page 15)

Experiments with circle hooks were also conducted in Colombia and Mexico. However, these were conducted under different conditions and, therefore, for the purposes of standardization, were not entered into the program's regional database of the program. In Colombia, a single experimental fishing line was used by different small artisanal vessels, while in Mexico; experiments were conducted by a research vessel in collaboration with the government. Starting in 2008, Mexico, Colombia and Nicaragua will begin conducting experiments following the standardized method and experimental model design used in the other countries and data will then be added accordingly to the regional database. This will allow a comprehensive comparison of the results of experiments across the countries from Mexico to Peru.

Table 2

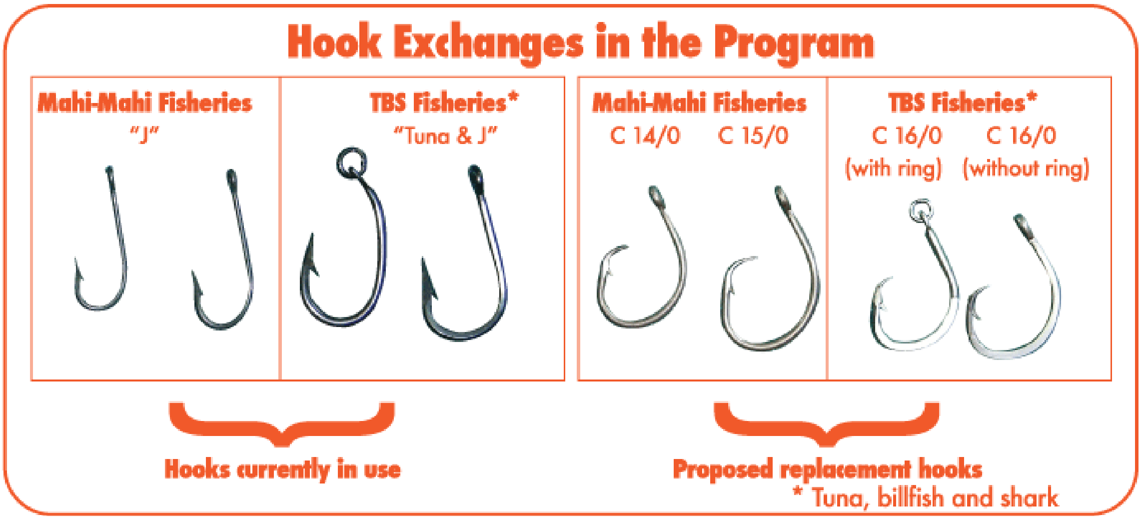
Experimental fishing, testing circle hooks against J hooks, with on-board observers in the Eastern Pacific Ocean, from 2003 to 2007

Country	Main ports	Number of observed trips	Number of observed sets	Number of observed vessels	Number of observed hooks
Costa Rica	Puntarenas, Cuajiniquil Quepos	110	1,060	33	579,614
Ecuador	Manta Esmeraldas Santa Marianita San Mateo	435	2,089	169	330,569
El Salvador	Santa Tecla	10	19	5	7,980
Guatemala	San Jose Las Lisas Champerico	691	1,576	52	488,656
Panama	Balboa Vacamonte Coquira Mensabe	75	822	8	728,479
Peru	Ilo	31	210	7	45,757
	Paita	28	218	18	60,626
	Pucusana	40	302	13	154,805
	Totals	*1,420*	*6,305*	*305*	*2,396,413*

The basic tests performed under this program are: J vs. C/18, J vs. C/16, J vs. C/15, J vs. C/14, J vs. C/13, and J vs. C/12 (Figure 6). Other types of tests performed in experimental fishing, such as C/16 vs. C/15, and tests of hooks with a stiff wire appendix conducted by IATTC and OFCF-Japan, are not part of this report.

Experiments comparing circular hooks of different sizes have limited sample sizes and are conducted to study if there is an additional gain to increase the size of the hook where circular hooks are already in use. These results will be subject of future analysis. Results of the experiments of hooks with wires can be consulted in Hall et al. (2006), but basically these experiments were conducted in search of alternative hook designs for the mahi-mahi fishery. Some fishermen have the perception that circular hooks C/16 or even C/15 are too large for mahi-mahi, and that a smaller circular hook with an appendage may look appealing to them.

Figure 6
J-shaped hooks commonly used in TBS and mahi-mahi fisheries and circle hooks tested in experimental fishing trips



8.0 Preliminary results of the program

8.1 Hooking rates

The first two mitigation properties to look at with respect to circle hooks as compared to J hooks are the difference in turtle hooking rates and the performance in fish catch rates. Ideally, a bycatch solution should reduce turtle hookings and have similar fish catch rates as that normally experienced with the J hooks. Meeting this condition will facilitate the technology transfer and adoption by fishermen and eventually its inclusion as part of regulatory fishing measures.

Hooking rates from experimental fishing are presented for a subset of the information contained in the project database. Data for this analysis come from Central America, Ecuador and Peru. The selection criteria for the data used in analysis were based on data quality requirements for every observed long-line set, including conditions such as edited data only, no missing data, a minimum and maximum proportion of J hooks to circle hooks in the set ($0.5 \leq (\#J / \#C) \leq 2.0$). From the 2,396,413 observed hooks, comparisons between hooking rates from J and circle hooks were done over a sample of 959,856 hooks (40%; Table 3).

Data were grouped in two basic fisheries: TBS and mahi-mahi, and pooled by type of hook comparison (i.e. hook sizes being compared) by port and year. Turtle bycatch rates as well as fish catch rates are indicated as the number of animals per thousand hooks. This figure is also referred to as Bycatch per Unit Effort or (BCPUE). Figures of BCPUE in this report are the total number of turtles caught in the experimental fishing trips (and represent mainly hard-shelled turtles since there are only 6 leatherback turtles reported as by-caught in these experiments). For this preliminary analysis, circle hooks were grouped by size without regard to other hook characteristics, such as material (stainless steel, non-stainless steel), offset degree or bait type[1].

Two-tailed Wilcoxon Signed-Rank tests for matched pairs were used to analyze the overall trend of the difference in hooking rates of J hooks and circle hooks (positive, negative or null). This non-parametric, two-tailed test considers both the direction of the difference between hooks and the magnitude of the observed difference. It was applied as a preliminary and conservative method of analysis for this type of data until development of a more adequate statistical test can be completed and reviewed. This is an on-going process promoted and facilitated by Martin Hall from IATTC.

Table 3

Sample sizes (number of hooks) for bycatch and catch rate analysis in the TBS and mahi-mahi fishery. TBS = tuna, billfish, sharks

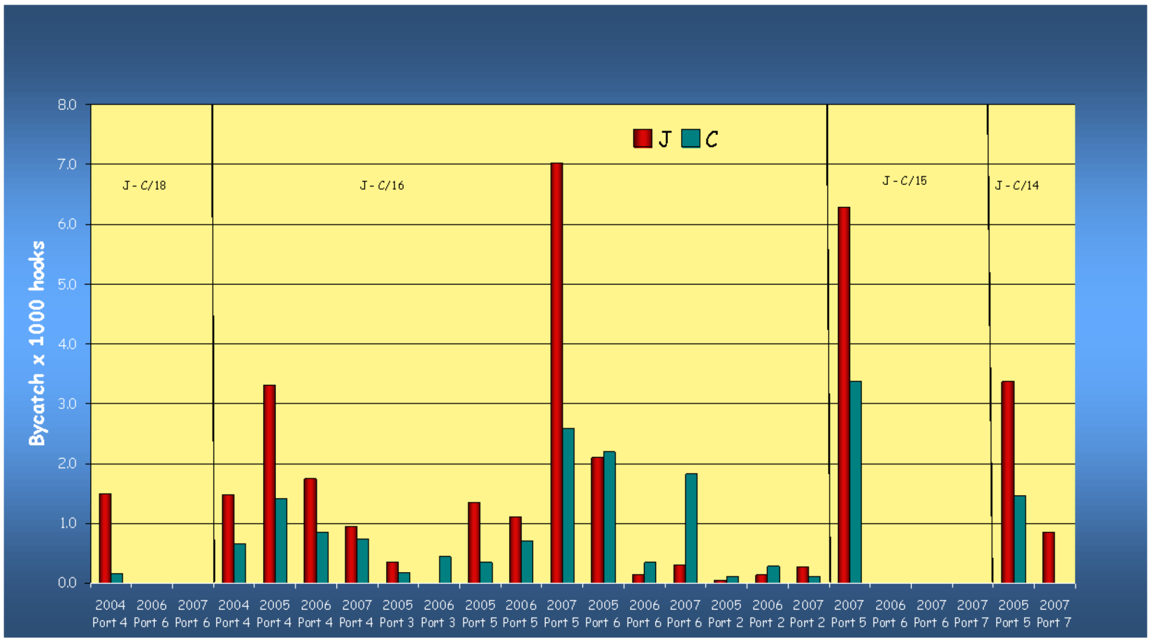
Comparison	TBS	%	Mahi-mahi	%	Total sample size
J-C/18	20,315	4	0	0	20,315
J-C/16	510,141	93	144,887	35	655,028
J-C/15	13,163	2	87,833	21	100,996
J-C/14	7,265	1	114,952	28	122,217
J-C/13	0		33,748	8	33,748
J-C/12	0		27,552	7	27,552
Subtotals	*550,884*		*408,972*	*Grand total*	*959,856*

[1] Baits utilized included squid, sardine, and several species of fish. While bait type is not controlled for in the experiments, fishermen were asked to try to distribute the different type of baits as evenly as they could among hook types, and avoid placing their preferred bait only on one type of hook.

