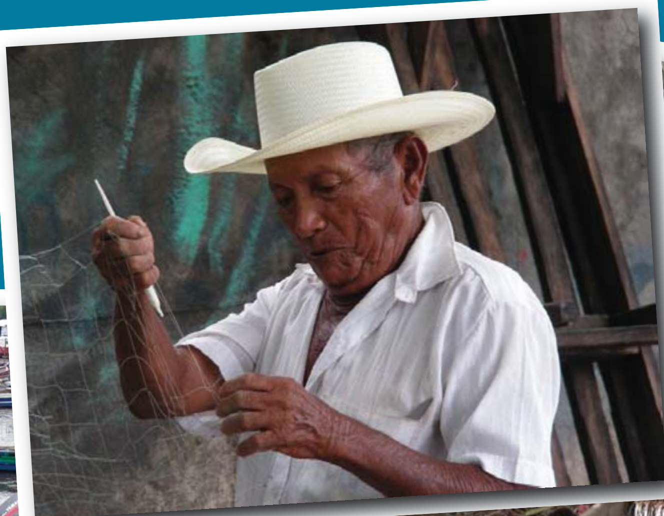
BYCATCH REDUCTION IN THE ARTISANAL LONGLINE FLEETS OF THE EASTERN PACIFIC 2004 – 2008

WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL



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SUMMARY OF ACTIVITIES FOR THE REGIONAL SEA TURTLE PROGRAM OF THE EASTERN PACIFIC - DECEMBER 2008

Prepared by Martin Hall (Inter-American Tropical Tuna Commission), with support from Takahisa Mituhasi (Overseas Fishery Cooperation Foundation – Japan), Nick Vogel and Cleridy Lennert-Cody (IATTC), and the staff of World Wildlife Fund's Eastern Pacific Regional Sea Turtle Program, (EPRSTP) led by Moises Mug, whose efforts produced the majority of the data used in the report.

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EXECUTIVE SUMMARY

The observer program that started in 2004 has continued, and as of December 2008, over 1,615 trips have carried observers in the eastern Pacific countries from Peru to Mexico, making. 7,725 sets and deploying 2,990,935 hooks during the 2004 – 2008 period. Close to 400 boats are testing circle hooks currently, or have already adopted them as a result of the program. The first trips from Mexico were added in 2008. A scientist from Chile was trained on the program activities, data collection procedures, etc.

The experiments with circle hooks continued, comparing J hooks vs circle hooks of different sizes, and when circle hooks were in use, larger circle hooks were offered, as a way to: 1) have an idea of the turtle hooking rates in those fisheries; 2) become familiar with the areas of operation of those vessels; 3) introduce the dehooking instruments, dipnets, and better procedures to release sea turtles; 4) build awareness.

Randomization tests, suggested as an outcome of a recent statistical workshop (see below) were performed for the first time, as a better way to test for statistical significance. Datasets for contrasts between J and C16 hooks, the most important match up, were compared for several country-year combinations. To try to account for bait differences, two sets were used: one with all sets included, and another one with only single bait sets. Data were also filtered according to several criteria to secure the "cleanest" dataset possible to perform the tests. The procedures and the characteristics of the tests are described with some detail. In general the results show that the majority of the tests are significant, and that the level of significance drops when the sample size is reduced by imposing more selective criteria to the data, but the signal is still quite positive. Circle hooks tend to reduce sea turtle hooking rates in most locations and years tested. The remaining combinations, and the target species catch rates, will be statistically tested in the near future, to complete the study.

The other important change produced by circle hooks is a change in the location of the hooks in the turtles. As deep, swallowed hooks, are believed to reduce the chances of survival of the turtles, especially when attempts are made to recover the hooks, then a reduction in those hookings should

be a positive step. For comparisons ranging from J vs C12, to J vs C16 hooks, there is a very clear pattern: circle hooks produce very large reductions in the proportion of swallowed hooks, which tend to be “replaced” by hooks in the lower jaw, or external. The statistical tests will be performed for a future publication, but the differences are quite large, and consistent in their direction. An interesting observation is that circle hooks of very different size do not seem to have major differences among themselves with regard to the proportion swallowed, suggesting that it is the shape what counts.

The program is adding information concerning the spatial distribution of the species of conservation concern. Taking into account the limitations of the sampling coverage, several areas show concentrations of hawksbills or loggerhead turtles that could indicate important habitats.

The data also provide very important information on the condition of the turtles encountered. The vast majority of the turtles (99.991%) hooked or entangled in the surface fisheries were encountered alive, thus providing the fishers with an opportunity to release them alive. Bottom longlines have much lower encounter rates, but the proportion of fatalities is higher. This is an interesting issue for conservation of turtle species more likely to be taken in bottom longlines because of their habitat preferences (e.g. hawksbills).

Scientists from the Overseas Fishery Cooperation Foundation – Japan are organizing a catalog of hooks used in the region that will be extremely useful to standardize fishing effort in the region. Another OFCF program is under way, looking in a comparative way to all longline gears used in the eastern Pacific. The gear from vessels from Guatemala, Nicaragua, El Salvador and Peru has been the subject of the first stage of the program. The description includes all details of the materials, construction, mode of operation, etc., that can be significant for standardizing both target effort, and for understanding the bycatch implications of the differences observed. There is a huge diversity in the fishing gear of the region, and also in the potential styles of circle hooks that are being tested or have already entered the fisheries. Detailed measurements of the hook dimensions and shape parameters will help understand which are the characteristics that have more significance for the selectivity of the hooks with respect to target and bycatch species hooking rates and locations.

A persistent problem for the exchange of hooks in the South American mahi-mahi fisheries, has been the lower production of circle hooks. The study of hook selectivity by T. Mituhasi (OFCF) has shed light on the problem. The difference in catch rates is predominant at smaller sizes, with J hooks outdoing circle hooks. Reducing further the sizes of circle hooks has not been considered as a good alternative, to avoid adding to a fishery based, at some part of the season, on juveniles, or small sized individuals. Further explorations are needed on alternative hook shapes, and on convincing the stakeholders that it is better to avoid catching the small fishes because of management and economic considerations.

The catch rates of the target species have been pooled to simplify the number of comparisons, but that introduces some spatial heterogeneity in the analyses. The results show that for the TBS surface fisheries there is a considerable parity between J and circle hooks, and that has allowed the replacement of the hooks in these fisheries. For the mahi-mahi fisheries the problems have been stated in the previous paragraph; only the smaller sized circle hooks (C12 and C13) approach the production of the J hooks. For bottom longline fisheries, circle hooks are very competitive in practically all cases, and are being adopted. The comparisons between sizes of circle hooks shows that the catch rates of consecutive numbers are very similar, and those separated by two sizes do not show more than a 20% difference

Major progress has been made towards developing best procedures to handle and release hooked or entangled turtles. We had the opportunity to bring a veterinarian to participate in an experiment testing wired hooks, and she was given the chance to see directly the instruments and procedures used by the observers, and being communicated to the fishers, to handle the turtles. The program was a combination of efforts by OFCF, IATTC, CRAM (Spain) and The Ocean Conservancy. The experience was very fruitful. It was very encouraging to see that the damage caused by the hooks themselves, and by the removal procedures were in most cases quite mild, and that survival was very likely in most cases. In the future, a video, instructing observers and fishers on the best procedures will be produced by OFCF-Japan with Vet. M. Parga. What was learnt during the trip has already been communicated to many at different conferences and workshops, and more activities are being planned for 2009. Another cruise is planned for 2009, where the documentation of the study will be improved by the use of endoscopes, and video cameras. An outcome of the observer program, and of the Veterinarian on Board program is that the definition of the equipment to be recommended to all longline vessels of the type encountered in our samples is becoming sharper, and we will propose the adoption of a set of release instruments including dipnets, types and sizes of dehookers, etc.

A second experiment was carried out by OFCF scientists on hooks with a wire added. This one is not an exact replicate of the first one because changes were made in the material used for the wires (softer material) and on the presence of a ring on the eye of the hook. Size 4 J hooks were the controls for a comparison with, J4 hooks with a wire added, and C13 hooks with a wire. Both hooks reduced significantly the hooking rates (63% and 50% respectively), but there were important losses in catch rates of target species (34% and 20% respectively). More circle hooks were swallowed, perhaps because of the differences in hook design, so additional tests are needed.

An experiment to reduce entanglements also preformed by Dr. T. Mituhasi from OFCF was very successful. Replacing sections of polypropylene lines with nylon/polyamide monofilament near the floats, the number of entanglements was reduced from 17 to 1, in a comparison of 2,367 floatlines of each type.

Several workshops were organized in recent times. The whole team of the Eastern Pacific Regional Sea Turtle Program from WWF met with the technical staff from OFCF, IATTC, NOAA, SUBMON, and with invited guests from Brazil, Chile, Japan, and the USA. We discussed recent advances, challenges and opportunities, shared results of data analyses, and planned future activities and experiments. A first approach to understanding the potential impact of nets on sea turtles was also included.

Another workshop addressed database issues, searching for consistency and improvements in data quality over the whole region. N. Vogel (IATTC) was in charge of this activity that included all the database managers of the countries participating in the EPRSTP from WWF.

Another major event of the period was the Statistical Workshop on Experimental Design and Analysis of Sea Turtle Mitigation Studies. Organized by scientists from IATTC, NOAA, Duke University, and The Institute of Statistical Mathematics – Japan, and sponsored by OFCF-Japan, IATTC, and NOAA. The workshop addressed the major questions posed by the analyses of the experimental results of the program, and proposed different approaches to advance in the analysis. The proceedings are available as an IATTC Special Report. The participants included Drs. Mary Christman, Daniel Hall, Paul Kinas, Bryan Manly, and Steven Thompson, besides the organizers Cleridy Lennert-Cody, Marti McCracken, Mihoko Minami, and Michelle Sims.

The staff of WWF's EPRSTP, of OFCF, of IATTC, and the Costa Rican fisheries agency (INCOPESCA) were very involved in the organization of the International Fisheries Forum 4, convened and sponsored by the Western Pacific Regional Fishery Management Council (NOAA). Several members of the team presented results at the Forum. The Foundation AVINA sponsored a meeting of artisanal fisheries leaders of the eastern Pacific countries that was also attended by some artisanal fishers from the Western Pacific, and from Asian countries.

The activities planned for the future include:

Additional experiments, currently under way, to reduce sea turtle entanglements, testing line with a metal core. This experiment is sponsored by The Ocean Conservancy, and carried out by staff of the WWF-Ecuador program.

Plans are being made to test a hook used in Japanese coastal fisheries for mahi-mahi in the South

American region, as an alternative to circle hooks.

An observer program is needed to assess the significance of bottom longline fisheries that are widespread in the region and could have an impact on the populations.

The selectivities of all hook types and sizes needs to be studied, to make an accurate assessment of the impacts of the hook exchanges on the different components of the ecosystem.

Post-hooking experiments, beginning with a simple conventional tagging program are needed to evaluate the effects of the changes in hooking locations, and in other hook characteristics (e.g. materials) on survival of turtles after release.

An implementation program is needed to work with the countries of the region and with regional organizations to implement the changes proposed. Nicaragua has just passed a law, eliminating import taxes and tariffs on circle hooks to help them become more competitive economically, and also to increase their availability. This example needs to be extended top other countries.

The hook catalog being prepared by OFCF needs to be completed, and analyses of the hook properties must be carried out to understand which are the hook features that help reduce hookings, or mitigate the impact of the hookings. A comparative study of longline gear from the region (an OFCF-IATTC program) will be completed in 2009, providing the basis for a classification of the fisheries of the region based on the gear they use that can help to stratify the sampling effort, and improve the discriminating power of the statistical tests.

Some fishing tests are needed to verify the behavior of fishes with respect to the distribution of hooks in the lines, that was suggested during the statistical workshop. Basically, the question is: Is the hooking rate of a J hook with J hooks on both sides similar to that of a J hook with circle hooks on both sides? The answer should help interpret the results of current experiments, and project the figures observed to lines with only one type of hook.

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1. Introduction

The Regional Sea Turtle Program of the eastern Pacific started in late 2003 in Ecuador, and it has turned into a major project of continental scale. In order to coordinate the activities, oversee the data collection, editing, and processing, several organizations participate in the planning and execution of the program. Scientists from IATTC and OFCF-Japan visit the different countries several times a year, to produce joint analysis of the data with local fishery scientists, and with members of WWF's (EPRSTP) to secure consistency in the data, and to produce the comparative results that are very important to integrate over the whole region.

In this report we summarize succinctly, the results up to late - 2008. A technical workshop in November, 2007 brought together most of the researchers participating in the project. Results for the initial years (2004-2007) are already available in the Western Pacific Regional Fishery Management Council website.

2. Basic description of the Program

The program has been described in previous reports.

http://www.wpcouncil.org/protected/Documents/Largacha%20et%20al_2005_Ecuador%20first%20year%20results.pdf

http://www.wpcouncil.org/protected/Documents/WestPacRpt2007MidYearRpt.pdf

and a brochure:

http://www.wpcouncil.org/protected/Documents/Brochures/Ecuador%20brochure_FINAL.pdf

Its main objective is to reduce sea turtle bycatch in the artisanal longline fisheries of the eastern Pacific by promoting the replacement of J-hooks by circle hooks, after the fishers have tested the hooks in their normal fishing conditions. The change can be beneficial in two ways: reducing hooking rates, and reducing the incidence of swallowed hooks that are believed to result in higher post-hooking mortality than the mouth hookings more commonly caused by circle hooks. The program also attempts to improve the methods and instruments used by fishers to handle hooked turtles (Epperly *et al*., 2004; McNaughton and Swimmer, 2004; Parker *et al.,* 2005), as another way to increase survival, and to build awareness among the fishing communities of the need to make every effort to help conserve these species.

3. Characteristics of artisanal longline fisheries in the region

Throughout the whole period of the Program the main institutions responsible for the implementation of the program (WWF, IATTC, OFCF, NOAA) gathered and analyzed information about artisanal longline fisheries of the region, in a bid to understand the actual situation of the fisheries and to develop effective and viable countermeasures against incidental catches of sea turtles.

In the eastern Pacific region, artisanal fishing vessels from Central and South American counties operate two categories of longline gears; surface longlines (drifting longlines) and bottom longlines. Surface longline fisheries target tunas (Yellowfin and Bigeye tuna), Billfishes, Sharks, Oilfish, Mahi-mahi, and occasionally Swordfish. The bottom longline fisheries target mainly Snappers, Groupers, Sharks, Rays, Catfishes, and Pike congers.

Surface longline fisheries from Peru and Ecuador target mahi-mahi in the summer, and tuna and sharks in the winter. The fisheries from Central American countries change their targets depending on the availability of the resources in fishing grounds.

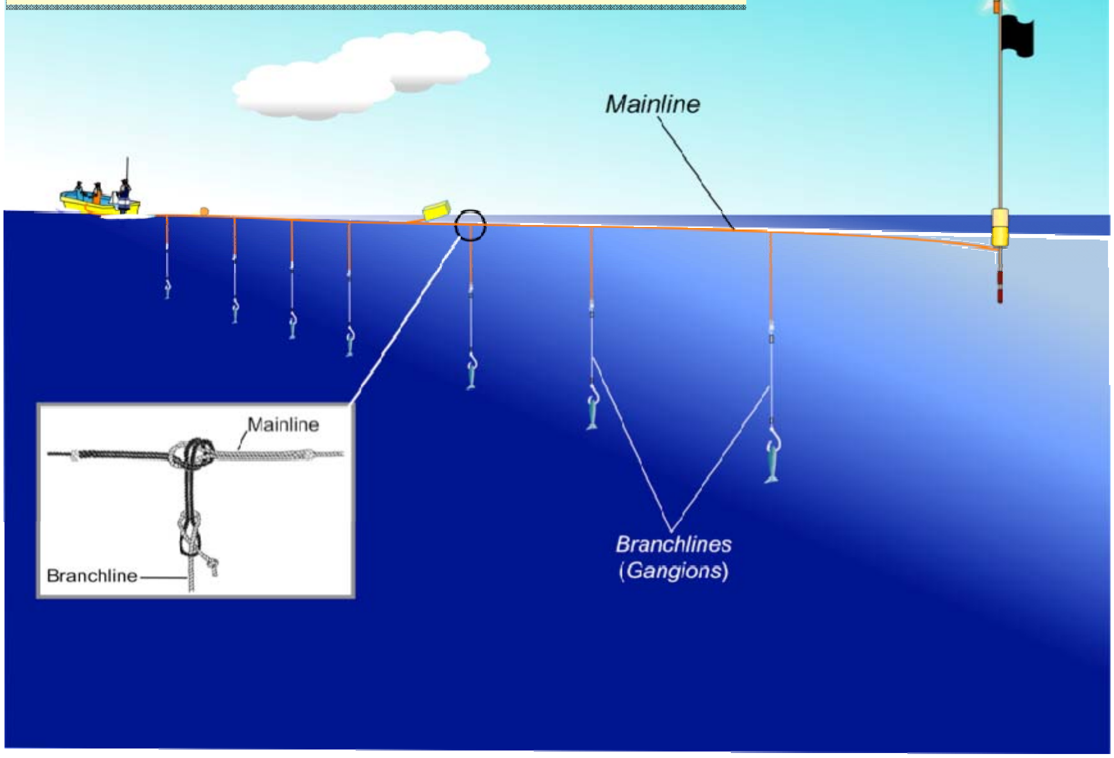
3.1 Description of Fishing gears and methods

3.1.1 Surface longlines (Drifting longlines)

In this region, artisanal fishers use two types of materials for their surface longline gears: Polypropylene (PP) or Polyethylene (PE) cordages, and Polyamide (Nylon) monofilament (PA-MF) (Fig. 1). Fisheries from Peru and Ecuador predominantly use longlines of PP or PE cordages. PP and PE have a tendency to float (specific gravities of PP and PE are lower than that of seawater), hence the mainline made of PP or PE extends just below the surface of the sea. Branchlines are fastened onto the mainline by a knot or by a swivel**.** Branchlines are fastened onto the mainline by a knot or by a swivel**.** This type of gear is usually operated manually and is stored in a box or storage bin without separating branchlines (gangions) from the mainline (Fig. 2). The hook spacing (distance between two neighboring branchlines) is not changed during a trip.