8.2 TBS fishery: turtle bycatch rates

BCPUE values for the TBS fishery from the data set analyzed show overall, significantly larger turtle bycatch rates in J hooks than circle hooks (Figure 7, Wilcoxon Signed-ranks test for matched pairs, $T^- = 37$, $p < 0.02$, $n = 19$). Among 24 cases[2] of paired experiments, distributed among 7 ports, circle hooks had lower turtle bycatch rates in 13 cases (54%), J hooks had lower bycatch rates in 6 cases (25%), while in 5 cases there were no turtles caught with either J or circle hooks (Figure 7). Note that the majority of the tests correspond to trials of J hooks against C/16 hooks (93%, Table 3). The same also trend holds for hook sizes C/14, C/15 and C/18, but each size was not tested separately for statistical differences between circle and J hooks.

Figure 7
Marine turtle bycatch rates (per thousand hooks) from a sample of TBS long-line sets in the Eastern Pacific Ocean

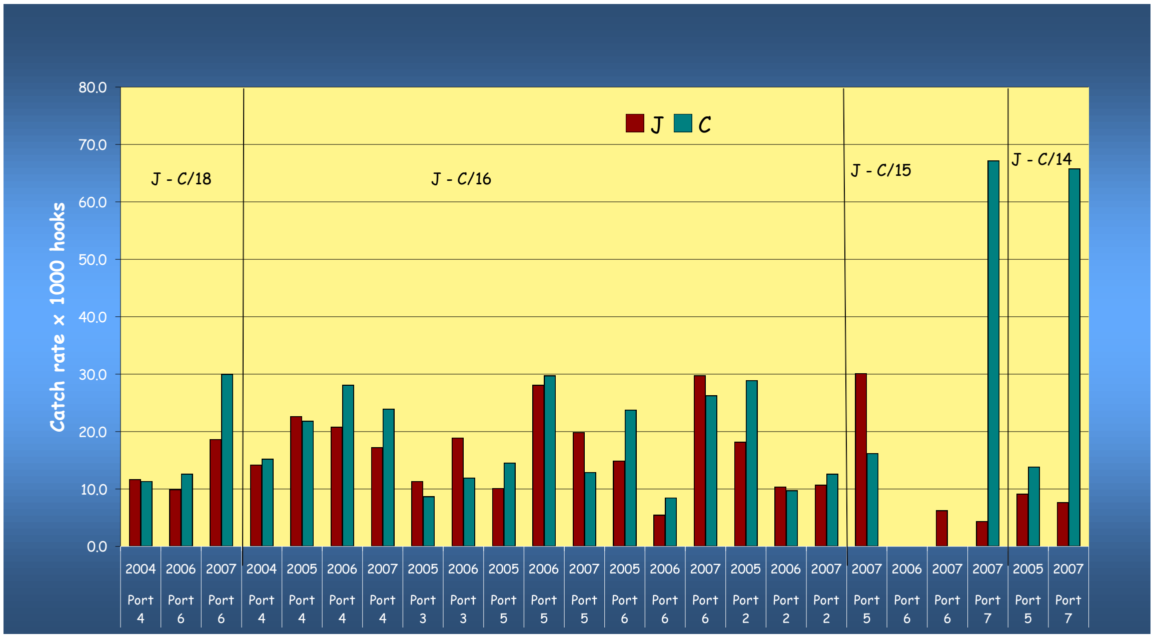


8.3 TBS fishery: fish catch rates

The CPUE values of the TBS fishery indicate overall larger fish catch rates in circle hooks than in J hooks, but this difference was not significant (Wilcoxon Signed-Rank test for matched pairs, $T^- = 88$, $p > 0.1$, $n = 23$). The largest differences between circle and J hooks were recorded among small circle hooks (C/15 and C/14), but sample sizes in these hook size categories were small (Figure 8, Table 3). Among the 24 comparisons, 14 (58%) cases show larger catch rates in circle hooks, while J hooks caught more fish in 9 cases (37%). Only one case showed zero fish for both types of hooks.

[2] BCPUE and CPUE were estimated from 24 cases for the TBS fishery and 28 cases from the Mahi-mahi fishery. Each case group a number of sets by port/year selected from the program database and that comply with certain elements of data quality conditions, such as proportionality of J and C hooks in the experiment, no selection of bait, etc.

Figure 8
Fish catch rates (per thousand hooks) from a sample of TBS long-line sets in the Eastern Pacific Ocean

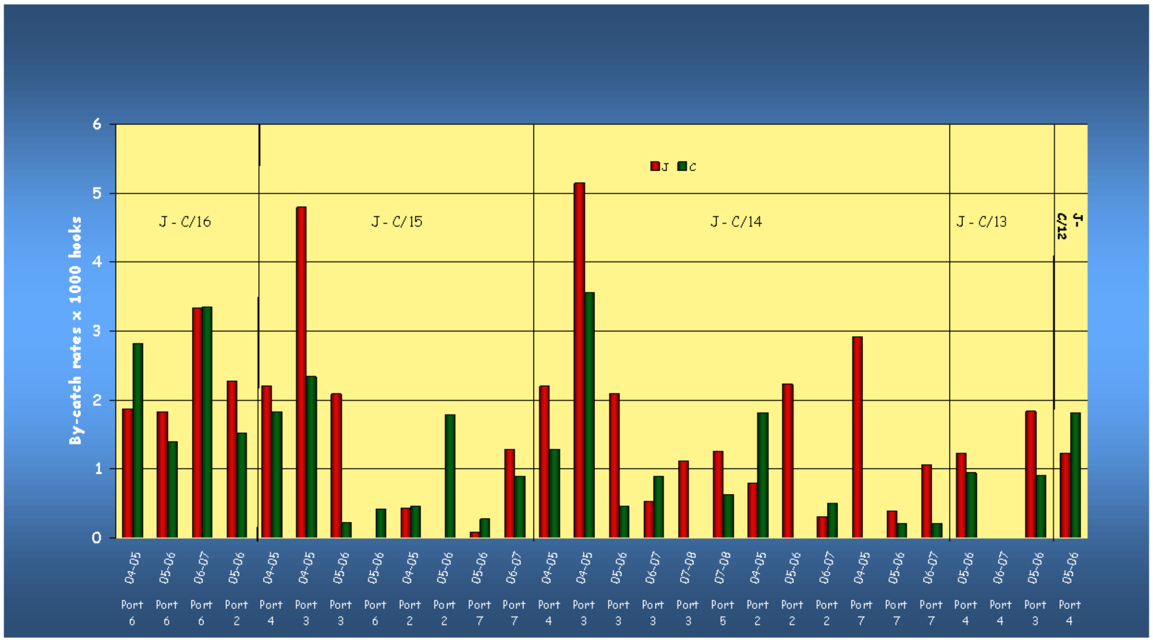


8.4 Mahi-mahi fishery: turtle bycatch rates

In the mahi-mahi fishery, BCPUE also followed the same pattern as in the TBS fishery, with significantly lower numbers of turtles caught with circle hooks than J hooks (Wilcoxon Signed-Rank test for matched pairs, $T^- = 101$, $p < 0.02$, $n = 27$). Again, the largest values of bycatch rates come from J hooks. From the 28 cases selected for this fishery, circle hooks resulted in lower numbers of marine turtles caught in 18 cases (64%), while J hooks resulted in lower bycatch rates in 9 cases (32%). Only one case had zero turtles caught for either J hooks or circle hooks (Figure 9).

Differences in bycatch rates between J hooks and circle hooks were more pronounced in the C/14 comparisons than in the C/16 comparisons (Fig. 9). These were the two hook sizes with the largest sample sizes in the mahi-mahi fishery (Table 3).

Figure 9
Marine turtle bycatch rates (per thousand hooks) from a sample of mahi-mahi long-line sets in the Eastern Pacific Ocean

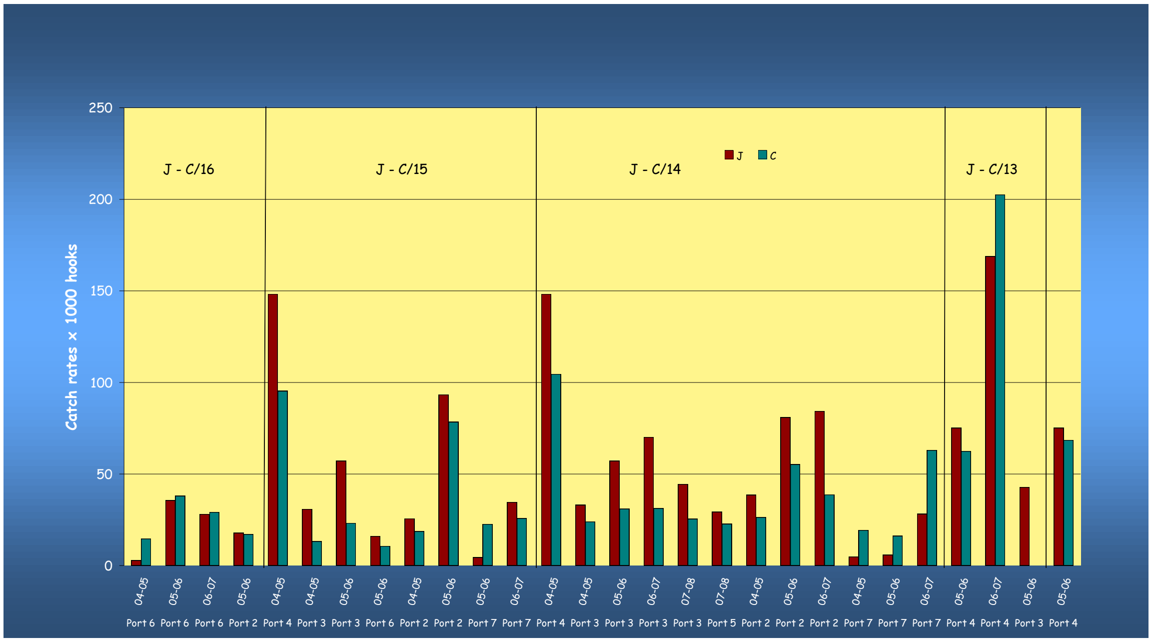


8.5 Mahi-mahi fishery: fish catch rates

The CPUE values of the mahi-mahi fishery indicate overall, significantly larger fish catch rates in J hooks than in circle hooks (Wilcoxon Signed-Rank test for matched pairs, $T^{-} = 101$, $p < 0.02$, $n=28$). In this sample of the mahi-mahi fishery experimental sets, there are 20 cases (71%) out of 28 in which J hooks have larger mahi-mahi catch rates than circle hooks, and 8 cases (29%) in which circle hooks caught more fish than J hooks (Figure 10). Tests with C/16, C/15 and C14 make up 84% of the hook sample (Table 3).

Differences in fish catch rates between J hooks and circle hooks were more pronounced in the C/14 comparisons than in the C/16 comparisons (Fig. 10). These are the two hook sizes with the largest sample sizes in the mahi-mahi fishery (Table 3). However, for this report, such a deviation was not statistically tested but will be subject of examination in the future.

Figure 10
Fish catch rates (per thousand hooks) from a sample of mahi-mahi long-line sets in the Eastern Pacific Ocean



8.6 Relationship between turtle bycatch and fish catch rates

There are four possible types of general results from fishing experiments:

a. cases where circle hooks have fewer turtles hooked and lower fish catch rates than J hooks
b. cases where circle hooks have fewer turtles hooked and higher fish catch rates than J hooks
c. cases where circle hooks result in more turtles hooked and lower fish catch rates than J hooks
d. cases where circle hooks result in more turtles hooked and higher fish catch rates than J hooks

These four general outcomes of the experiments are represented as colored areas in Figure 12, where results of the TBS and mahi-mahi fishery were plotted for differences in turtle hooking rates (Y axes) and fish catch rates (X axes).

The cases selected for this analysis (each one representing a year/port combination) resulted in different patterns for the mahi-mahi and TBS long-line fishing. The mahi-mahi fishing cases are more scattered across the four types of general results or outcome areas. Here, more of the points or year/port combinations are in the region of fewer turtles hooked, with a particular concentration in the lower fish catch area of the graph.

The TBS points tend to group around the center of the graph with few data points outside the center. Most of the data for the TBS fishing fall within the preferred outcome region of fewer turtles hooked and avoid over-fishing (smaller fish catch differences with J hooks).

Figure 11
Four outcome areas of experiment results for the mahi-mahi and TBS long-line fishing data

Each point in the graph represents a year/port combination. The light blue area represents the preferred outcome region where circle hooks catch less turtles and avoid over-fishing (smaller differences in fish catch rates compared to J hooks). Catch rates are the number of individuals per thousand hooks. Differences in catch rates are provided as the overall difference of all circle hook sizes compared to all J hook sizes for both turtle catch and fish catch rates. Source: Martin Hall (Personal communication 2008)

Plots of the combined difference in sea turtle hooking rates and the difference in target fish hooking rates provide a graphical image of the overall trend in fishing experiment results. With the information that we currently have, circle hooks are performing properly as a bycatch mitigation method in the TBS artisanal fishery for both critical conditions that such tools should fulfill: reduction of turtle bycatch with maintenance of commercial fish catch rates. Results of the mahi-mahi fishery have the same general outcome pattern in the reduction of turtle bycatch, but tend to have smaller fish catch rates than J hooks. Further examination of possible factors influencing both bycatch and fish catch rates is needed to refine a prescription of bycatch mitigation tools. This is particularly important for the mahi-mahi artisanal fishery, since mahi-mahi is an important target species and source of income for many fishermen in the Eastern Pacific Ocean.

Some of the possible factors are:

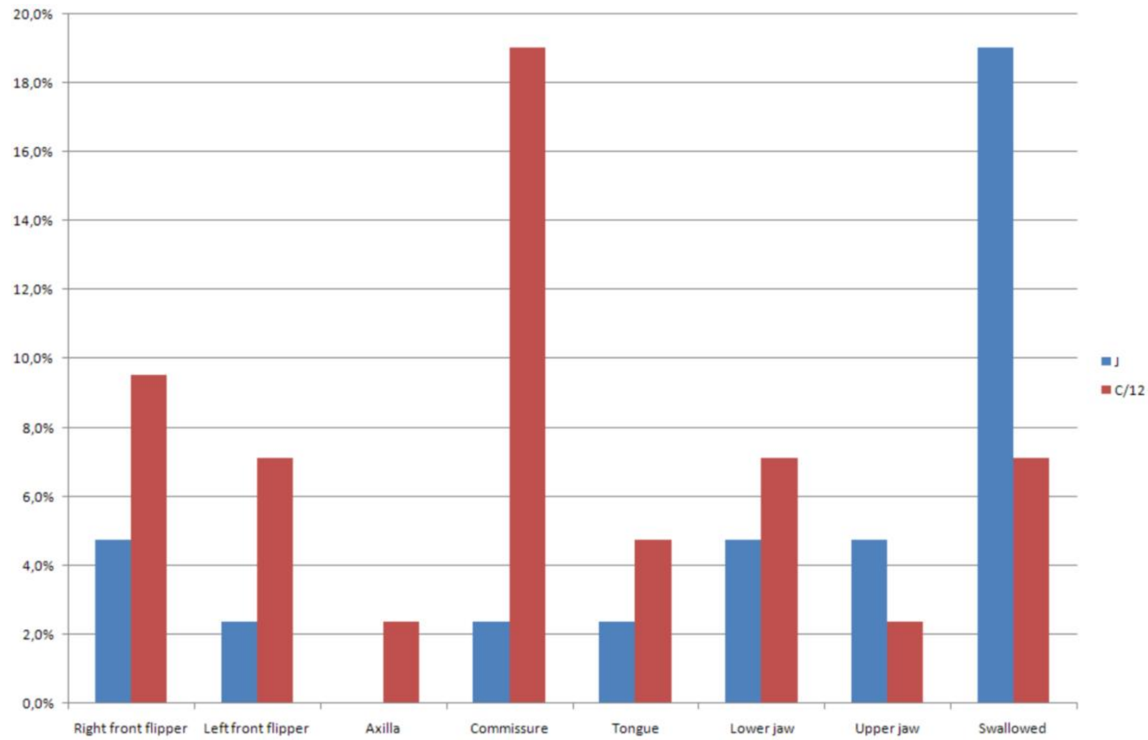
1. Catch rates and size selectivity of the hooks in relation to the anatomical characteristics of the hook, such as: hook size, width, off-set degree, shank size, point to shank angle, hook material, and presence of a ring, among others.
2. Possible geographical and temporal segregated distribution of size classes.
3. Type of bait and/or baiting techniques.
4. Potential effects of the long-line gear construction and materials used: polypropylene versus monofilament, branch line construction and methods to connect branch lines to the mainline (snaps, knots).