Surface longline fisheries from Panama and Costa Rica mainly use longlines made of PA -MF. In other Central American counties, this type of gear is in a minority. As Polyamide has a tendency to sink, longline gears made of PA-MF are suspended horizontally at a predetermined depth with the help of floats (Fig. 1). Branchlines are stored in a box (Fig.2) or on branchline's hanger ropes (Fig. 3b). Longline vessels with PA-MF longline usually have a hydraulic reel to haul and store the mainline (Fig. 3a). Branchlines and Floatlines are attached to the mainline with snaps while setting the gear, and are detached from the mainline while hauling the gear.). For this type of longlines, the hook spacing, the number of hooks between floats, and gear setting depth may vary between sets. In Panama, a vessel usually has two or three kinds of branchlines; one for the TBS fishery and the others for mahi-mahi or bottom fishes.

Fig. 1a: Longline material Polypropylene or Polyethylene



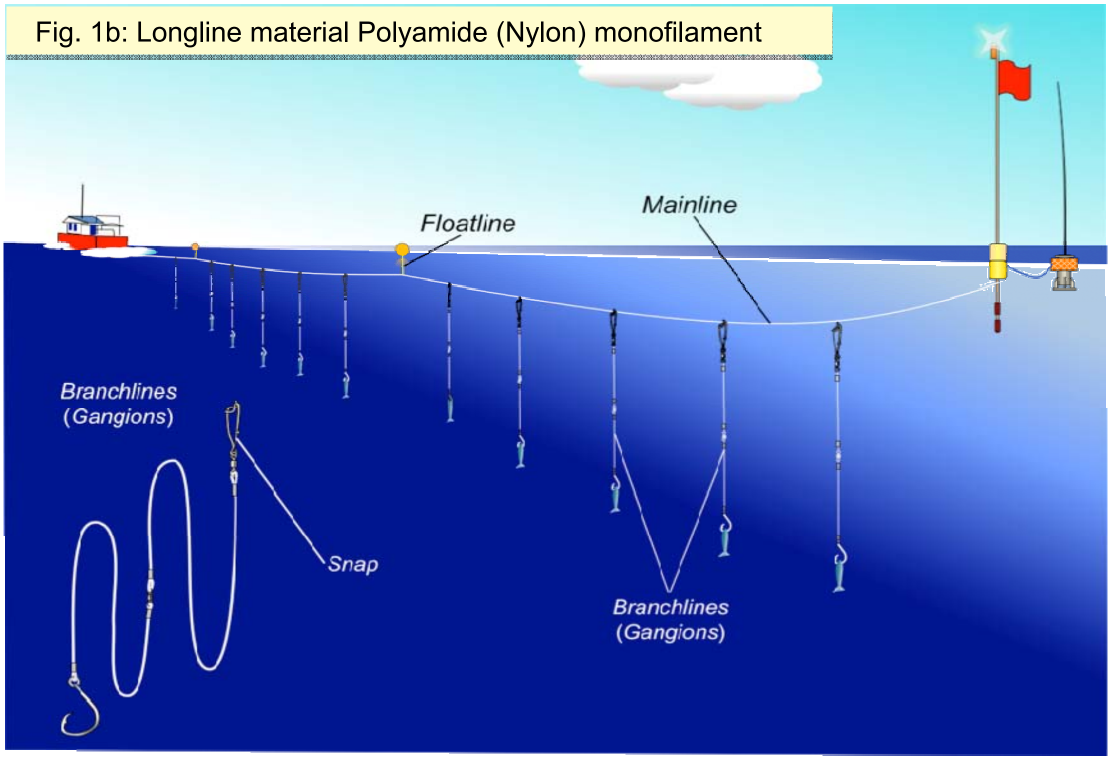


Fig. 1a and 1b: Diagram of artisanal surface longlines used in the eastern Pacific region

Fig. 2 Gear storage for PP longline

Fig. 3a and 3b: Hydraulic reel for mainline and storage bins for branchlines 3a (left), and hanger ropes for branchlines 3b (right)

3.1.2 Modes of fishing operation

The gear can be deployed by the stern (stern setting) or by the side (side-setting).Shooting of monofilament longline is done from the stern of the vessel, regardless of vessel size and type. Meanwhile, “side-setting (shooting longline gear from the side of the vessel)” is more common for PP and PE longlines used in Ecuador, Peru, and Central American countries.

3.1.3 Fishing Period

In most situations, surface longlines are set in the morning, sometime around first light, to adapt to the main feeding periods of the target fish species and avoid the feeding period of predators such as Jumbo flying squid (Dosidicus gigas), which are mainly night feeders. However, sometimes fishers also shoot the gear in the late afternoon because tunas and other species also tend to bite at dusk. The longline is hauled starting in the afternoon or early in the evening. The ending time of the hauling varies depending on the number of fish hooked and problems encountered (line tangles, line breaks, etc.).

3.1.4 Special setting methods

Fishers form Ecuador and Panama sometimes set longlines in special ways when they target tunas.

3.1.4.1 “A la rueda” setting – Ecuador. Ecuadorian fishers set the gear in a way called “*a la Rueda*”. This type of setting is done only at night with live squid baits that could have more possibility of catching tunas and billfishes than dead baits. Crewmembers begin by fishing squid with jigging gears. They string the captured squids from the side of vessel with short cordages to keep them alive until they begin to set the longline. Once they have captured the amount of live squids needed, they begin to set the gear without using the engine. The vessel drifts with the current and wind, and a crewmember shoots the longline putting live squids on the hooks while other crewmembers continue fishing for squid. If they do "A la rueda" setting, usually the time spent setting is longer than that for normal setting and the numbers of hooks deployed is smaller than those of normal settings (Fig. 4).

3.1.4.2 "Dolphin setting" – Panama

Panamanian longline fishers often use dolphin schools to fish tunas that are associated with dolphins. They set several longlines around a dolphin school. These longlines have shorter mainlines with smaller number of hooks than those of longlines for normal setting (Fig. 5).

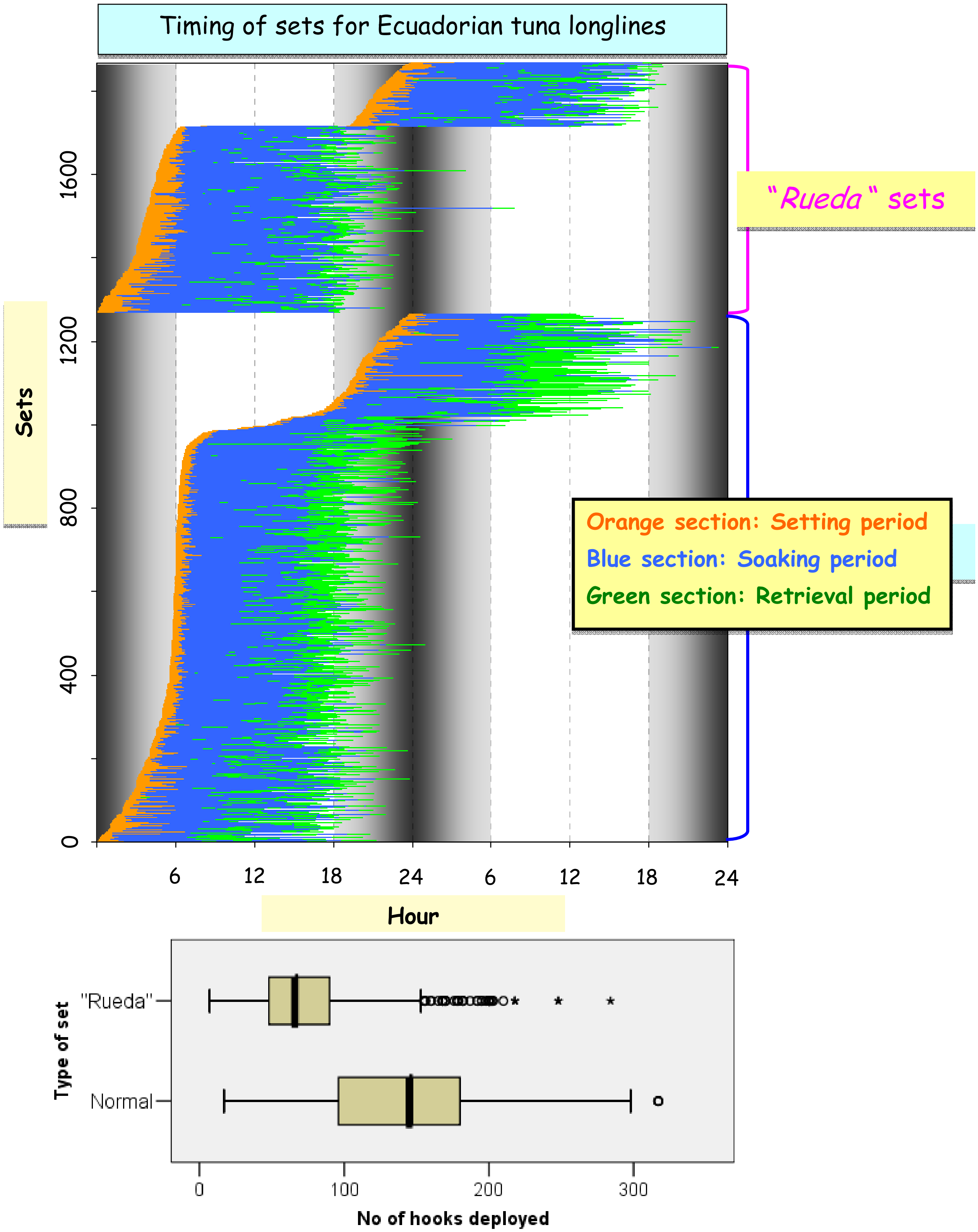


Fig. 4. Timing of sets for Ecuadorian tuna longline fisheries (above) and number of hooks deployed by type of set (below).

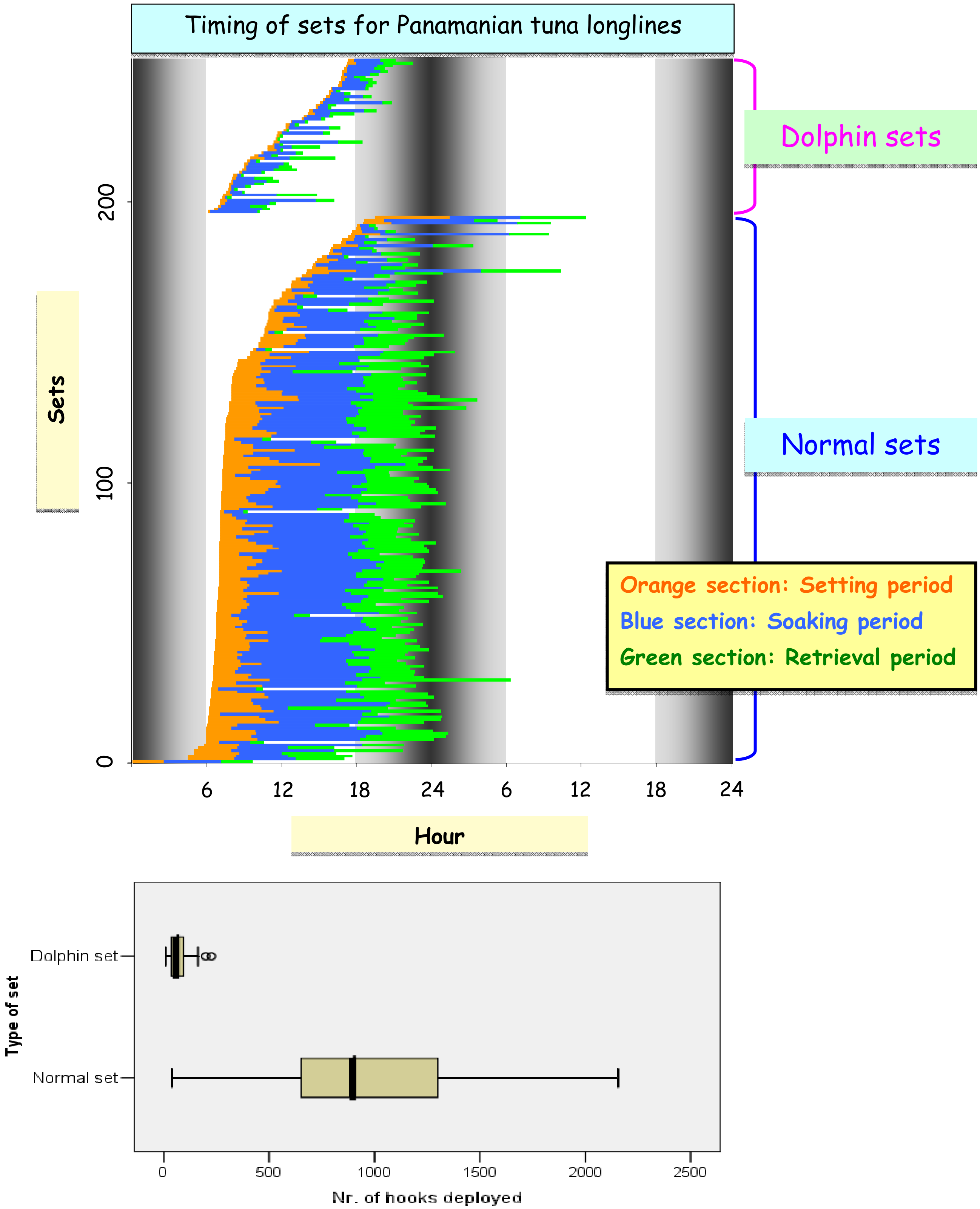


Fig. 5. Timing of sets for Panamanian tuna longline fisheries (above) and number of hooks deployed by type of set (below).

3.1.7 Bottom longlines

Bottom longline gears of this region consist both of synthetic fiber ropes (PP, PE, or PA) or PA monofilament. Four types of hooks are currently used in this fishery; J-type, Circle hooks, Japanese-type tuna hook, and E-Z baiter type. Comparing to surface longline gears, bottom longline gears have shorter branchlines and shorter hook-spacings. For some bottom longlines, lead weights are attached to the mainline or branchlines. For better understanding of sea turtle interactions with bottom longlining, region-wide monitoring of bottom longline operations is absolutely essential.

3.2 Vessels

In the eastern Pacific region, there are two categories of artisanal longline vessels that we should be aware of; small fishing boats ranging from 6.5m to 9.0m in length, and larger vessels ranging from 12m to 30m in length. Almost all the small vessels are made of fiberglass (and they are called "*Fibras*" in Ecuador for this reason), and are equipped with one or two outboard motors of 40hp – 110 hp (Fig. 6). The larger vessels are made of different materials (Fiberglass, wood, and steel) and usually equipped a diesel inboard engine (Fig. 7).

Longline fishing vessels from Mexico, Guatemala, Nicaragua, Costa Rica, Panama, Colombia, and Peru operate independently. For Ecuador, there are two modes of operation; individual operation and mothership operation. When the fishing ground is very close to the coast, a fibra can operate independently, but most fibras operate further offshore, in association with a vessel called "bote". A bote tows a number of fibras to the fishing grounds, acting as a mothership, carries the supplies, and receives and stores the catch.

Fig.6　Longline fishing vessels made of fiberglass with an outboard motor

Fig.7　Longline fishing vessels with an inboard engine

4. Reducing incidental catches of sea turtles by longline gears

4.1 Sampling effort

The spatial distribution of the sampling effort, accumulated over the whole period of the experiments is shown in this contour map. The map only shows the numbers of J hooks, the controls in the experiments.