8.7 Proportion of swallowed hooks and hooking locations

A second and very important property of the hooks is the proportion swallowed by the non-target species. Swallowed hooks can cause fatal injuries to turtles in the throat or deeper in the esophagus. Other hooking locations produce different levels of injuries depending on the part of the body affected: axilla, mouth commissure, flippers, upper jaw, lower jaw, tongue, neck, head, shell, tail and epiglottis.

Graphical examination of TBS and mahi-mahi fishery for parts of the data with sufficient information suggests that J hooks are more frequently swallowed than circle hooks. This trend can be observed when J hooks are compared circular hooks of different sizes for the hooking location (Figures 12 to 19).

Figure 12
Hooking location of J vs. C/12 hooks in the mahi-mahi fishery. Percentages are the number of turtles hooked in a particular location of their body to the total number of hooked turtles; n = 42 turtles.



In the mahi-mahi fishery when circle hooks C/12, C/13, C/14 and C/15 are compared to J hooks, hookings with circle hooks tend to be more frequent in the commissure of the mouth and the jaw, whereas J hooks have a strong tendency to be swallowed by the turtles. C/12 hookings in the flippers are also important (Figures 12 to 15).

When J hooks are compared to C/16 hooks, hookings with J hooks tend to be more spread between the different parts of the body, with a larger proportion of swallowed, upper jaw and tongue locations. C/16 hooks follow a similar pattern but usually with a smaller percentage of dangerous hookings such as swallowed hooks (Figure 16).

The pattern of hooking locations in the TBS fishery is similar to that of the mahi-mahi fishery for both J and circle hooks, and the proportion of swallowed hooks is still higher for J hooks than for circle hooks (Figures 17 to 19).

Figure 13

Hooking location of J vs. C/13 hooks in the mahi-mahi fishery. Percentages are the number of turtles hooked in a particular location of their body to the total number of hooked turtles; n = 36 turtles

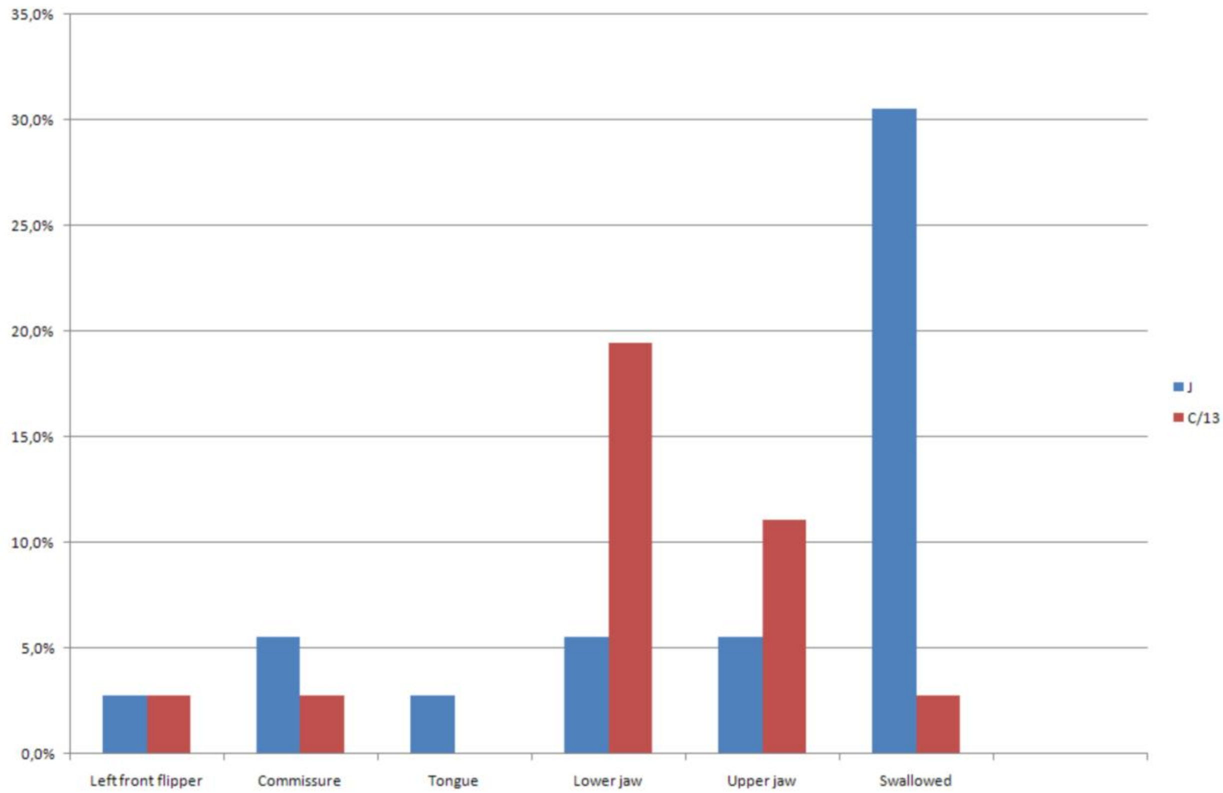


Figure 14

Hooking location of J vs. C/14 hooks in the mahi-mahi fishery. Percentages are the number of turtles hooked in a particular location of their body to the total number of hooked turtles; n = 95 turtles

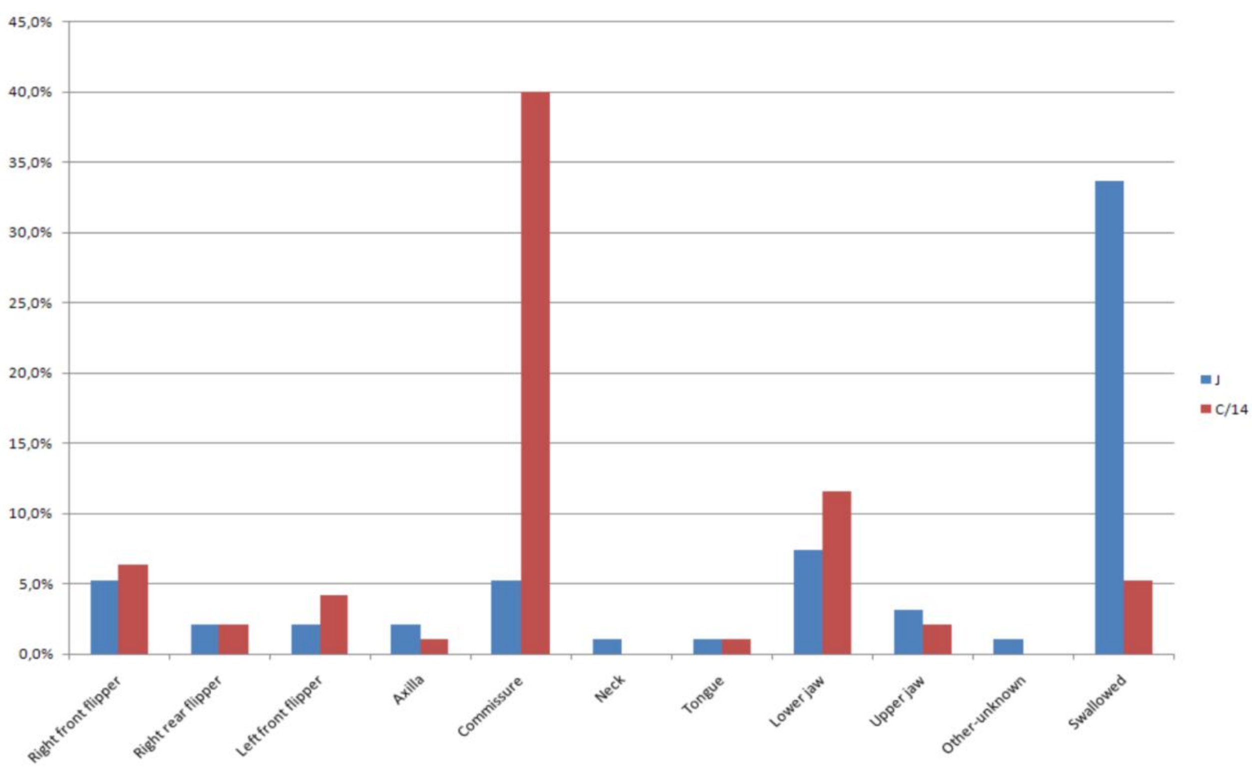


Figure 15
Hooking location of J vs. C/15 hooks in the mahi-mahi fishery. Percentages are the number of turtles hooked in a particular location of their body to the total number of hooked turtles. n = 82 turtles