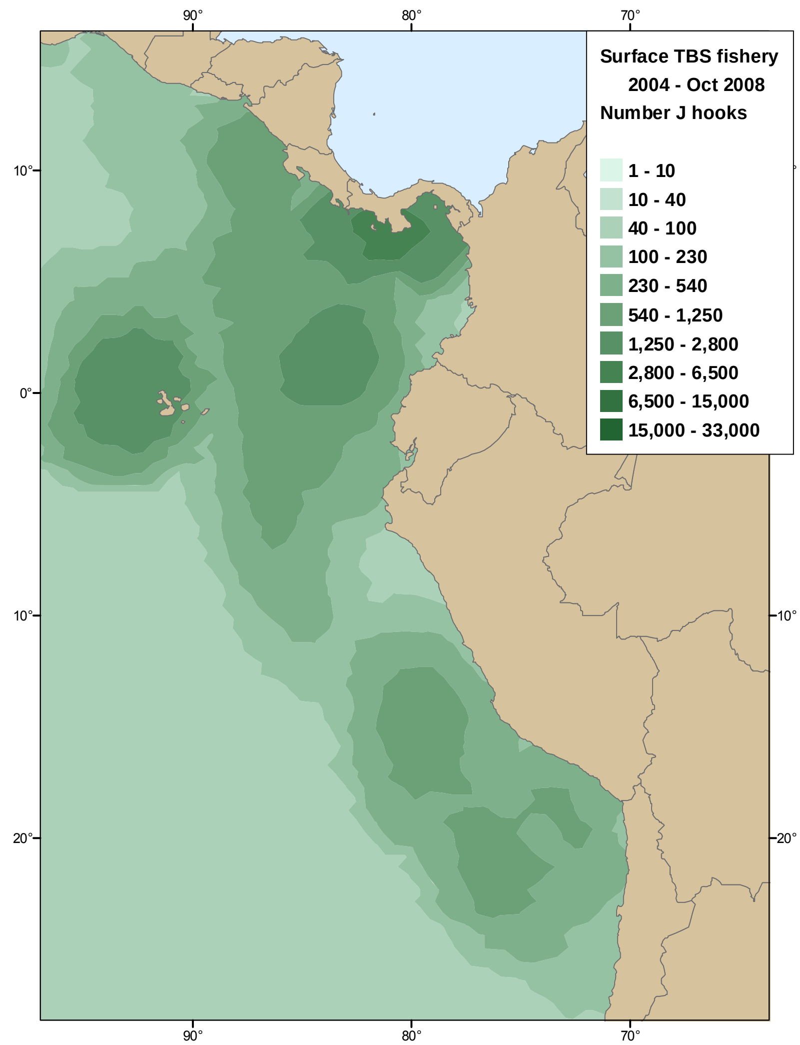


Fig. 8 Contour map of sampling effort

The distribution of trips by flags is shown in the following table:

Table 1. Regional sea turtle program
Summary of sampling effort (2004 – Dec 2008)

Country	LL vessels sampled	Total hooks (sample size)	LL fishing trips observed	LL experimental sets
Ecuador	186	395,949	488	2,469
Peru	44	328,089	123	896
Panama	13	870,492	93	999
Costa Rica	50	852,380	170	1,610
Guatemala	63	509,236	643	1,633
El Salvador	8	10,062	13	25
Mexico	24	1,763	25	25
Colombia	3	22,964	60	68
Totals	**391**	**2,990,935**	**1,615**	**7,725**

Table 1. Distribution of trips by flag, and sample sizes. LL= Longline

4.2 Effects of the adoption of circle hooks

There are two potential effects of the replacement of J hooks by circle hooks (Watson *et al*., 2005; Gilman *et al*., 2006): a) an effect on the hooking rates; and b) an effect on the survival of hooked turtles because of the change in the location of the hooks in the turtle. As a general observation, J hooks (and the similar Japanese style tuna hooks) tend to be swallowed by the turtle, and end up lodged deeper in the esophagus of the turtle, while circle hooks tend to lodge in the mouth (mostly in the lower jaw and commisure). In order to test these two effects, hook replacement experiments were carried out over the whole eastern Pacific region.

4.2.1 Testing for differences in hooking rates

A recent workshop (http://www.iattc.org/PDFFiles2/SpecialReport17.pdf) considered several alternative ways to analyze the hooking rate data to test for statistical differences, and research projects were suggested to produce an in-depth analysis and comparison of the methods. As a first approach, a simple randomization test was applied to the main comparison of the program the one covering the widespread TBS fisheries.

There are two tables below that show results of comparisons of J *vs* C16 hooks for Manta (Ecuador), Balboa (Panama), and Puntarenas (Costa Rica), for the TBS fishery. Randomization methods make minimal assumptions about the data, and do not attempt to explicitly model the processes underlying the data. For these reasons, randomizations tests may not be optimal for the purpose of estimating the relative magnitude of hooking effects, but to test the general null hypothesis of no difference in hook performance, a randomization test is a quick and straightforward method for testing the null hypothesis, and the results of randomization tests are easy to interpret.

The question of interest is: Is there a difference in hooking rates between J and C hooks? Thus, the null hypothesis is, H_o: the 'hook type' effect = 0, or equivalently, H_o: the hook type makes no difference to the relative hooking rate.

To test this null hypothesis, permutations of the data should be generated in accordance with the study design, assuming no hook effect. The actual method of randomizing the data will depend on the experimental design and should preserve the data structure.

In experiments for which longlines have different numbers of J and C hooks within the same line, and for which the actual hook placement on the line is not known, randomization of the data must be handled differently. In some cases, we start with a perfectly alternating distribution, but processes of hook loss-replacement, loss of segments of lines, etc., could result in perturbations of the initial design, and we have to switch the approach.

Null hypothesis = sea turtles are equally likely to be hooked on J hooks as C hooks.

If such is the case, assuming only two hook types for each set, each hook that caught a turtle would be randomly assigned a hook type, either a J or C, based on the proportion of J and C hooks on the longline. For example, suppose the longline set had 100 J hooks and 200 C hooks, and that five turtles were caught, three on J hooks and two on C hooks. To obtain a randomization of these data under the null hypothesis, each of the five hooks that caught turtles would be randomly assigned a hook type according to the following probabilities: 1/3 for J (= 100/300) and 2/3 for C (=200/300). To randomize data from multiple longline sets, where each set had different numbers of J and C hooks per longline, these probabilities must be computed separately for each longline. Note that by randomizing the labels of hooks that caught turtles (without randomizing the total hooks by type), we are testing for additive hook effects, not interactions.

In the case of equal numbers of J and C hooks on the line, the sum (across sets) of differences in numbers of hooked animals (i.e., number of animals on J hooks minus the number of animals on C hooks) could be used as a summary statistic. For lines with unequal numbers of J and C hooks, the sum across sets of the differences in the proportions of hooks with animals could be used.

Following general randomization procedures for constructing confidence intervals (Manly, 2007) and the permutation procedures outlined above, confidence intervals based on randomization methods can also be computed.

The first table shows results from an analysis of all sets (i.e., regardless of bait type or other types of C hooks on the longline). The second table shows results of an analysis of single-bait sets (single bait according to the bait code table, i.e., not according to grouped bait categories) and longlines with only J and C16 hooks (i.e., no other types of C hooks on the longline). Note that 'single-bait' means only that the bait within a longline was the same, not that bait was the same among longlines. Bait types differ considerably by port.

<u>Definitions of variables in tables</u>:

Sum difference = Sum of individual set differences: (Nr. turtles on J hooks/Nr J hooks) – (Nr. turtles on C16 hooks/Nr. C16 hooks).

A randomization test was used to obtain all p-values. In the table, p-values for the two-tailed tests are presented (null hypothesis there is no difference in hooking rates). Alternatively, some could argue that the hypothesis of interest is only whether circle hooks significantly reduce the hooking rates, against the alternatives (no difference or increase in hooking rates) which are both undesirable outcomes (i.e. no effective mitigation). In this case, the tests should be one-tailed, and for these cases, the one-tailed p-values are very close to one half of the p-values on the table.

The data used in this analysis (both tables) were limited to sets with the following characteristics:

- edited data only;
- standard longline sets;
- surface fisheries only;
- no missing data on hook/catch information;
- hooks 'in balance' ($0.5 \leq$ (Nr.J hooks / Nr.C hooks) ≤ 2.0).

The statistical design of the experiment was based on alternating hooks on the lines, but it must be taken into account that as the fishing operation proceeds, lost hooks (e.g. caused by shark bites or other reasons) will need to be replaced, and it will be very difficult for observers, and even more to fishers to maintain the original distribution. So, some drifts in the proportions will occur, and boundaries were arbitrarily chosen to isolate the egregious cases (ratios higher than 2:1 or 1:2).

For lines with more than one type of C hook, the requirement of 'in balance' was generally applied to all hook types on the line, even though only J and C16 hooks were compared. The exception to this was for Balboa in 2007 where the 'in balance' requirement was applied only to J and C16 hook types; there would not have been a minimum number of sets for the comparison if the number all other C hook types were required to have been in balance with the number of J hooks.

Tests were only performed for years with at least 20 sets and at least 10 turtles. Dashes in the table indicate insufficient data.

To note is that for Manta in 2007, many of the sets were apparently "rueda" sets (a mode different from the standard), and were not included in this analysis.

Year	Sede	Number of sets	Sum difference - turtles	p-value turtles (2-tailed test)	Sum difference - fishes	p-value fishes (2-tailed test)
2004	Manta	213	0.077	0.43	0.113	0.82
2005		395	0.825	<0.01	-0.058	0.93
2006		271	0.243	0.03	-2.344	<0.01
2007		308	0.227	<0.01	-1.323	<0.01
2008		100	0.115	0.08	-0.522	0.07
2005	Balboa	35	0.038	<0.01	0.338	<0.01
2006		25	0.008	0.63	0.025	0.86
2007		32	0.155	<0.01	0.311	<0.01
2005	Puntarenas	83	-0.017	0.71	-0.565	<0.01
2006		27	0.020	0.37	-0.075	0.22
2007		65	-0.047	0.03	0.234	0.04

Table 2. (A) All sets

Year	Sede	Number of sets	Sum difference - turtles	p-value turtles (2-tailed test)	Sum difference - fishes	p-value fishes (2-tailed test)
2004	Manta	------	-----	-----	-----	-----
2005		244	0.602	<0.01	-0.135	0.81
2006		126	0.118	0.13	-1.009	<0.01
2007		153	0.160	<0.01	-0.654	0.04
2008		------	-----	-----	-----	-----
2005	Balboa	25	0.017	0.01	0.039	0.43
2006		------	-----	-----	-----	-----
2007		------	-----	-----	-----	-----
2005	Puntarenas	33	-0.019	0.60	-0.544	<0.01
2006		------	-----	-----	-----	-----
2007		------	-----	-----	-----	-----

Table 3. (B) single-bait, single C

Positive values in the column *"Sum difference turtles"* indicate that the direction of the change is towards a reduction in hooking rates when using circle hooks

Ideally, these reductions will be coupled with no change or a small negative change in the *Sum difference – fishes* column, showing that catch rates are maintained or slightly improved by the circle hooks. Large increases could lead to, or augment, overfishing problems. No significant changes in target hooking rates would be a desirable outcome of the experiments.

For the Ecuadorian fleet, that has contributed by far the largest sample, both outcomes are within the desirable range. For most of the fleet-year combinations, there are significant reductions in sea turtle hooking rates (using either one- or two-tailed tests), with the exception of Puntarenas, Costa Rica, where the changes tend to be not significant. From the point of view of the target catches, Ecuador shows in general significantly higher hooking rates with C16 hooks, Panama's rates on circle hooks are lower, and in Costa Rica the results are mixed.

4.2.2 Changes in the location of hookings by type and size of hooks

Looking at the distribution of hooking locations in the plots below (Figures 9 – 15), it is very clear that an effect of the circle hooks is the strong reduction in the proportion of hooks swallowed. Even though it appears intuitive that swallowed hooks will result in lower survival rates than hookings in the mouth, this has not been demonstrated, and some veterinarians believe that further analyses are needed. If fishers attempt to recover the hooks (rather than cutting the line), as is the case in the very tight economic situations prevailing in the region, then mouth hookings will be much easier to handle, and damage to the animals will be much less than in the case of deep hookings. If a hook is swallowed, then it may be easier for the turtle to deal with a smaller hook (J) than a larger one, and also to deal with a corrodible material than with stainless steel. In spite of these very real concerns, the overall positive effects of circle hooks (reduction in hooking rates, and location changes) seem clear in view of the evidence acquired up to now.

Given the fact that the location data cover many sizes of circle hooks, it is of interest to explore how the effects vary with changes in hook size, as a way to try to isolate the effect of size from that of shape. It has been said that circle hooks are not swallowed because they are much wider based on some experimental data (Watson et al., 2003a; 2003b), while other explanations emphasize that the shape is the cause of the change in hooking location (Geir Sivertzen, aka “Dr.Hook” from O. Mustad and Son A.S., pers. comm.). Figure 16 shows the way the proportion of hook swallowed changes from larger to smaller circle hooks, and it includes the J hooks for comparison, The fisheries have been kept separate, but a C16 hook from a mahi-mahi fishery should not behave differently from one from a TBS fishery, unless there are biases in the characteristics of the turtles encountered or other factors.

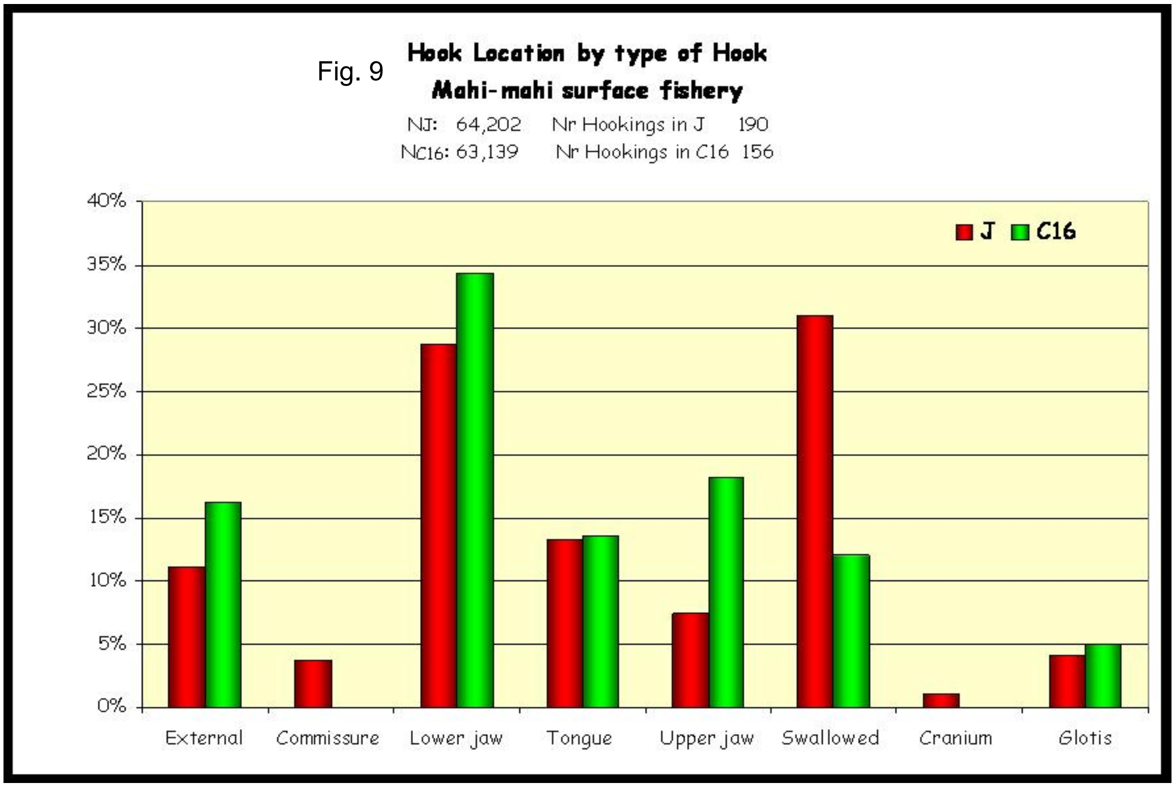


Fig. 9
Hook Location by type of Hook
Mahi-mahi surface fishery
NJ: 64,202 Nr Hookings in J 190
NC16: 63,139 Nr Hookings in C16 156
J
C16
40%
35%
30%
25%
20%
15%
10%
5%
0%
External
Commissure
Lower jaw
Tongue
Upper jaw
Swallowed
Cranium
Glotis

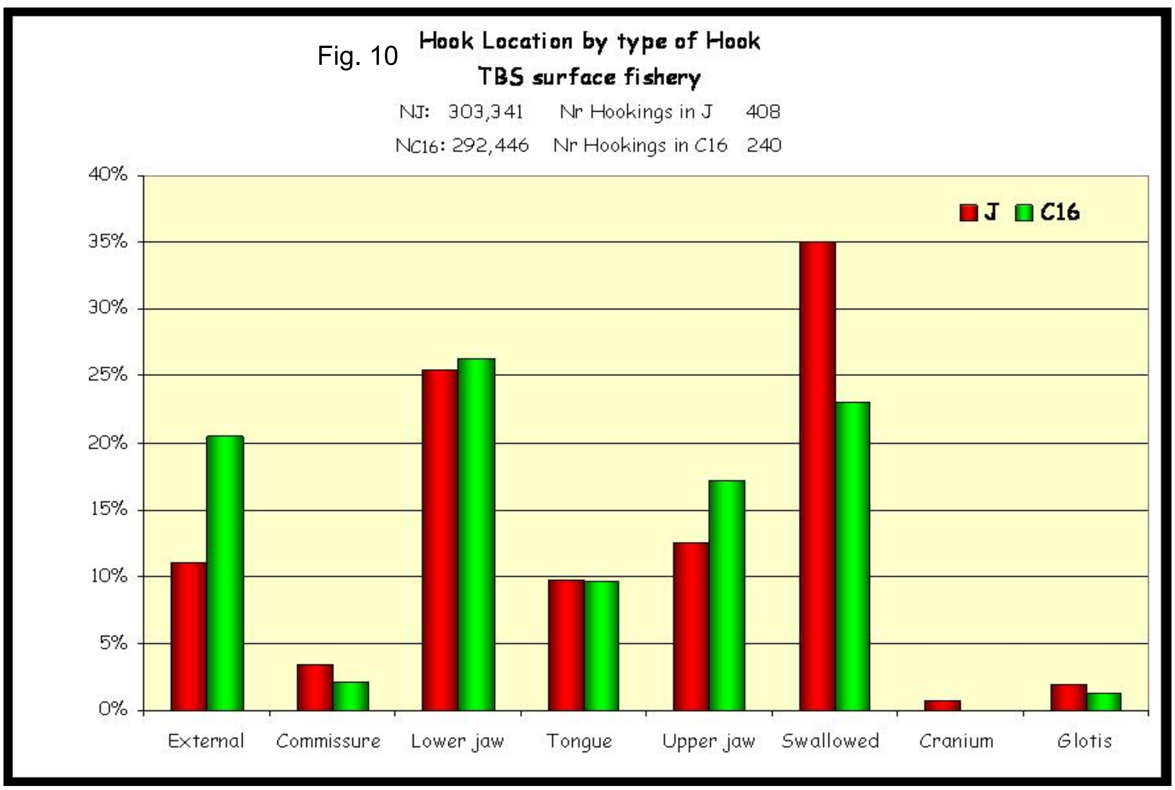


Fig. 10
Hook Location by type of Hook
TBS surface fishery
NJ: 303,341 Nr Hookings in J 408
NC16: 292,446 Nr Hookings in C16 240
J
C16
40%
35%
30%
25%
20%
15%
10%
5%
0%
External
Commissure
Lower jaw
Tongue
Upper jaw
Swallowed
Cranium
Glotis

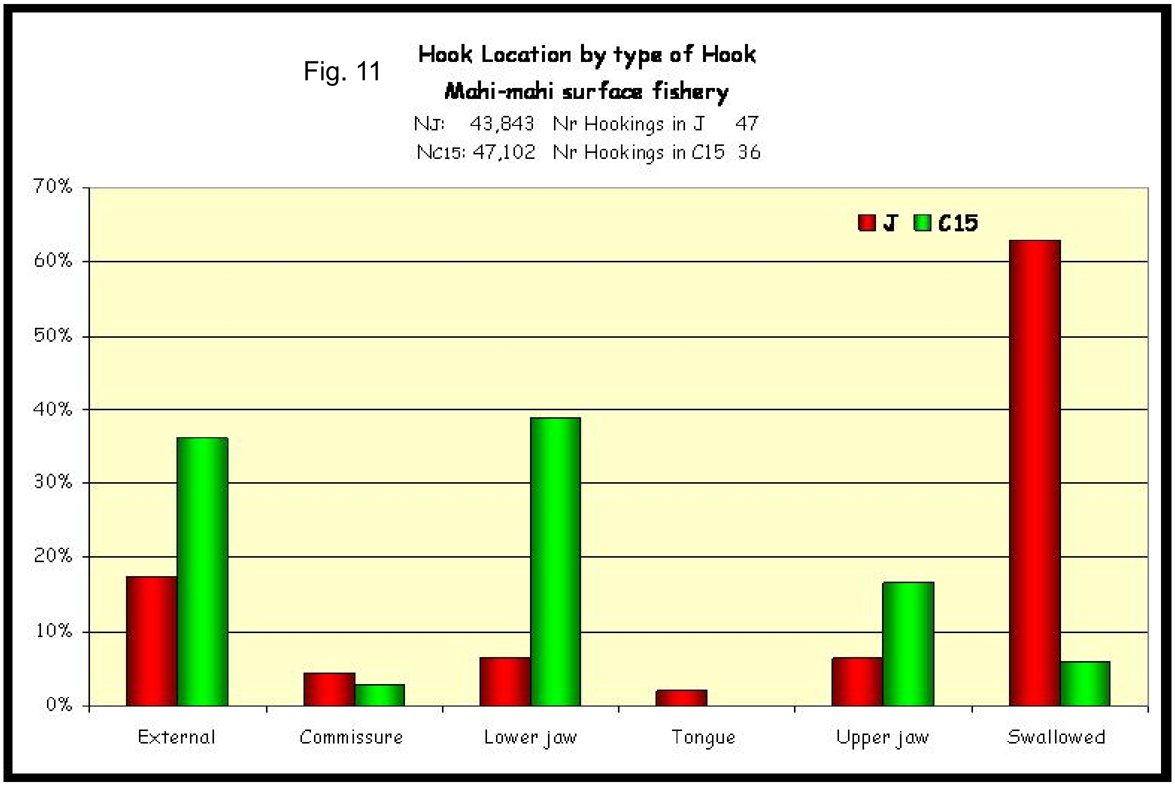


Fig. 11
Hook Location by type of Hook
Mahi-mahi surface fishery
NJ: 43,843 Nr Hookings in J 47
NC15: 47,102 Nr Hookings in C15 36
J
C15
70%
60%
50%
40%
30%
20%
10%
0%
External
Commissure
Lower jaw
Tongue
Upper jaw
Swallowed

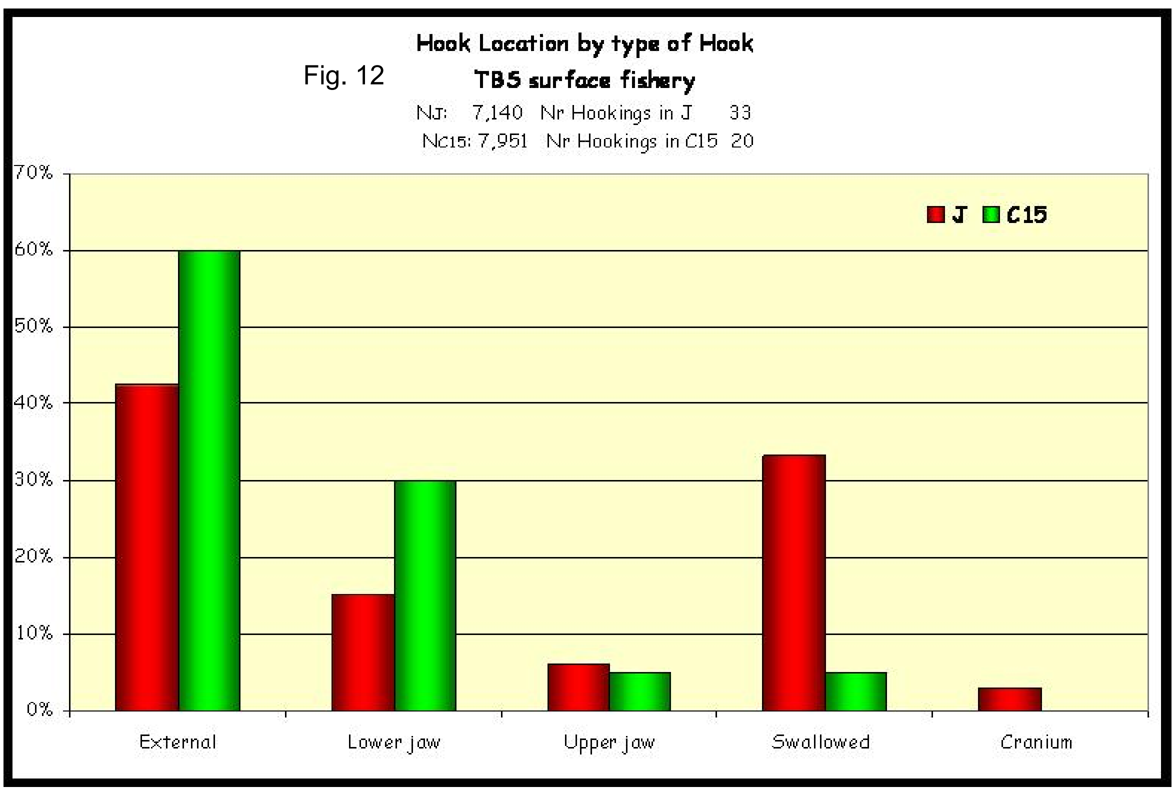


Fig. 12
Hook Location by type of Hook
TBS surface fishery
NJ: 7,140 Nr Hookings in J 33
NC15: 7,951 Nr Hookings in C15 20
J
C15
70%
60%
50%
40%
30%
20%
10%
0%
External
Lower jaw
Upper jaw
Swallowed
Cranium

Fig. 13

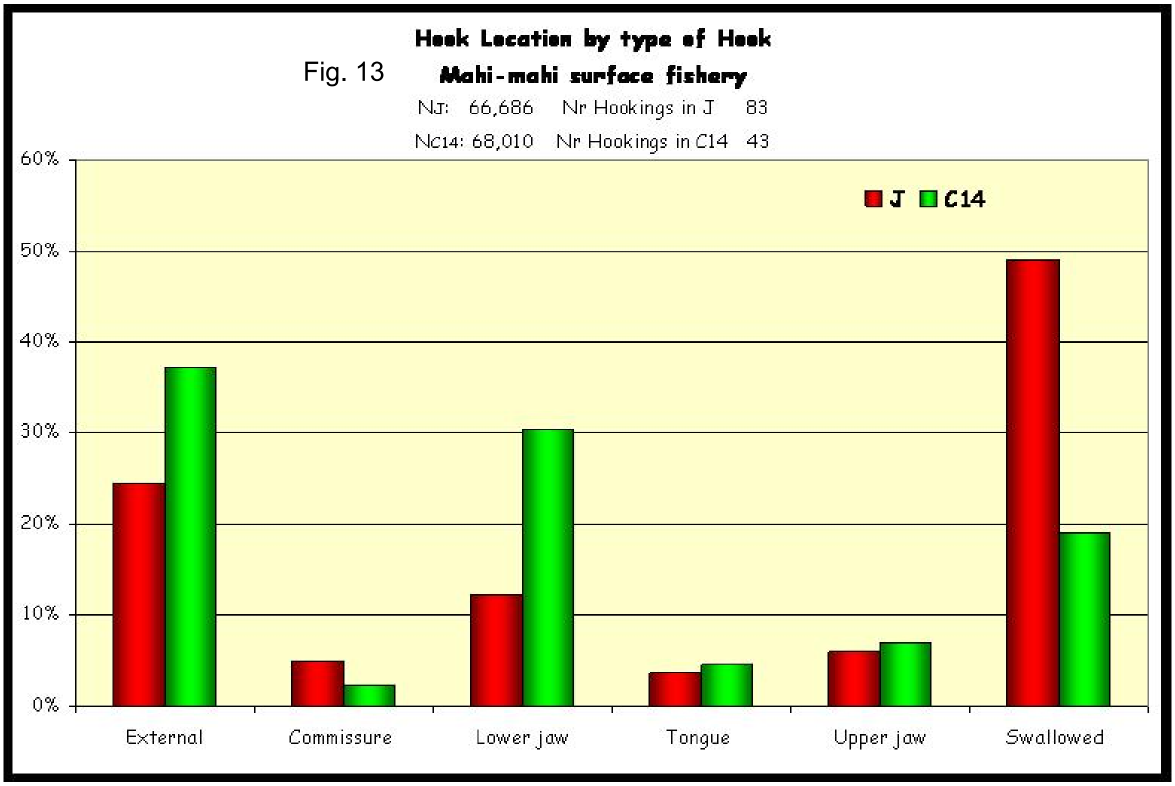

Hook Location by type of Hook
Mahi-mahi surface fishery
NJ: 66,686 Nr Hookings in J 83
NC14: 68,010 Nr Hookings in C14 43
J
C14
60%
50%
40%
30%
20%
10%
0%
External
Commissure
Lower jaw
Tongue
Upper jaw
Swallowed

Fig. 14

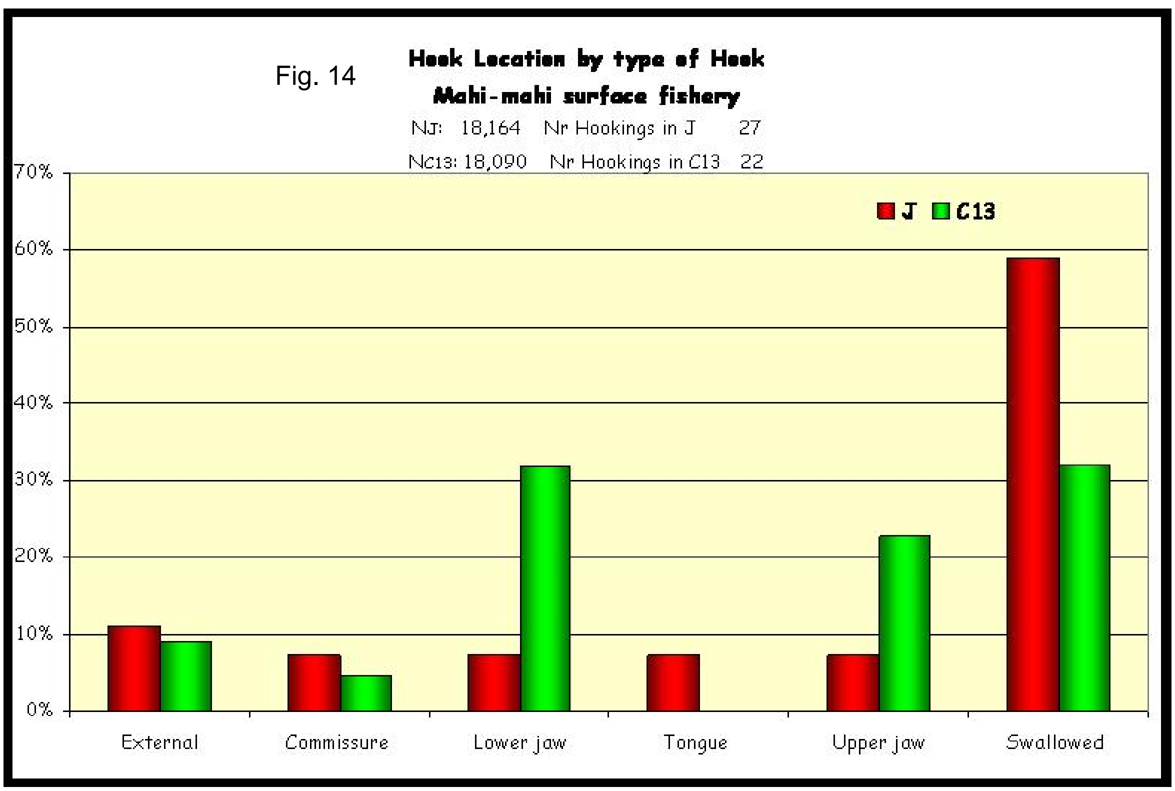

Hook Location by type of Hook
Mahi-mahi surface fishery
NJ: 18,164 Nr Hookings in J 27
NC13: 18,090 Nr Hookings in C13 22
J
C13
70%
60%
50%
40%
30%
20%
10%
0%
External
Commissure
Lower jaw
Tongue
Upper jaw
Swallowed