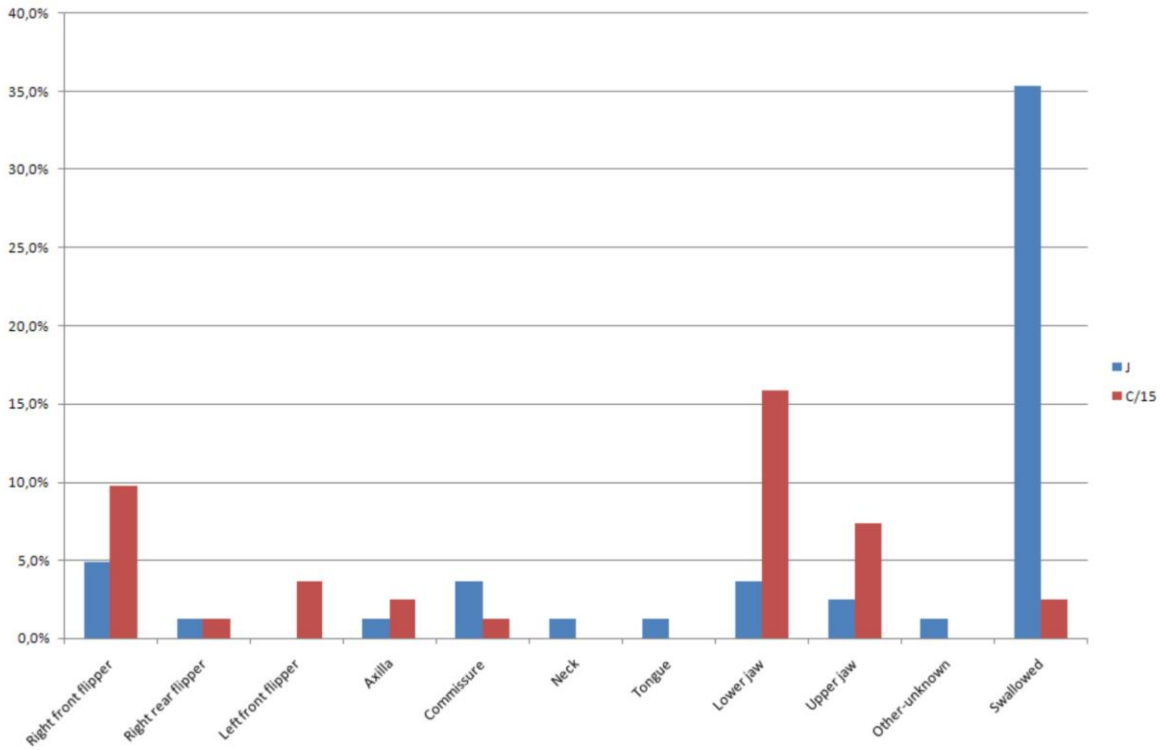


Figure 16
Hooking location of J vs. C/16 hooks in the mahi-mahi fishery. Percentages are the number of turtles hooked in a particular location of their body to the total number of hooked turtles; n = 306 turtles

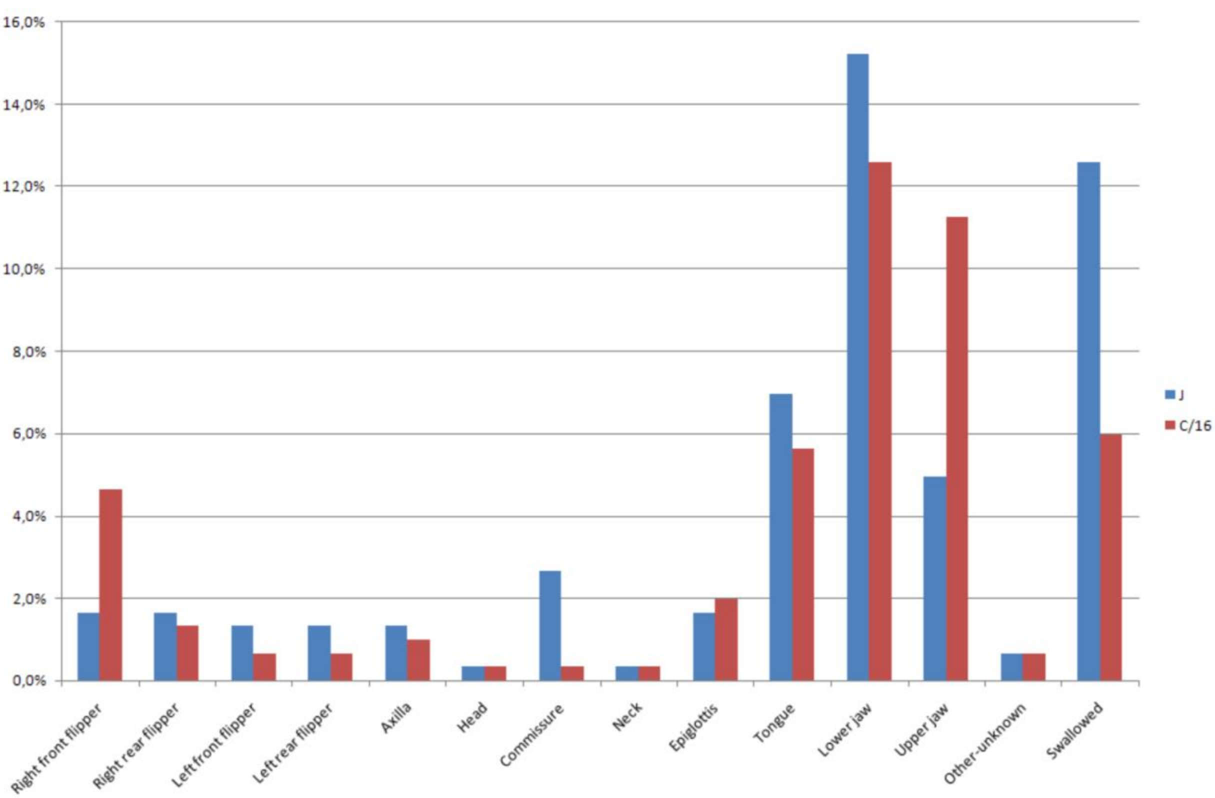


Figure 17
Hooking locations of J vs. C/14 hooks in the TBS fishery. Percentages are the number of turtles hooked in a particular location of their body to the total number of hooked turtles; n = 12 turtles

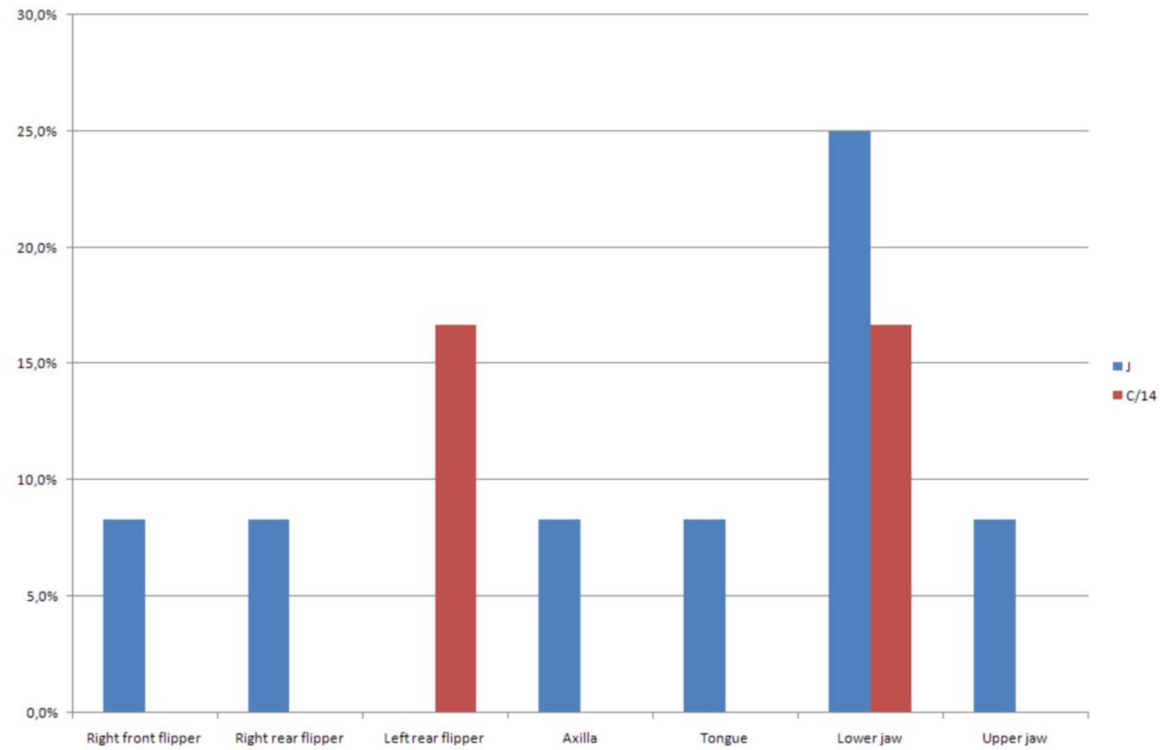


Figure 18
Hooking locations of J vs. C/16 hooks in the TBS fishery. Percentages are the number of turtles hooked in a particular location of their body to the total number of hooked turtles; n = 556

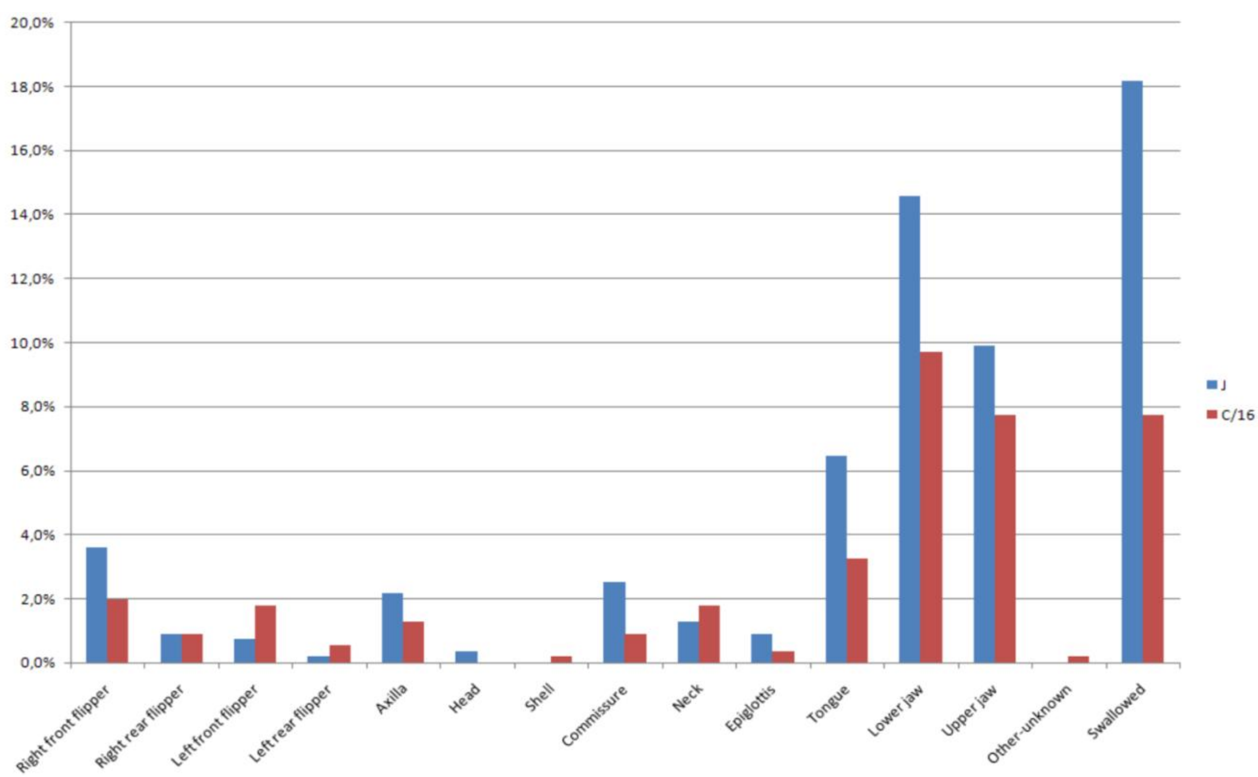
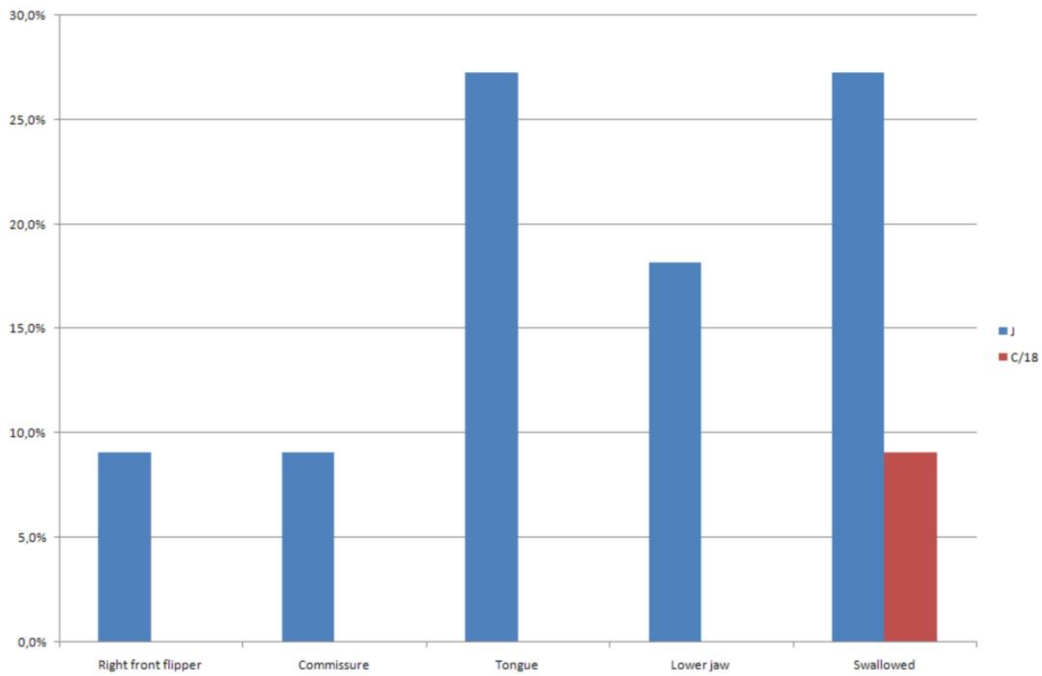


Figure 19
Hooking locations of J vs. C/18 hooks in the TBS fishery. Percentages are the number of turtles hooked in a particular location of their body to the total number of hooked turtles; n = 11 turtles hooked



8.8 Entanglements

A different type of bycatch challenge occurs when turtles become entangled in the various parts/areas of the gear. Data show that most entanglements occur in the float line and in the branch line, with more entanglements around floats than in branch lines in the mahi-mahi fishery and more entanglements in the branch line for the TBS fisheries (Figure 20). The material of the gear plays an important role. For example, the number of turtles entangled per nautical mile is relatively high when polypropylene is used, and minimal when monofilament is employed (Figure 21).

Polypropylene lines are the predominant material used in Peru and Ecuador to construct the long-line, whereas the use of monofilament is a common practice in other EPO countries. Dr. Takahisa Mituhasi, from OFCF-Japan, and staff from IATTC have proposed experiments aimed at comparing polypropylene and monofilaments materials in the float line in addition to experiments that compare transparent floats with normal floats (to elucidate the role float color plays as a turtle attractant) in the same line (Hall 2007).

Figure 20
Location of entanglements. Floats: entanglements in the float's line. Line: entanglements in the branch line. Percentage refers to the number of turtles entangled in a given part of the fishing gear to the total number of turtles entangled by fishery; n = 739 turtles.

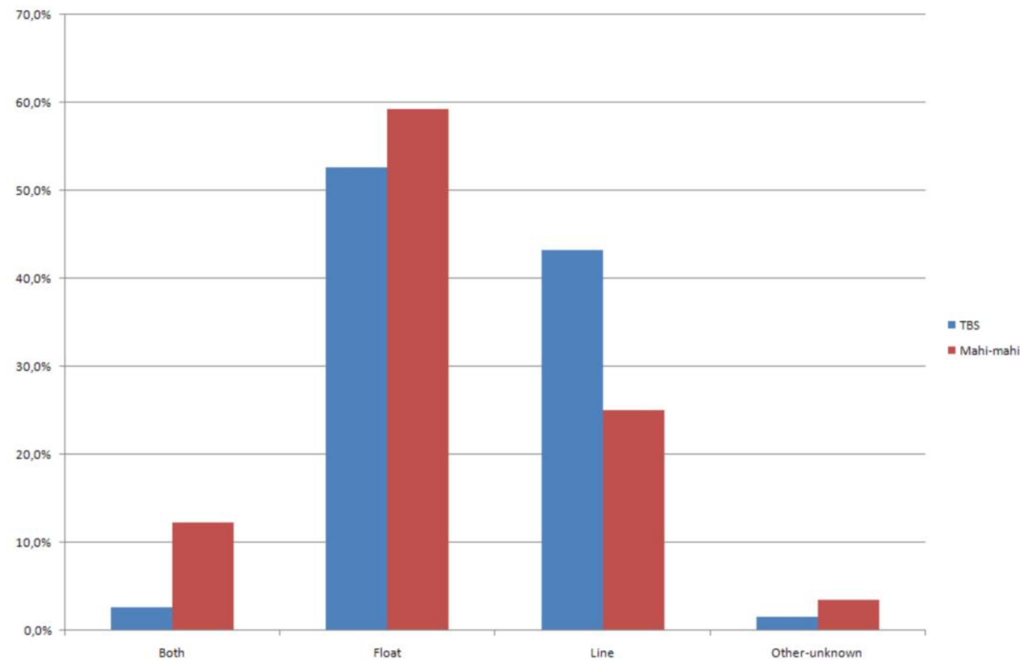
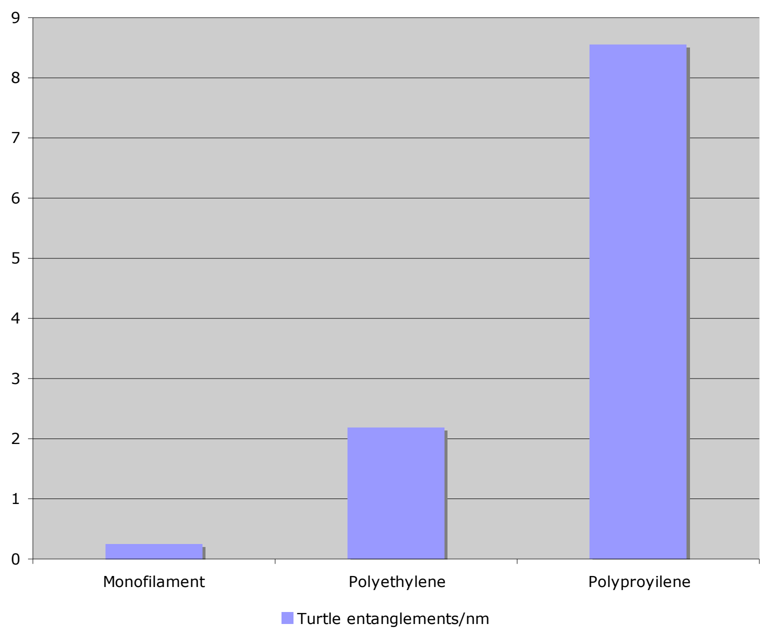