Fig. 15

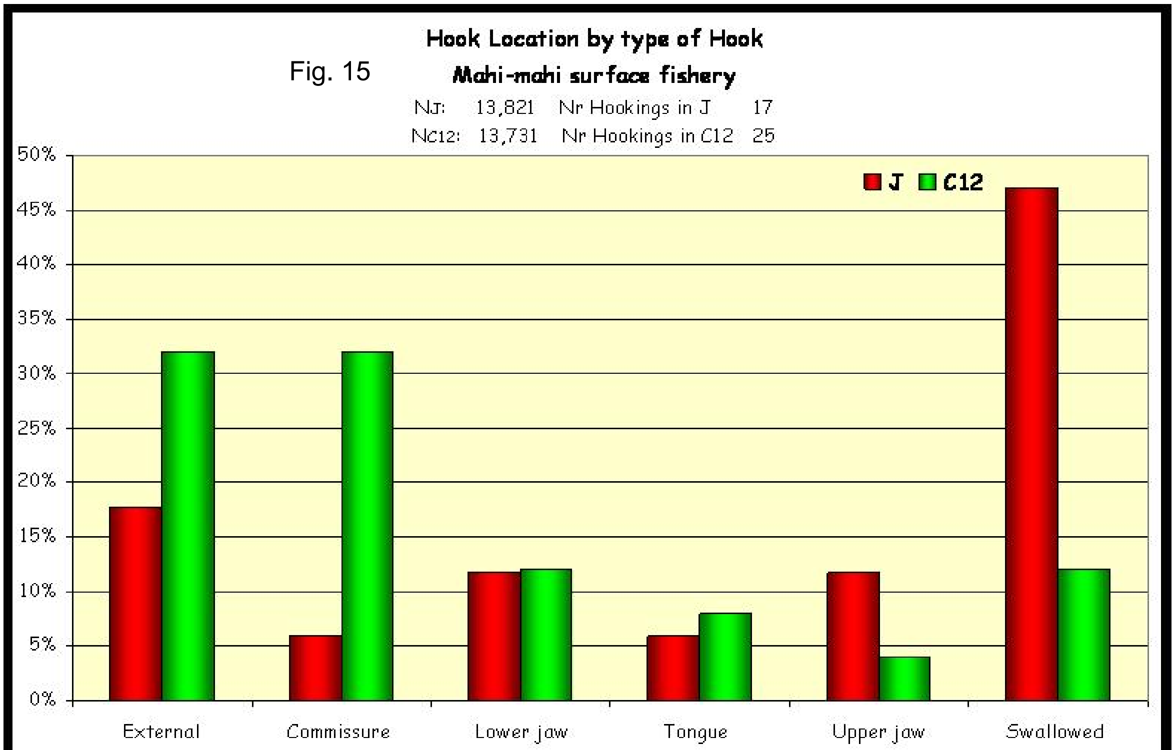

Hook Location by type of Hook
Mahi-mahi surface fishery
NJ: 13,821 Nr Hookings in J 17
NC12: 13,731 Nr Hookings in C12 25
J
C12
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
External
Commissure
Lower jaw
Tongue
Upper jaw
Swallowed

Fig. 16

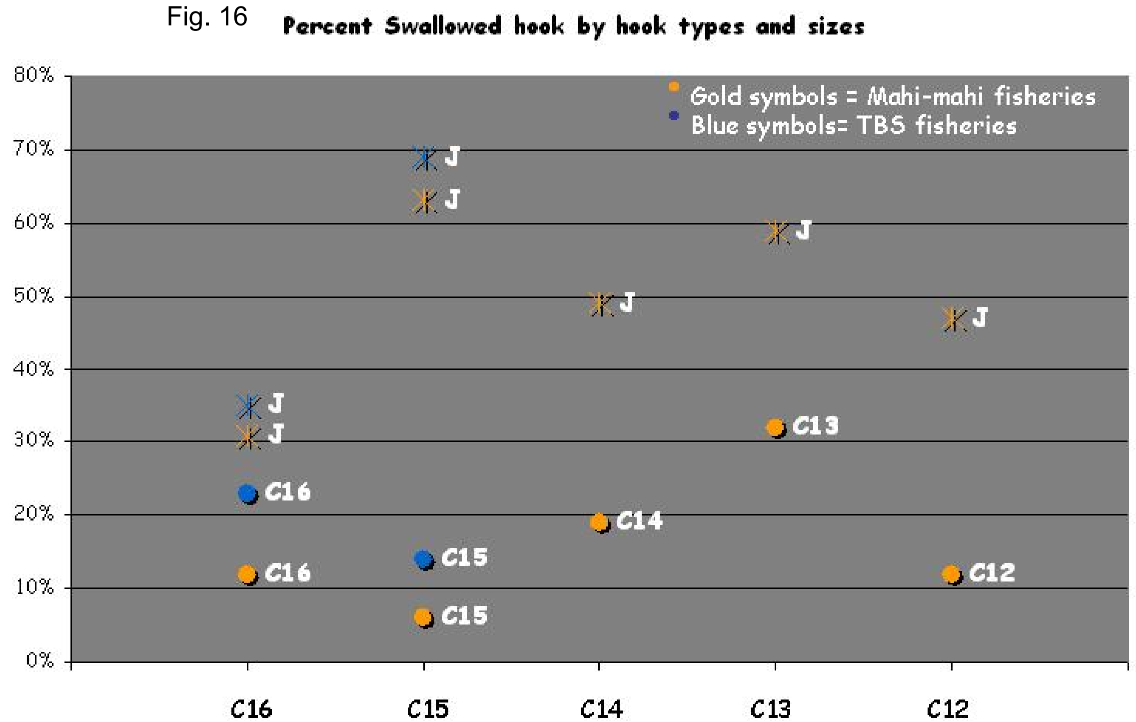

Percent Swallowed hook by hook types and sizes
Gold symbols = Mahi-mahi fisheries
Blue symbols= TBS fisheries
80%
70%
60%
50%
40%
30%
20%
10%
0%
J
C16
C15
C14
C13
C12

Figure 16 will be the basis for some additional analyses, but it shows some interesting results. Circle hooks may reduce hookings or change the location of hookings because of their size (much wider than J hooks for the same fisheries), or because of their shape. If the width of the hook is the decisive factor, then the larger circle hooks should have many fewer swallowed hooks than smaller circle hooks. But there is very little change in the proportion of hooks swallowed throughout the range C12 to C16 in Figure 16. They are all clearly below the level of the J hooks, but there is no dramatic increase going from a much smaller C12 to a C16. A test for the significance of the slope, with the appropriate weighting should be performed, but the plot points toward no size effect, leaving the shape of the circle hooks as the determinant factor in their hooking location.

Much research is needed to produce solid survival statistics for animals caught in different ways, with different types of hooks, and handled differently (Swimmer et al., 2002). A conventional tagging program for the turtles released after hooking or entanglement is one of the relatively simple and inexpensive approaches to follow.

4.3 Distribution of infrequent turtle species

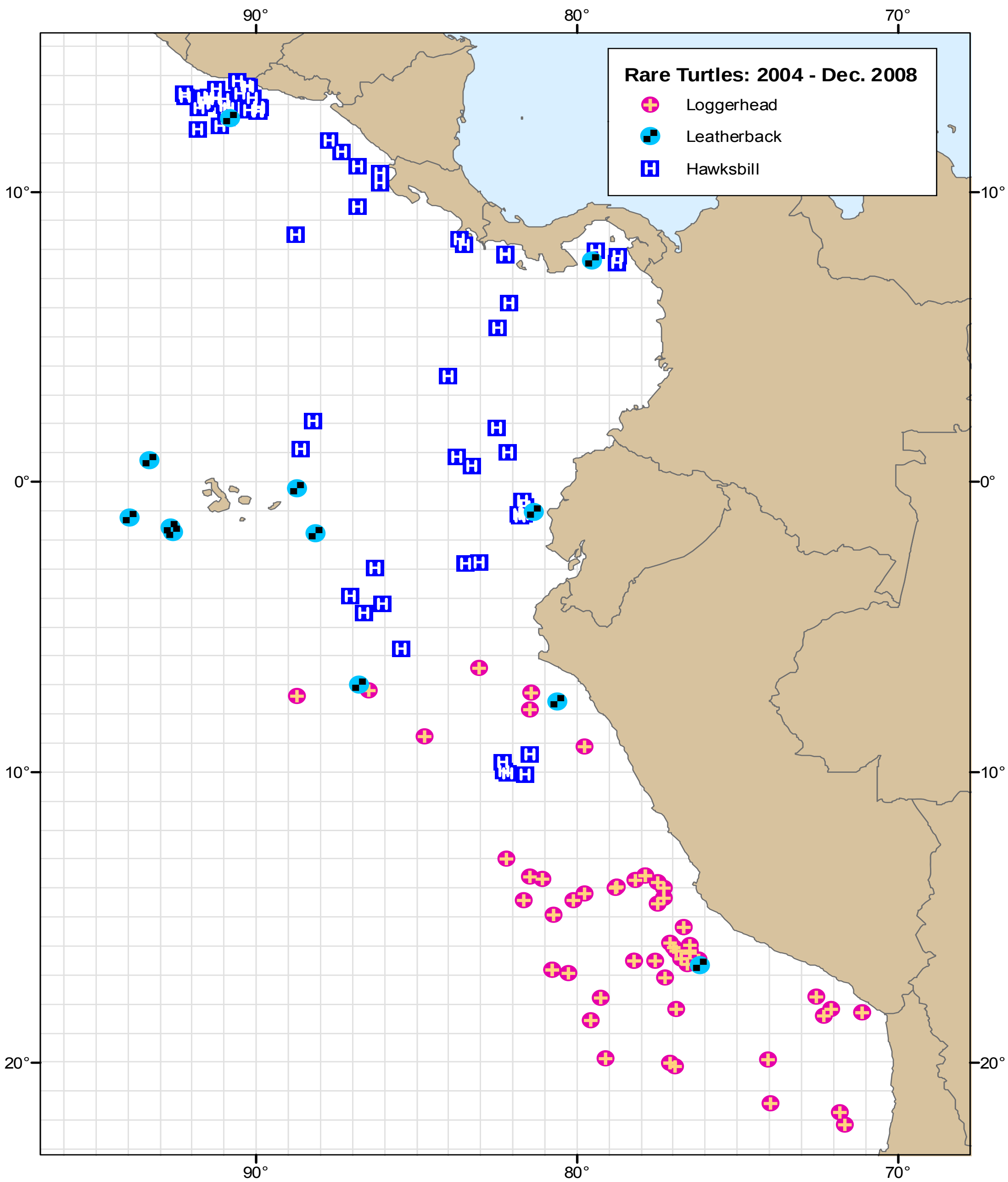


Fig. 17 Distribution of interactions of infrequent turtle species

The map (Fig. 17) shows the locations of the interactions of the fishing gear with the Leatherback, Loggerhead, and Hawksbill turtles. It has ecological interest and some potential management value. Loggerheads (probably from the Australian population, Limpus and Limpus, 2003) are encountered at the Southern end of our sampling area. Hawksbills show a very patchy distribution, which may be associated to their special habitat requirements, but giving the status of these populations, the information may prove valuable. All these distributions only make sense if viewed in conjunction with the effort map shown earlier, since some areas have little or no coverage, and other receive considerable effort.

5. Condition of hooked and entangled turtles

An important factor to design mitigation measures is the knowledge of the opportunities available to improve the survival of the sea turtles. Data from these experiments shed light on some of those opportunities.

Of the 4806 interactions with turtles in the surface fisheries that have a known condition at the moment of encounter, 3,828 correspond to hookings, and 978 to entanglements. Only 68 interactions occurred in bottom longline fisheries (62 hookings and 6 entanglements).

	Entangled Dead	Entangled Live	Hooked Dead	Hooked Live	**Total**
Surface mahi-mahi	2	233	10	2,795	3,040
Surface TBS	4	739	25	998	1,766
All Surfaces	6	972	35	3,793	4,806
Bottom longline	1	5	19	43	68

Table 4. Condition of turtles entangled and hooked

Of the 3,828 turtles hooked in surface fisheries, only 35 (0.009%) were dead when encountered, and this shows that the fishers have an opportunity to release the turtles alive, because they encounter them alive. This is the opposite of the case with seabirds, which in most cases are encountered dead. Mitigation in that case must focus only in avoidance of hookings, while here there is an additional option. Still, we would prefer to avoid the hookings altogether.

Bottom longlines have many fewer interactions, but of 62 hooked, 19 (30.6%) were dead when encountered, so the focus should also be on avoidance, or on facilitating that the turtles reach the surface to breathe after hooking. For the entanglements, 6 (0.006%) of the 978 turtles entangled in surface fisheries were encountered dead, while 1 (16.6%) out 6 entangled turtles were found dead in bottom fisheries. Because of habitat preferences, feeding behavior, etc., it is likely that the species that tend to interact with bottom gear include loggerheads, and hawksbills, and these are two of the main concerns in the region. Less than 1% of the Olive ridley interactions occurred in bottom longlines, but almost 10% of the hawksbills interactions were with bottom longlines.

6. Regional fishing hook Catalog

In order to correctly identify the type and size of fishing hooks used in the fisheries, OFCF researchers are leading an effort to prepare a Regional Fishing Hook Catalog. In general, denomination of size and type of fishing hooks varies among manufactures and countries. This means that hooks of the same nominal size do not always have the same shape and dimensions. Furthermore, fishers and fishing equipments retailers often use alias names (nickname) which are more commonly-used among them. Under such conditions, we started preparing an illustrated catalog of fishing hooks currently used in artisanal longline fisheries of the region, which should be useful for observers of the Program to identify the type and size of fishing hooks that would be monitored and for researchers during experimental work. To describe the shape and size of hooks quantitatively, we applied the measuring points proposed by Yokota *et al*., 2006.

7. Features of 16/0 size circle hooks tested in the Program

As part of the above mentioned catalog, 10 different circle hooks of size 16/0 tested in the Program were measured to evaluate the effect of hook design on the catch rate of sea turtles and target species (Fig. 18). These circle hooks seemingly have the same shape, but the features are different among them (shapes, materials, ring on the eye, offset, etc.) (Table 5).

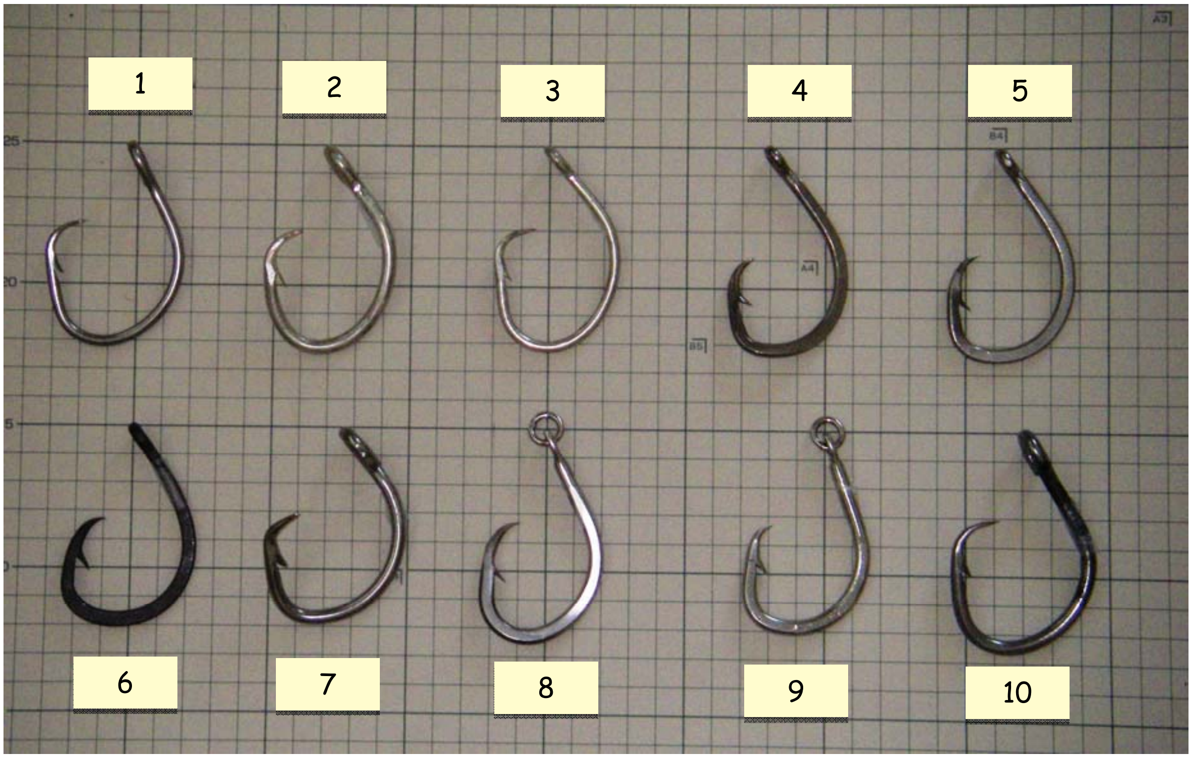


Fig. 18. 16/0-size circle hooks tested in the Program

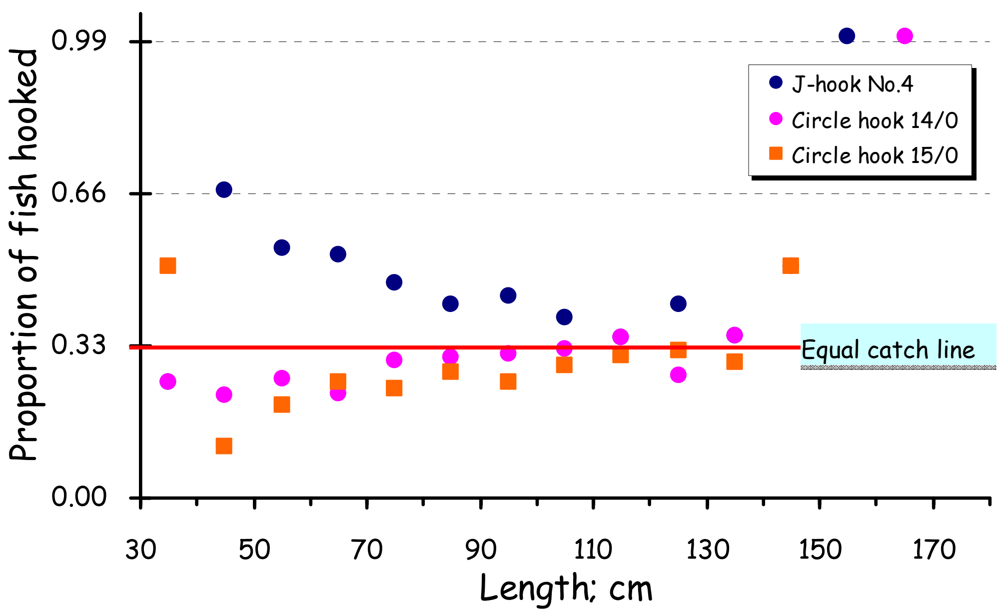
Table 5. Features of 16/0 Circle hooks tested in the Program