Figure 21

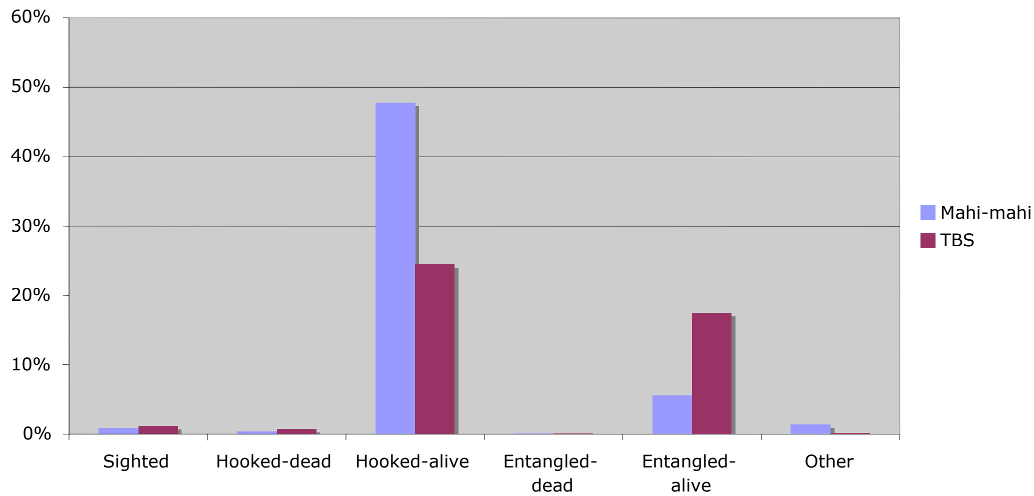
Number of turtles entangled per nautical mile of line by gear material (monofilament, polyethylene, polypropylene). Data from mahi-mahi and TBS fisheries are pooled



8.9 Condition of hooked and entangled turtles

From 2003 to 2007 the program has collected information from 3,379 turtles caught in experimental fishing trips, either hooked or entangled. Interestingly, most of the turtles were recovered alive (3,218 turtles (95%) (Figure 22). This information is very important and highlights the critical role of education, training and awareness of fishermen. Convinced fishermen are more likely to contribute to marine turtle conservation. Proper retrieval, de-hooking or disentanglement of turtles, coupled with adequate on-board handling and release of turtles is essential to increase post-release survival of the animals. It is therefore tremendously valuable that more fishermen have access to this type of knowledge and even make contributions using their own experience to develop better ways to unhook and release turtles safely and efficiently.

Figure 22
Condition of turtles hooked or entangled in TBS and mahi-mahi fisheries; n = 3,379 turtles. Sighted turtles refers to those turtles observed to be swimming near the gear, or able to escape the gear without being brought onboard.



9.0 Awareness and Education of fishermen

This program was established to work with fishermen in bycatch mitigation, circle hook testing, and collection of information through on-board observers, in addition to informing fishermen of the importance of saving marine turtles inadvertently caught during their own fishing operations. This information was provided in an open and frank, but friendly, environment, and they had a chance to express their concerns and opinions. Fishermen also had a chance to give their point of view about the conservation problem and offer their experience to seek and test solutions. In this simple but significant manner, a critical communication channel was established over the solid grounds of collaboration.

Awareness and education of fishermen is achieved through several methods in this program, starting with workshops held in fishermen villages, to one-on-one communication and convincing of captains, their crew and boat owners. In Ecuador, there are many fishing villages along the coast, where more than 80 workshops with 3,500 fishermen have been conducted. In other countries, workshops have also been conducted, with more than 800 fishermen trained. Fishermen leaders have been crucial facilitators for this program, opening many doors to the fishermen communities.

The practical approach of the program and the transparency of its objectives have helped build a trustful relationship with fishermen across the Eastern Pacific. Staff and partners of WWF visit fishing ports and villages and meet with fishermen at their usual gathering places. After a brief and simple presentation of information, explanations of objectives and method of work, fishermen are given the opportunity to join the program. Those captains and crew that have worked with the program to test circle hooks are well acquainted with the practice of carrying an observer aboard their vessels, and consequently become effective communicators, able to convince other captains to join the initiative.

This process of fishermen awareness and education had a high point in November 2007, when the program participated and presented its results at the Fourth International Fishers Forum (IFF4) in Puntarenas, Costa Rica. The IFFs series serve as important fishermen gatherings to discuss bycatch and sustainable fishery issues. The forum is organized by the WPRFMC, and IFF4 was hosted by INCOPESCA (Costa Rican Institute of Fisheries and Aquaculture), with important logistics and coordination support by WWF and Dr. Martin Hall (IATTC).

At IFF4, 250 fishermen, seafood retailers, scientists, and management authorities from Latin America, North America, Europe, and Asia gathered to discuss ways to proactively solve bycatch problems.

WWF´s Director General, Dr. Jim Leape, was the keynote speaker of the conference and spoke about the urgency of transforming current fishing practices to save the world's oceans, their ecosystems, economies and the livelihoods of millions of people. He also described the bycatch program occurring in the Eastern Pacific Ocean as a real life example that illustrates how change is possible.

At the end of IFF4, fishermen signed the Puntarenas Declaration in which they expressed their willingness and commitment to continuously seek solutions to stopping bycatch by trying new techniques and gears such as circle hooks (IFF4 Puntarenas Declaration 2007, Appendix I).

10.0 Technical meetings and collaboration with other programs

10.1 Puntarenas I and Puntarenas II

IATTC and WWF, with financial and technical support of OFCF-Japan, WPRFMC and NOAA, organized two regional technical meetings of this program. Both meetings were held in the port city of Puntarenas, Costa Rica. The first, Puntarenas I, was in June 2006, and the second, Puntarenas II, in November 2007. Both meetings were held in The Fiesta Hotel convention center, where the IFF4 was held, shortly after.

The purpose of these meetings is to enhance the technical and scientific capacity of the program to better achieve the objectives of bycatch mitigation. To this end, participants undertook a comprehensive revision and exchange of information among all countries and teams participating in the program. Revisions included: description of long-line fisheries in each country; technical details of long-line gears and how they are constructed, baited, set and retrieved; the type of hooks used and their market availability; a review of the observer programs; detailed examination of the databases and database requirements, such as data quality control and editing, and planning of future experiments. The meetings also included special training topics such as database management; turtle identification and biology; paired with basic data analysis methods.

Participation in the meeting was open to other interested groups and scientists. Researchers from Brazil, Spain, Chile, Uruguay, Japan, and the US took this opportunity to attend. Both meetings had around 50 participants each and were facilitated by Dr. Martin Hall with the assistance of Nick Vogel (data base management) and with technical support by WWF staff, Sandra Andraka, Alejandra Fonseca and Moises Mug. Scientists who attended and provided important information and input were Dr. John Watson, Dr. Chris Boggs, Dr. Yonat Swimmer, and Dr. Marti McCracken, all of the NOAA, and Dr. Cleridy Lennert-Cody of the IATTC. Dr. Takahisa Mituhasi, an expert in fishing gear and artisanal fisheries from OFCF-Japan, and technical coordinator of the Ecuador and Panama program, also played an important role.

10.2 Workshop on turtle bycatch mitigation for longline fisheries: experimental design and data analysis

Preliminary analysis of data collected by this program have shown that there can be considerable differences in longline gear configuration and fishing practices among vessels, fisheries and countries. There are also differences among vessels, fisheries and countries in the extent to which the alternating hook design was actually implemented. In addition, bycatch and catch data of this program can be highly skewed. For these reasons, statistical methods referred to in the literature on hook experiments may not be appropriate for analysis of the data collected by this program, and thus other methods need to be identified to adequately address these aspects.

With this purpose in mind, Dr. Cleridy Lennert-Cody and Dr. Martin Hall organized a statistical workshop that took place in San Ramon, Costa Rica, November 7-8, 2007, to discuss options for experimental design and data analysis. Participants in the workshop were:

1. Mary Christman (University of Florida, U.S.A.)
2. Daniel Hall (University of Georgia, U.S.A.)
3. Martin Hall, (IATTC)
4. Paul Kinas (Fundacáo Universidad Rio Grande, Brazil)
5. Cleridy Lennert-Cody (IATTC)
6. Bryan Manly (Western Ecosystem Technology, Inc, U.S.A.)
7. Marti McCracken (NMFS/NOAA-Hawaii, U.S.A.)
8. Mihoko Minami (Institute of Statistical Mathematics, Japan)
9. Michelle Sims (Duke University, North Carolina, U.S.A.)
10. Steven Thompson, (Simon Fraser University, Canada).

Sampling design and data collection:

The following questions were put forward to motivate discussion at the workshop (Lennert-Cody, pers. comm.):

1. What is the optimal placement of control and treatment hooks on the longline when the goal is to compare hook performance: alternating individual hook types along the length of the longline; same hook type per block (i.e., between floatlines), but alternating hook types between blocks, or some other design? If the requested design was alternating individual hook types, what would be an acceptable deviation from perfectly alternating individual hooks?
2. Should there be restrictions on the total length of longline (total number of hooks) in the experiment? How would suitable ranges of longline length (total number of hooks) be determined?
3. Given the paucity of hookings per longline, what unit of measurement is best to estimate the necessary sample size for an experiment (e.g., total numbers of animals hooked, regardless of hook type; total number of longlines with at least one animal, total numbers of longlines, total number of hooks)?

Statistical methods for comparing hook performance

1. Is there a conceptually nested set of models that can be used to compare hook performance for both turtles and marketable fish species (e.g., mixed effect binomial/beta-binomial models; hierarchical zero-inflated mixed effects models)?
2. What kind of experiments and analysis can be done to look into hook interactions (i.e., to evaluate the assumption that hooks on the same longline function approximately independently)?
3. How should the nested structure of the data (sets within trips within vessels) best be accommodated in the analysis when some trips or vessels are represented by only one longline set?
4. How might potentially confounding factors (e.g., mixed bait types within a longline, different bait types among longlines) be best accommodated in the analysis?

Workshop proceedings will be published shortly. Further development and evaluation of suggested statistical methods for the analysis of the program’s data will help advance the scientific knowledge on bycatch interactions in artisanal fisheries. These tools will be valuable to assist managers and scientist in the region, and will strengthen the scientific component of this program.

10.4 Sharing information at international conferences.

Preliminary results of this program have been shared at three major conferences. Two posters were presented at the International Sea Turtle Symposium with the first being presented at the ISTS 2007 in Myrtle Beach, South Carolina, and the second at the ISTS 2008 in Baja California, Mexico. Another poster was presented at the 5th International Fisheries Observers Conference in Victoria, Canada in 2007.

It is important to share the experience of working with fishermen in turtle bycatch mitigation and sustainable fisheries with interested researchers and conservation practitioners in these international events. These conferences also provide the opportunity to share technical information about the long-line fishery and marine turtle interactions. In our view, this is valuable since fishermen-based conservation is still believed to be a utopia by some, and more programs working collaboratively with the fishermen are needed in order to meet the challenges of marine and fisheries conservation.

11.0 Discussion and lessons learned

Back in 2003, the first observer was placed onboard an Ecuadorian artisanal long-line vessel and tasked with the job of collecting experimental information regarding circle hooks as a means to reduce turtle bycatch. Since that important step, this program has been able to build a unique region-wide database on the marine turtle and long-line interactions in the Eastern Pacific Ocean.

Statistical analysis of the data collected by this program may require the development of proper analytical methods. Such step may be necessary to account for the multiple design, structure, and operational differences encountered in artisanal long-line fisheries across the Pacific coast of Latin America, in which these experiments are taking place. Ten scientists, each a leading expert in statistical examination of fishery data, looked at this problem during the workshop held in San Ramon, Costa Rica in November 2007. Now the process is advancing and efforts will be devoted to identify, refine and adapt such analytical tools. Not only will this be a great contribution to the program, but also a significant contribution to the efforts of bycatch mitigation in artisanal fisheries in other parts of the world, where similar conditions exist.

After four years of work, we believe the programme demonstrates a very positive outcome trend from the circle hooks experiments. For the two long-line artisanal fisheries predominant in the Eastern Pacific, TBS and mahi-mahi, circle hooks reduce bycatch of marine turtles, in accord with the first essential condition of any bycatch solution. Circle hooks also may result in more benign hookings as preliminary suggested by the data of hooking location.

An interesting and very positive finding is that 95% of all turtles caught in long-line experiments, either hooked or entangled, were reported to have been recovered alive by observers. This finding is most encouraging since it is a strong endorsement of the value of proper turtle handling and releasing techniques by fishermen. In turn, this stresses the central role that fishers can play in reducing marine turtle mortalities as a result of the education and awareness raising.

Additionally, the data show that where entanglements constitute a recurrent problem, the use of monofilament to construct the gear could dramatically reduce entanglements. In our program we found that polypropylene and polyethylene lines do increase entanglements, and this is the most common material used in Peru and Ecuador. This will be an area to focus future efforts, since the change in material may be challenging as it entails an increase in cost, equipment and training. Regulatory aspects of the change may also need to be addressed by governments, since it may require revision of the legal definition of what constitutes an artisanal vessel.

The second most important condition that circle hooks need to meet as a bycatch solution is to catch fish at a similar rate to the J hooks they are going to replace. Preliminary findings of the experiments indicate that circle hooks do perform as well as J hooks in the TBS fishery. The large C/16 circle hook has been widely accepted by fishermen, and this size is the dominant treatment hook in the experiments. In general, the larger C/18 circle hook is not very popular, as the fishermen believe that it is too big. They frequently refuse to place C/18 hooks on their lines when their vessel joins the program to test hooks. Some fishermen, however, especially captains in Costa Rica, who fish for larger tuna and billfish, like the larger hooks.

Results of experiments with circle hooks in the mahi-mahi fishery show a wider range of results in fish catch rates. Here, there are more cases of where circle hooks exhibit lower commercial catch rates than J hooks. The program will continue its research in the mahi-mahi fishery to ascertain the correct fishing condition that will allow commercial catch rates to be maintained whilst simultaneously reducing turtle bycatch. In contrast to TBS tests, fishing experiments in the mahi-mahi fishery have tested five hook sizes, with most of the sample in the smaller sized hooks. It is important to notice that some mahi-mahi fishermen react negatively when presented with the larger C/16 hooks, as they feel the hook is too big. In Costa Rica, some fishermen prefer C/16's more than smaller circle hook sizes, because, although, they reported lower mahi-mahi catches, this was compensated for by an by an increase in the proportion of larger fish. In addition to other factors mentioned before, baiting techniques and economic analysis of the fishing trip are areas for future work. The ultimate aim being to find the conditions in which circle hooks perform best as a viable bycatch solution for the mahi-mahi fishery.

This project started because of the urgency to abate the threat to marine turtle population survival in the Eastern Pacific posed by long-line fishing. Additionally, the partner organizations believed in a bottom-up, participatory approach to marine turtle conservation that engages fishermen from the start. In four years, a huge effort by all partners has been devoted to this aim. Meanwhile, our understanding of the problem and the type of adjustments to solutions has since greatly increased. It is likely that the TBS fishery is on the verge of a large-scale change, while more work is still needed in the mahi-mahi context.

Clearly, there are other challenges to make the transformation of the fleet to circle hooks a reality. These are, among others: a) making circle hooks and other bycatch tools available in local markets at reasonable and competitive prices; b) promoting the institutional adoption of the observer program by local actors to provide sustainability to the program in the medium and long term; c) continue and strengthen the awareness and education of fishermen; d) facilitate the technological adaptation and transformation of the fleet with proper regulatory measures; and e) find and develop potential markets for fish coming from fisheries with circle hooks and turtle-friendly practices.

Therefore, the work of this program will expand from its original fishing experiments focus (which will be continued) to other areas, such as those mentioned above. The intention will remain the same though, that being to ensure that solutions to bycatch can be effectively implemented to save marine turtles and at the same time laying the foundations to move the artisanal long-line fishery in the Eastern Pacific Ocean toward sustainability.

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