No.	**No.1**	**No.2**	**No.3**	**No.4**	**No.5**	**No.6**	**No.7**	**No.8**	**No.9**	**No.10**
Manufacture	Mustad(?)	Mustad	Mustad	Pacific Fishing Tackle	Pacific Fishing Tackle	-	Beko	Forman Tech	King Fe	-
Hook name	Circle hook	Circle hook	Circle hook	Circle hook	Circle hook	-	-	Circle hook	Circle hook	-
Standardized size	16/0	16/0	16/0	16/0	16/0	16/0	16/0	16/0	16/0	16/0
Code No	39966									
Material	Carbon steel	Carbon steel	Carbon steel	Stainless	Stainless	Carbon steel	Stainless(?)	Stainless	Stainless	Carbos steel
Hook eye	Ring	Ring	Ring	Ring	Ring	Ring	Ring	Hole	Hole	Ring
Shank thickness	4.0	5.2	4.1	4.0/5.0	4.0/5.0	3.2/5.0	5.2	4.5/5.6	5.5	5.2
Straight total length	62	61	60	66	66	59	54	66	64	68
Straight total width	53	57	55	54	52	56	61	51	51	56
Minimum total width	49	47	46	44	42	44	48	43	43	51
Maximum total width	73	73	73	75	75	72	71	76	73	79
Frontal length	46	47	46	41	40	42	46	43	42	49
Minimum inner width	25	24	20	24	24	24	30	20	25	21
L-W ratio	1.17	1.07	1.09	1.22	1.27	1.05	0.89	1.29	1.25	1.21
Max-Min ratio	1.49	1.55	1.59	1.70	1.79	1.64	1.48	1.77	1.70	1.55
Offset	Straight	Kirbed	Straight	Straight	Reversed	Reversed	Kirbed	Reverced	Reverced	Kirbed
Note	Shank: Round	TripleX Shank: Round	Shank: Round	Shank: Forged	Shank: Forged	Shank: Forged Color: black	Shank: round	Shank: Forged with Ring Ring d=13mm	Shank: Forged with Ring Ring d=13mm	Shank: Round

8. Size selectivity and catch efficiency of circle hooks for mahi-mahi in the Ecuadorian longline fishery

In the first year of the Program, two different sizes of circle hooks (14/0 and 15/0) were tested with control J-hooks (size No.4) in Ecuadorian mahi-mahi longlines. The results showed that target hooking rates of circle hooks were at least 30 percent lower than those of J-hooks. The width of both circle hooks tested was larger than those of control J-hooks. For fishery resources management, increasing hook size would be used to reduce catches of undersized fish. We therefore examined the size selectivity and catch efficiency of hooks used in Ecuadorian mahi-mahi longline fishery, in order to find out the role of hook size in the differences in catch rates. We applied SELECT analysis method (Millar, 1992, Millar and Walsh, 1992) to analyze the data.

The results show that the proportion of fish hooked on J-hooks for fish length classes below 90cm was much higher than on circle hooks. In contrast, for fish length classes above 90cm, the plots of each hook type distributed around the "equal catch line"; all hook types catch mahi-mahi evenly for length classes of 90cm and larger. These results imply that the catch loss by circle hooks could be due to differences in size-selective properties of J-hook and circle hooks.



	Hook type			
	J	C14	C15	Total
Number	10919	10900	10381	32200
Proportion	0.339	0.339	0.322	1.000

Fig. 19 Proportion of mahi mahi hooked on each type of hook

9. Catch rates for target species

The table below (Table 6) shows the sample sizes used in the contrasts for the different fisheries and hook combinations. Only combinations with over 5,000 hooks of each type are presented.

Depth	**Hooks**	**Targets**		**Nr Hooks 1**	**Nr Hooks 2**
Surface	J - C18	TBS		37,172	34,757
Surface	J - C16	Mahi-mahi		64,202	63,139
Surface	J - C16	TBS		303,341	292,446
Surface	J - C15	Mahi-mahi		43,843	47,102
Surface	J - C15	TBS		7,140	7,951
Surface	J - C14	Mahi-mahi		66,686	68,010
Surface	J - C13	Mahi-mahi		18,164	18,090
Surface	J - C12	Mahi-mahi		13,821	13,731
Surface	C13 - C12	Mahi-mahi		14,386	14,395
Surface	C14 - C13	Mahi-mahi		35,787	28,691
Surface	C15 - C13	Mahi-mahi		39,218	24,992
Surface	C15 - C14	Mahi-mahi		213,470	208,553
Surface	C16 - C14	Mahi-mahi		11,624	12,106
Surface	C16 - C15	Mahi-mahi		110,011	115,379
Surface	C15 - C14	TBS		27,179	27,252
Surface	C16 - C15	TBS		69,424	66,834
Surface	C18 - C16	TBS		18,049	17,283
Bottom	J - C15	Catfish		40,468	26,974
Bottom	J - C14	Catfish		58,827	45,309
Bottom	J - C12	Catfish		6,268	6,268
Bottom	C15 - C14	Catfish		83,830	81,972
Bottom	C14 - C13	Catfish		6,884	5,704

Table 6. Sample sizes used in the contrasts for the different fisheries and hook combinations

Surface fisheries

As reported earlier, circle hooks match up very closely the hooking rates of J hooks in the fisheries for tunas, billfishes, and sharks, but not in the mahi-mahi fisheries from South America, where the targets are frequently small-sized mahi-mahi (Fig. 20).

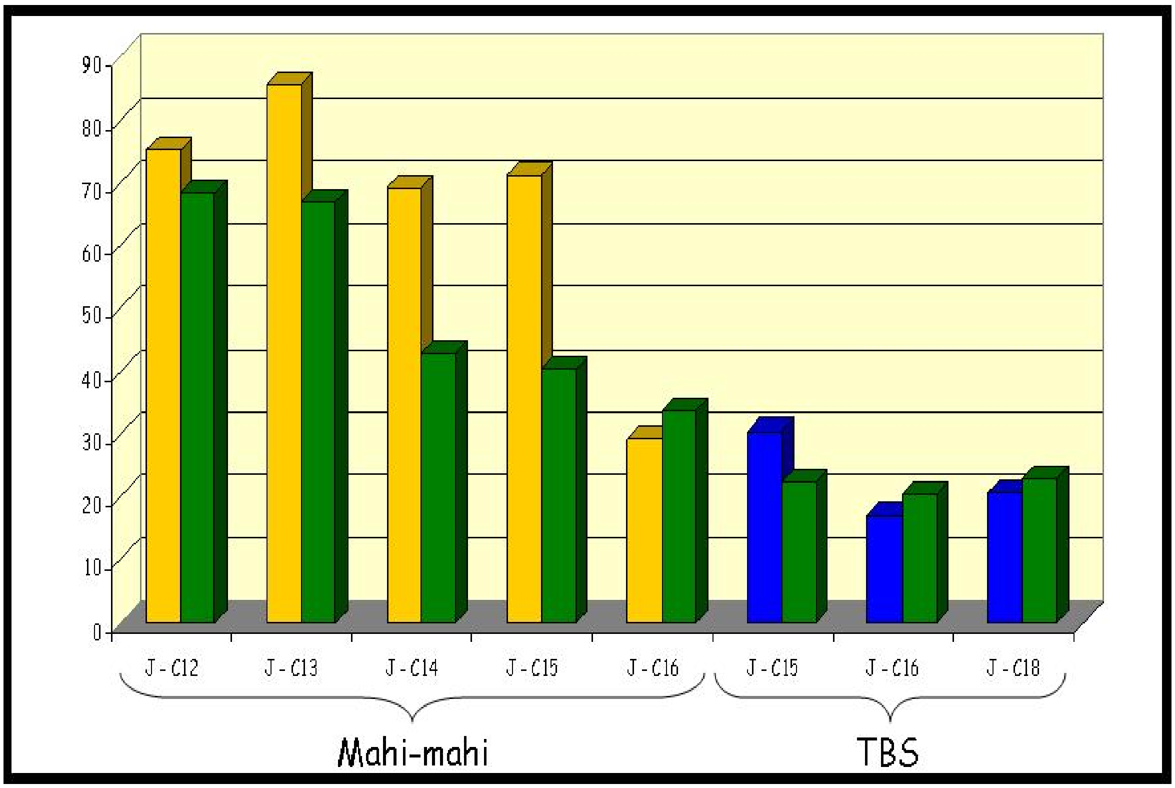


Fig. 20 Hooking rates target species (J vs Circle Hooks) for surface mahi-mahi & TBS longline fisheries in fishes per 1000 hooks

The previous section shows that for individuals larger than 90 cm., circle hooks produce very similar hooking rates to J hooks, but not for smaller sizes. The dilemma has been whether to test smaller sizes of circle hooks, seen that the C12s are performing close to the J hooks on the targets. This may reduce sea turtle mortality mainly due to reducing deep hookings, but at a cost of becoming a part of a fishery targeting small fishes. Without more information on the impact of these juvenile takes on the stock, it was considered risky, to perhaps contribute to a non sustainable or at least undesirable fishery. Unless additional information suggests otherwise, we will not offer for testing hooks of sizes smaller than C13, and even for the C13, it is necessary to explore the potential of the wire appendages to be discussed later. There is a growing awareness among the fishing sector and government agencies in South America that those catches of small fishes should be avoided.

Bottom fisheries

In this case, circle hooks are very competitive in most cases, with small differences in either direction.

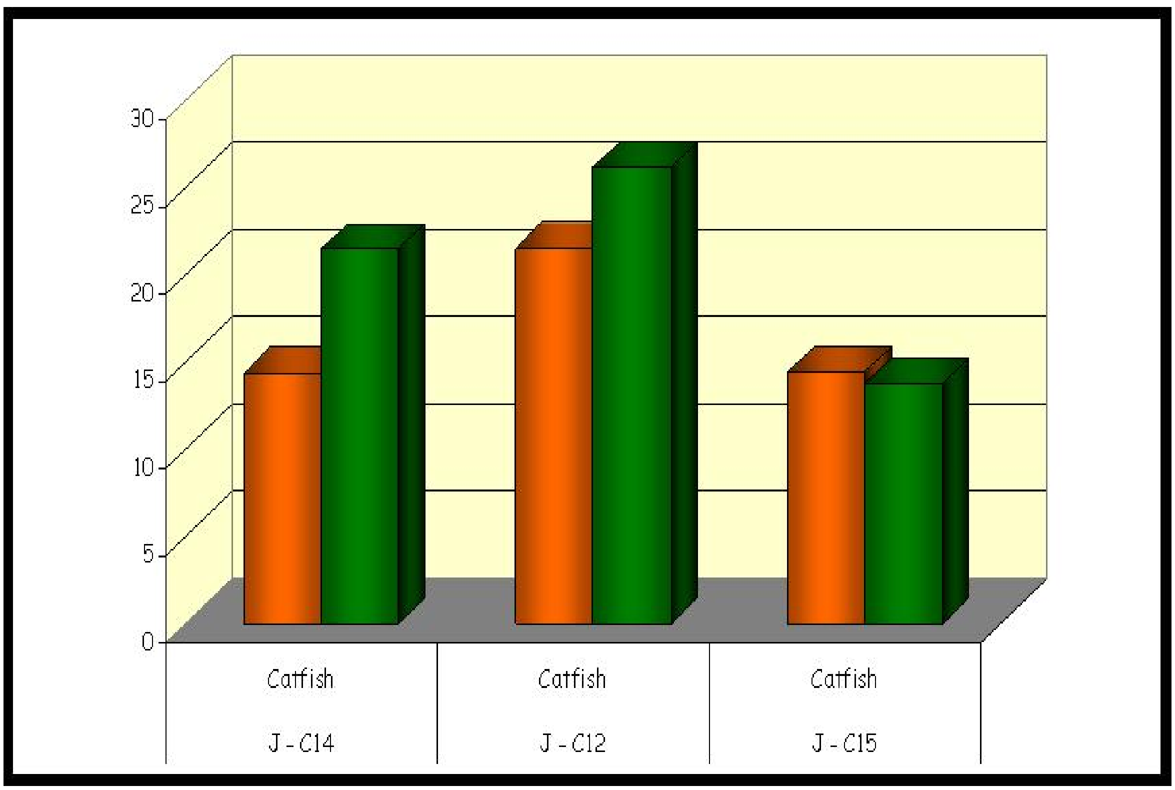


Fig. 21 Hooking rates target species (J vs Circle Hooks) Bottom longline fisheries in fishes per 1000 hooks

Comparisons of different sizes of circle hooks:

Circle hooks, separated by only one size do not show very different catching performances, and even those separated by two sizes are reasonably close (Figure 22).

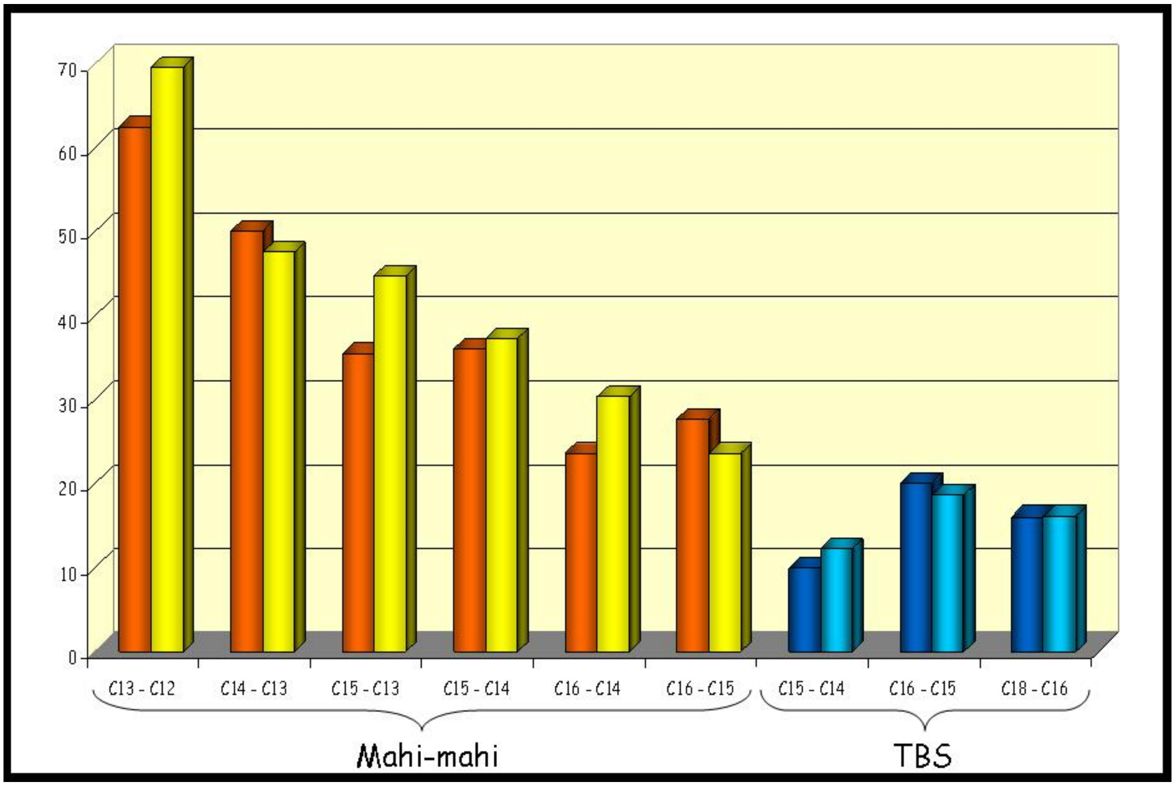


Fig. 22. Hooking rates of target species in fishes per 1000 hooks. Comparison of different sizes of circle hooks in surface longline fisheries

10. Handling of incidentally caught sea turtles

10.1 Assessment of hooking and dehooking impacts on sea turtles – a veterinarian on board

Major progress has been made towards developing best procedures to handle and release hooked or entangled turtles. We had the opportunity to bring a veterinarian to participate in an experiment testing wired hooks, and she was given the chance to see directly the instruments and procedures used by the observers, and being communicated to the fishers, to handle the turtles.

Dr. Mariluz Parga, a veterinarian from the Centro de Recuperacion de Animales Marinos (Barcelona, Spain) was invited to participate in the Ecuadorian experiment (January, 2007) because of her expertise in treating hooked turtles from Mediterranean fisheries. Scientific staff and observers practiced the normal dehooking procedures in close to 60 turtles for her observation and evaluation. Extensive photographic documentation of the resulting injuries, was obtained, that will contribute towards improving the procedures. In general, the anatomic characteristics of the sea turtle esophagus are of great help in facilitating retrieval of hooks, or in reducing the damage caused.

The program was a combination of efforts by OFCF, IATTC, CRAM (Spain) and The Ocean Conservancy. The experience was very fruitful. It was very encouraging to see that the damage caused by the hooks themselves, and by the removal procedures were in most cases quite mild, and that survival was very likely in most cases. In the future, a video, instructing observers and fishers on the best procedures will be produced by OFCF-Japan with Vet. M. Parga. What was learnt during the trip has already been communicated to many at different conferences and workshops, and more activities are being planned for 2009. Another cruise is planned for 2009, where the documentation of the study will be improved by the use of endoscopes, and video cameras. An outcome of the observer program, and of the Veterinarian on Board program is that the definition of the equipment to be recommended to all longline vessels of the type encountered in our samples is becoming sharper, and we will propose the adoption of a set of release instruments including dipnets, types and sizes of dehookers, etc.

10.2 Equipment for adequate handing of sea turtles (dipnets, dehookers, mouth openers, etc.)

<u>Dipnets</u>

Dipnets are useful for lifting hooked or entangled sea turtles to the deck unharmed, in particular for the vessels which have large distance between the deck level and water surface. In Ecuador and Panama, the OFCF program made and distributed dipnets of stainless steel or aluminum (Fig. 23) and distributed them for artisanal longline vessels. These dipnets were designed based on the opinions of longline fishers and manufactured in local iron works. Observers of the Program demonstrate their correct use and collect fisher's opinions to improve the design.

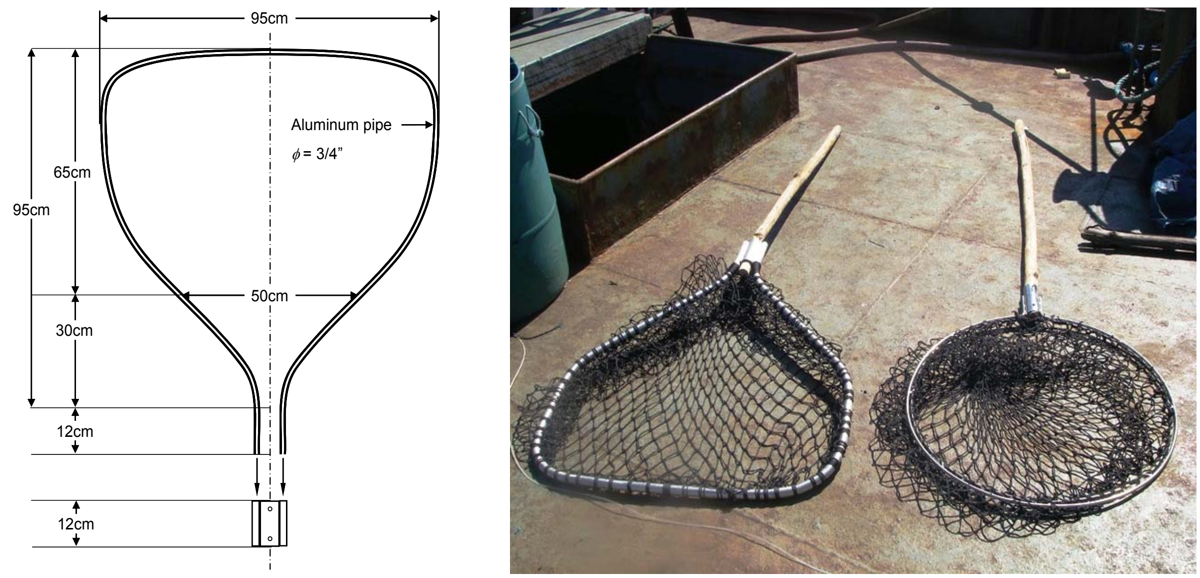


Fig. 23. Two different types of dipnets manufactured by local iron works (Panama)

10.3 Dehooking equipments

Based on the results of a revision of the instruments and techniques that were used to handle hooked sea turtles, the OFCF program manufactured "Inverted-V" and other dehookers and mouth openers (avuncular speculum) in local iron works to be distributed to Panamanian longline fishing vessels. Locking pliers were tested as a dehooking equipment and were effective with hooks in the mouth area of the turtle.

11. Other Experiments

11.1 Second "Wired-hook" experiment (January, 2007, Ecuador)

A research cruise was conducted from Ecuador in January, 2007 to carry out:

-Experiments with wired hooks,

-Experiments to reduce entanglement of sea turtles in longline

-Feasibility study of monofilament longline for the mahi-mahi fishery

The experiments were supported and organized by the Overseas Fisheries Cooperation Foundation of Japan with the cooperation of local scientists and technologists.

In the experiments conducted in Peru and Ecuador, the addition of a wire appendage on the back of small circle hooks (size 13/0 without ring) promised to be a simple and economic way to reduce sea turtle hooking rates and the proportion of hooks swallowed deeply by the turtles. Fishers operating mahi-mahi longlines in Ecuador are reluctant to replace their J-hooks by circle hooks because of catch losses. The OFCF program in Ecuador therefore tested J hooks with a wire appendage, (J4W) circle hooks size 13/0 with a wire, (C13WR) and control J-hooks (J4). Four Fibras were chartered and each Fibra conducted 12 sets of mahi-mahi longline with 660 hooks (Observed fishing effort: approximately 24,000 hooks).

Both wired hooks reduced turtle hookings (63% for J4 with wire, 50% for C13 with wire), but there were significant target catch losses (Fig. 25). A modification introduced in this experiment was the addition of a ring through the eye of the circle hook. As more hooks with wire appendages were swallowed than last year, it is possible that the flexibility added to the hook and line by the ring may have resulted in an unwanted consequences. More studies comparing what happens with hooks with and without rings in the ingestion and lodging of the hook in the turtles are needed.

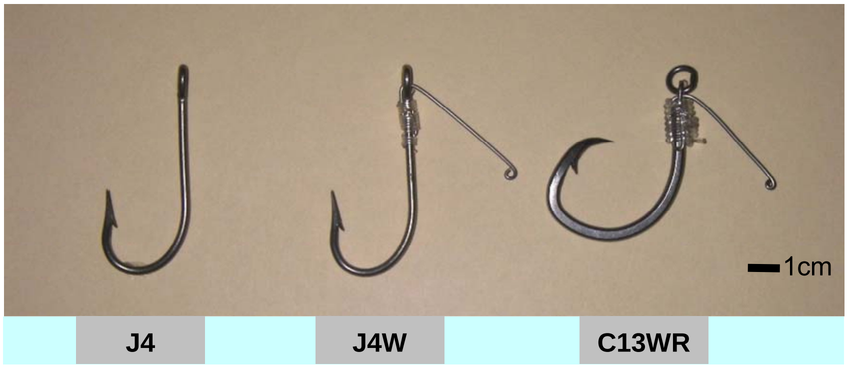


Fig 24. Hooks used in the experiment: J hooks, J hooks with wire, and Circle hooks with wire

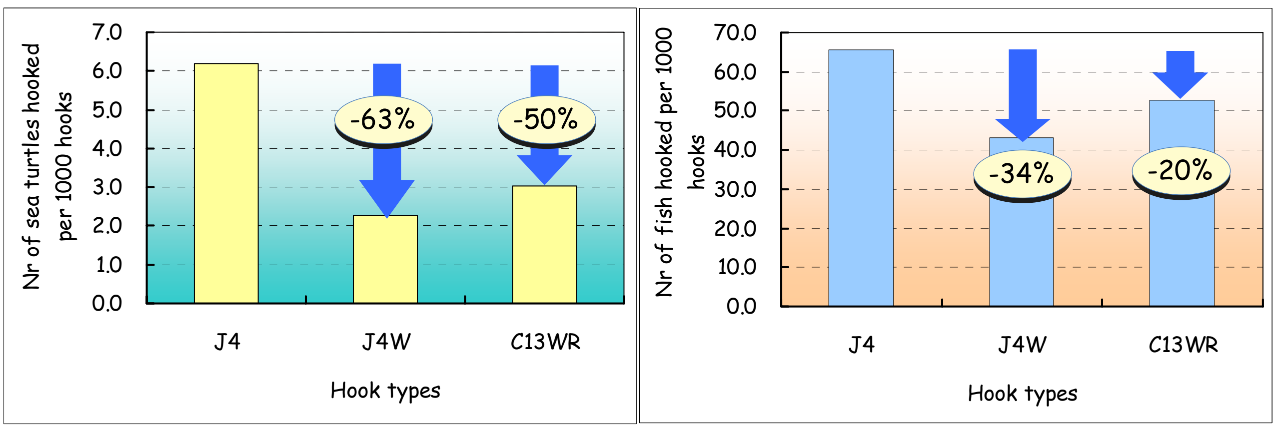


Fig. 25 Comparison of hooking rates of sea turtles (left) and target species (right)

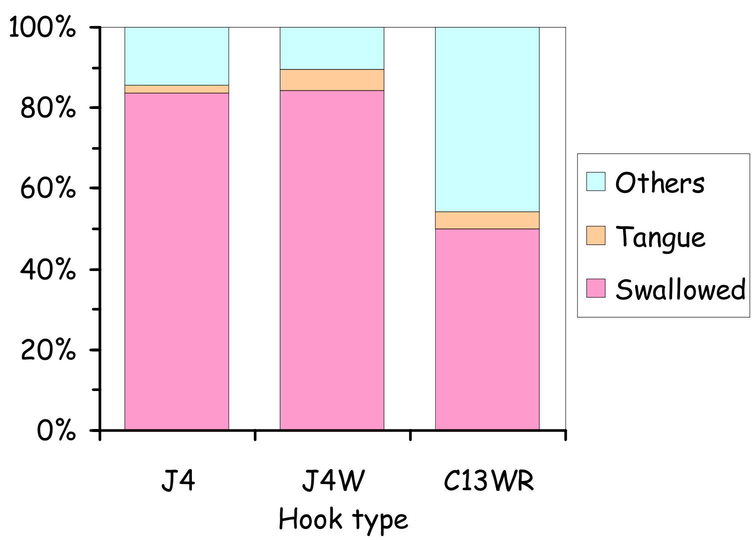


Fig. 26. Proportion of hooking locations by hook type

11.2 Experiments to reduce entanglements of sea turtles (Ecuador)

Entanglements can be a problem if the turtle escapes or is released with gear still on, or if the turtle is injured in the attempt to disentangle. A series of experiments were conducted in Ecuador to assess the effectiveness of modified longline gear in the reduction of entanglements of sea turtles in mahi-mahi longlines.

A statistical comparison (Fig. 27) showed that higher percentage of longlines made of Polypropylene (PP) cordages, resulted in higher sea turtle entanglement rates. PP has a tendency to float. In contrast, entanglement rates were very low where Polyamide (PA) monofilament is used predominantly for longline gears. PA monofilament sinks and is less flexible than PP cordages.

In the TBS and mahi-mahi longline fisheries from Ecuador, sea turtle entanglements were most prevalent around the floats (about 80% of all entanglements). Observers reported that turtles followed the mainline toward a float after encountering the gear, and then swim around the float as if they were playing with it. In time, they got entangled with the line. These observer reports support the high incidence of entanglements around floats. Consequently, in order to reduce entanglements, the floatlines, and a short portion of the mainline adjacent to them were modified (Fig. 28), replacing the polypropylene (PP) by monofilament (MF). An experiment was carried out, where floatlines ere modified in an alternating pattern (one float PP, one MF). A full MF line and a full PP line were also ran in parallel. The results showed very clearly the advantages of the MF material to reduce turtle entanglements.

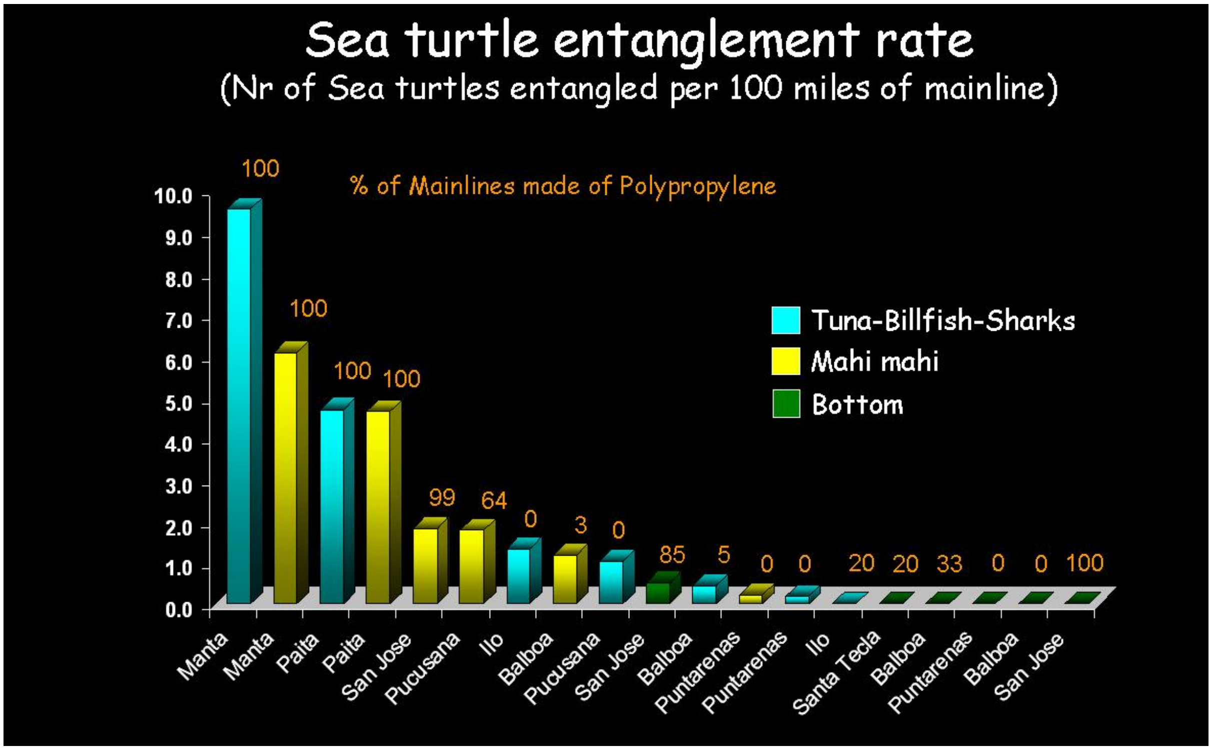


Fig. 27 Sea turtle entanglement rates by port and target species

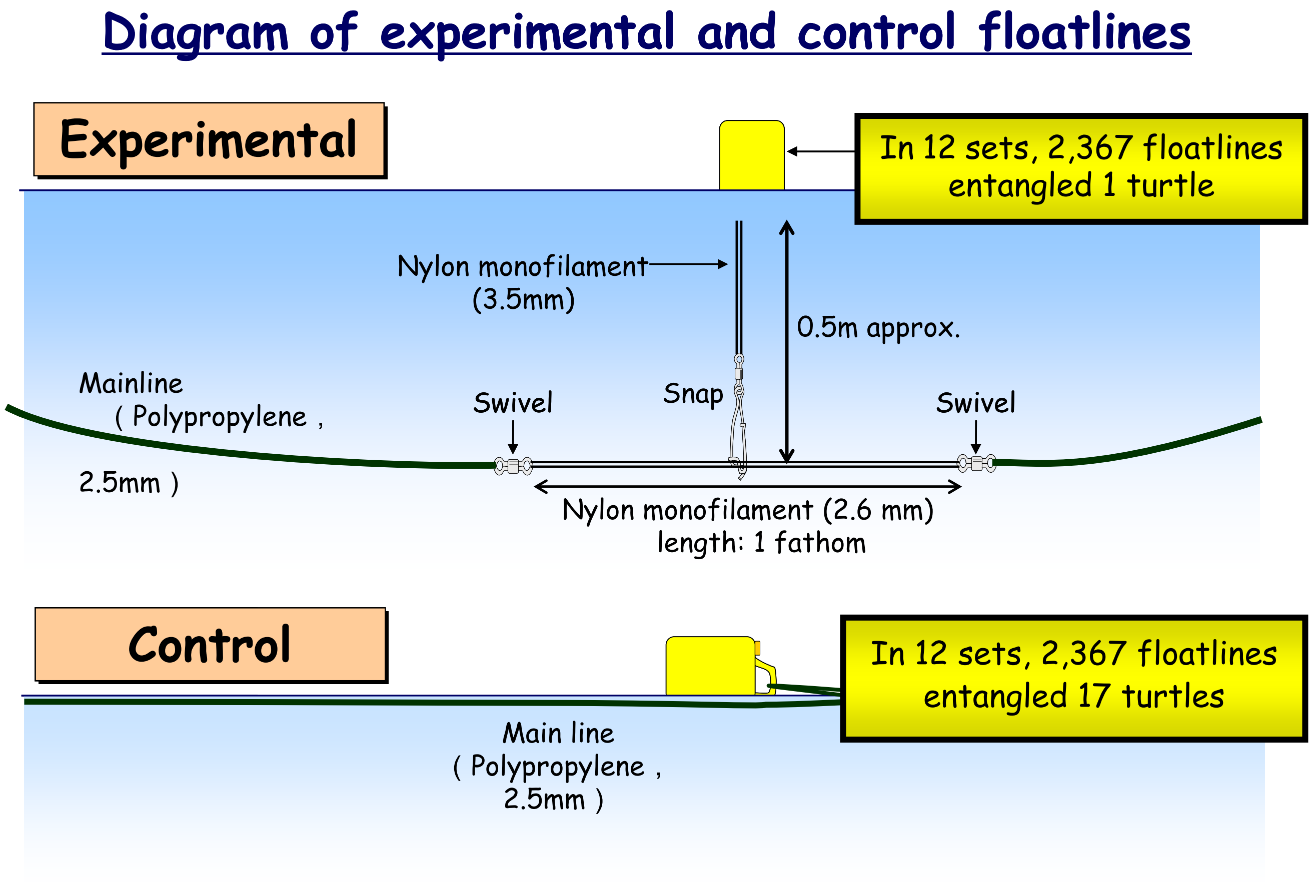


Fig. 28. Diagrams of experimental and control floatlines

	Number of turtles entangled		
	Experimental	Traditional	Monofilament
(Floatline)	(PP / MF)	(PP)	(MF)
Nr. of line	4	1	1
Branchline	1	1	No entanglement
Mainline	2		
Branchline + Mainline	1		
PP Floatline	13	3	
MF Floatline	1	-	
		1	

Table 6. Results of the entanglement experiment.

12. Workshops

12.1 Second Regional Technical Workshop of the Eastern Pacific Regional Sea Turtle Program (WWF) (November 9-11, 2007, Puntarenas, Costa Rica)

The Second Regional Technical Workshop of this program was held in Puntarenas, Costa Rica, November 9-11, 2007, with about 50 international participants. The workshop was sponsored by WWF, WPRFMC, OFCF-JAPAN, NOAA, and IATTC.

The main purpose of the workshop is to compare results, discuss future steps, and enhance the technical and scientific capacity of the program to better achieve its goals for bycatch mitigation. To this end, participants undertook a comprehensive revision and exchange of information among all countries and teams participating in the program. The following were the major topics of the workshop.

1 - Overview of trends in fishery of participating countries: recent changes and interannual variation (Peru, Ecuador, Colombia, Panama, Costa Rica, Nicaragua, El Salvador, Guatemala, Mexico, Brazil, and Chile)

2 -Turtle entanglements: Type of entanglements and their consequences, results of recent experiments

3 - Bottom long-lines in the region

4 - Research on reduction of by-catch related sea turtle mortality in Japan Yokota Kosuke

5 - Activities in Brazil by TAMAR: Bruno Giffoni

6 - Programs in Chile: Carlos Guerra and Miguel Donoso

7 - Comparison of sea turtle hooking rates in different counties and fisheries

8 - Turtles: identification problems, population status, nesting beaches, geographic ranges, daily movements and seasonal distribution, behavior: feeding and diving

9 - Turtle hookings: Description of hooking locations, Statistical exploration of hook location distributions.

10 - Target species hooking rate in different counties and fisheries

11 - Regional Catalog of fishing hooks

12 - Other incidental catches in the fisheries (seabirds, marine mammals, etc.)

13 - Report from the Statistical Workshop

14 -Topics for future activities

Experiments

IFF4 and the regional program

Sustainable seafood labels and bycatch.

Proposals for regional fishery management

12.2 Database Workshop

N. Vogel (IATTC) organized a database workshop that took place in Puntarenas, Costa Rica, November 8 and 15, 2007, to train observer database managers of the Program and to discuss the contents of observer datasheets, so that the datasheet format could become an option for all the types of longline fisheries that would be monitored (e.g. non-experimental as well as experimental). The workshop was interactive and very practical with a good set of training materials.

12.3 Statistical workshop on experimental design and analysis of turtle mitigation studies

Drs. Cleridy Lennert-Cody (IATTC), Mihoko Minami (Institute of Statistical Mathematics), Marti Mcracken (NMFS/NOAA-Hawaii), and Michelle Sims (Duke University) organized a statistical workshop that took place in San Ramon, Costa Rica, November 7-8, 2007. The discussions at this workshop were focused on methods of analysis of the existing data of Eastern Pacific Regional Sea Turtle Program with some discussion as to variations of the current sampling design that might be considered for future experiments. The workshop was sponsored by the OFCF-JAPAN, IATTC, and NOAA, with logistic supports by WWF-Centro America.

The following questions were put forward to motivate discussion at the workshop.

-Sampling design and data collection

-Statistical methods for comparing hook performance

Workshop proceedings were published as IATTC Special Report 17 (http://iattc.org/PDFFiles2/SpecialReport17.pdf). Besides the organizers participants in the workshop were Mary Christman (University of Florida, U.S.A.), Daniel Hall (University of Georgia, U.S.A.), Martin Hall, (IATTC), Paul Kinas (Fundacáo Universidad Rio Grande, Brazil), Bryan Manly (Western Ecosystem Technology, Inc, U.S.A.) and Steven Thompson, (Simon Fraser University, Canada). Some fishing tests are needed to verify the behavior of fishes and turtles with respect to the distribution of hooks in the lines, that were suggested during the statistical workshop. Basically, the question is: Is the hooking rate of a J hook with J hooks on both sides similar to that of a J hook with circle hooks on both sides? The answer should help interpret the results of current experiments, and project the figures observed to lines with only one type of hook.

13. Fourth International Fisher's Forum (IFF4)

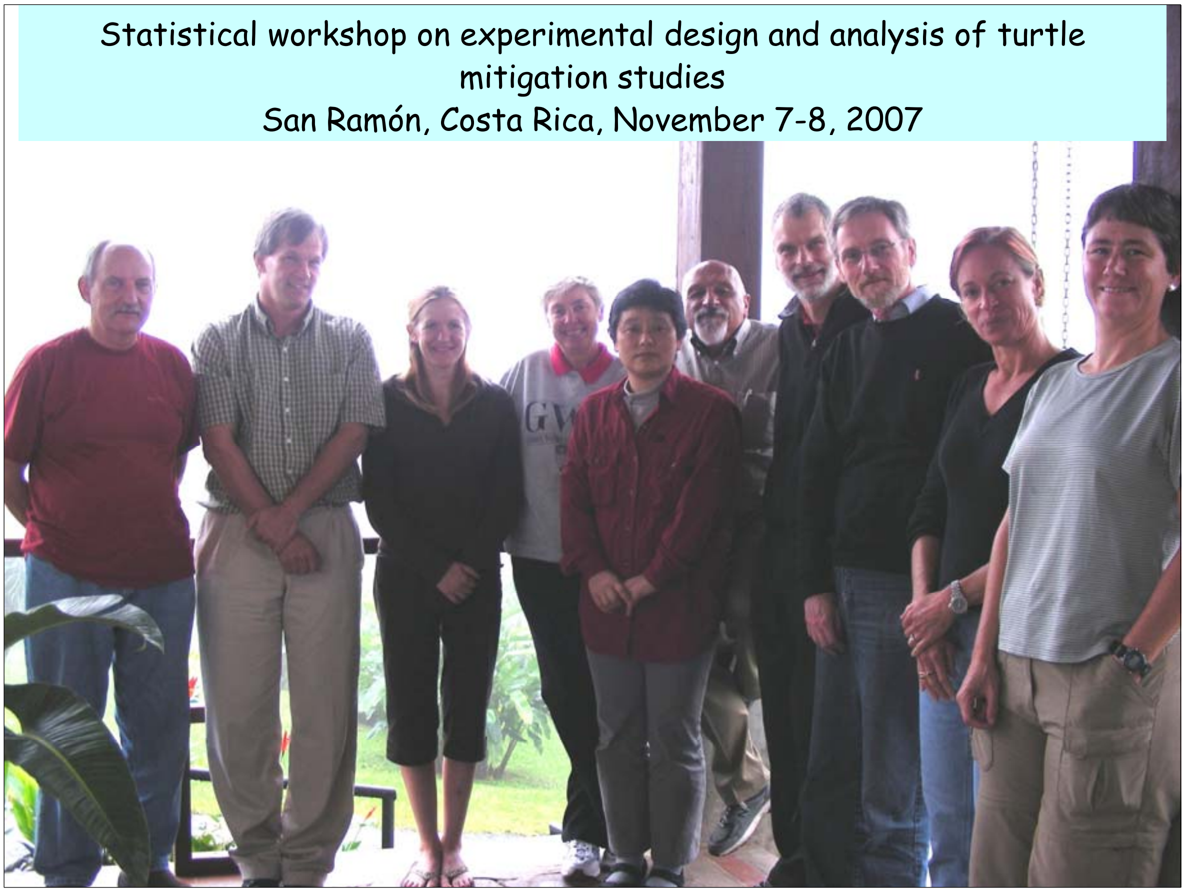
The recent results of the Eastern Pacific Sea turtle Program were presented at The 4th International Fishers Forum (IFF4), which was held in November 12-15, 2007 in Puntarenas, Costa Rica. Martin Hall (IATTC), Moises Mug (WWF), and Takahisa Mituhasi (OFCF) presented different aspects of the program. The Foundation AVINA sponsored a meeting of artisanal fisheries leaders of the eastern Pacific countries that was also attended by some artisanal fishers from the Western Pacific, and from Asian countries.

14. Presentation Program Results

Results of the Program have been presented at the following meetings:

- International Fishers Forum IV, Puntarenas, Costa Rica, November 12-15 2007
- 28th. International Sea Turtle Symposium, Loreto, México, January 19 - 26 2008
- 5th International Fisheries Observer Conference, Victoria, BC, Canada, May 15 – 18 2007

2nd. Technical Workshop
Regional Sea Turtle Program of the Eastern Pacific
Puntarenas, Costa Rica. November 9 – 11, 2007



Brian Manly, Daniel Hall, Michelle Sims, Mary Christman, Mihoko Minami, Martin Hall, Steven Thompson, Paul Kinas, Cleridy Lennert-Cody, and Marti McCracken

15. Future developments

Many activities such as the hook exchanges and observer programs are on going, and will continue into the future. Besides continuing to analyze the experimental results, the data generated will be used as a component part of the stock assessment of many of the species involved (mahi-mahis, sharks, etc.), in association with interested government agencies and regional organizations. The data it is the most complete and accurate documentation of the activities of the artisanal fleets for the region, including catches, bycatches, gear characteristics, operational modes, etc.

Additional experiments or activities:

- Experiments are currently under way, thanks to the support of The Ocean Conservancy, to test the use of segments of line with a metal core to reduce sea turtle entanglements. These segments are placed in the vicinity of the floats, where most entanglements occur.

- A different hook style, used in Japanese coastal fisheries for mahi-mahi will be tested in the future to see if it could be successful at catching mahi-mahi in the South American coasts, where circle hooks have not matched the catch rates of J hooks. Their impacts on sea turtle hookings need to be evaluated.
- There are very significant bottom longline fisheries in the region that have not been sampled. For instance fisheries targeting snappers use lines of over 1200 – 1500 small J hooks. Some observations will be needed to assess their significance for sea turtle bycatches.
- It is quite clear that circle hooks and J-hooks have different selectivities for different species (Yokota *et al.* 2006; Kerstetter and Graves, 2006; Mapleston *et al*., 2008). The changes in hook size and shape, some of which happen in the fisheries as simple evolution, others are motivated on mitigation issues like the change we propose need to be understood. Their ecosystem impacts need to be placed on a scale with a holistic view.
- It is also clear that hooking locations, and therefore survival vary with hook types and sizes. Post-hooking survival experiments are needed to complement these studies (Swimmer *et al*., 2002).
- Many steps are needed to complete the implementation of the change. One of them has recently been taken by the Nicaraguan government, as a result of the program activities, and it is the exemption of all tax duties and tariffs to circle hooks imported into Nicaragua. This reduces the costs of the hooks, and makes them more competitive with J hooks. Increasing the availability of circle hooks is also critical for the adoption process. As implementation strategy will be needed to complement the other activities. This should include economic approaches (market incentives) subsides for hook replacement, etc), regulatory approaches (adoption of hooks, mandatory equipment) and international cooperation.
- A regional hook catalog is being prepared by researchers from the Overseas Fishery Cooperation Foundation of Japan. This is necessary to organize the data collection, and the data analyses, and also to determine what are the characteristics of circle hooks needed to achieve the goals of bycatch reduction.

A comparative study of longline gear used in the eastern Pacific is also being carried out by an OFCF-IATTC project, with the support of the countries fisheries agencies. A detailed description of the materials used, and the configurations will help to produce a meaningful stratification of the fisheries into groups with similar characteristics from the point of view of catch and bycatch rates.

16. Participating and Cooperating Institutions

The program is a combined effort of several institutions. The Inter-American Tropical Tuna Commission, and the Overseas Fishery Cooperation Foundation – Japan provide the technical support. The World Wildlife Fund, through their offices in Peru, Galapagos-Ecuador, Colombia, Panama, Central American Office in Costa Rica, Guatemala, and Mexico is the lead organization and manages, and finances, the majority of the observer program, and many of the outreach activities, training of scientists from the region, training of observers, etc. Several of the experiments have been financed by OFCF, but The Ocean Conservancy, Defenders of Wildlife - Mexico, the Centro de Recuperación de Animales Marinos have also supported experiments or other activities aimed at reducing hookings and entanglements increasing survival after hooking, and increasing awareness of the conservation status of sea turtles and of the solutions proposed.
The Central American Organization of Fisheries – OSPESCA has supported the program in many ways, and it has signed an MOU with WWF about it. Recently the International Fund for Animal Welfare – LatinAmerica Regional Office – began supporting some of the activities of the program to get started in Chile, and there are plans to expand the activities in the continent to improve the training of veterinarians working on sea turtles.

At the national level the program relies on the support and participation of all stakeholders: fisheries agencies, fishers cooperatives, exporters, conservation organizations, academia, etc. Over the years a unique network has been developed through the efforts of the leading organizations that carry out the activities of the program in a consistent manner throughout the region. WWF is present in Mexico, Guatemala, Costa Rica, Panama, Colombia, Ecuador-Galapagos, and Peru through national offices, and in Nicaragua, and El Salvador through the WWF - Central America (WWF-CA) office. The WWF – CA office coordinates the programs in the whole region. IATTC has offices in Ecuador, Panama, and Mexico. OFCF led programs in Ecuador, and Panama, and it is currently involved in a more regional program involving IATTC’s member countries. The program was started as an initiative of the government and fisheries sector of Ecuador, and received its initial support from the Western Pacific Regional Fishery Management Council (WPRFMC - NOAA) and from WWF. Most of the activities of M. Hall (IATTC) in the region were made possibly by the WPRFMC.

Mexico
Instituto Nacional de la Pesca (INP)
Procuraduría Federal de Protección al Ambiente (PROFEPA)
Comisión Nacional de Acuicultura y Pesca (CONAPESCA)
Defenders of Wildlife - Mexico
Centro Mexicano de la Tortuga (CMT)
School for Field Studies (SFS)- Francisco Ollervides
Universidad Autónoma de Sinaloa (UAS)

Central America
Organización del Sector Pesquero Centroamericano (OSPESCA)

Costa Rica
Instituto Costarricense de Pesca y Acuicultura (INCOPESCA)
Cámara Nacional de la Industria Palangrera (CNIP)-
Federación Nacional de Pescadores (FENASPES)
Cámara Nacional de Exportadores de Productos Pesqueros (CANEPP)
Cámara de Pescadores Artesanales de Puntarenas (CAPAP)

El Salvador
Dirección General de Desarrollo de la Pesca y Acuicultura (CENDEPESCA)
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Cooperativa Isla Tasajera
Cooperativa de Pescadores el Majahual
Cooperativa de Pescadores San Antonio los Blancos, Playa los Blancos

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Federación Nacional de Pescadores (FENAPESCA)

Asociación de Pescadores de Champerico (ASOPECHAMP)

Nicaragua

INPESCA – Instituto Nicaraguense de la Pesca y Acuicultura

FENICPESCA – Federacion Nicaraguense de Pescadores Artesanales

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Asociacion de Pescadores de Pesca Blanca (ASOEXPEBLA)

Federación Nacional de Cooperativas de Pescadores del Ecuador (FENACOPEC)

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APECO Asociacion Peruana para la Conservacion

Federación Única de Pescadores Artesanales del Perú (FIUPAP)

Universidad Peruana Cayetano Heredia

Desembarcadero Pesquero Artesanal de Pucusana

Asociación Mutualista de Pescadores Artesanales de Puerto Nuevo. Paita

Sindicato de Pescadores artesanales de Ilo

Chile

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Spain

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Divulgació, estudl I Conservació de l'entorn natural (SUBMON)

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WWF