First Sea Turtle Informal Intersessional Working Group Meeting (STIIWG01)

Review of CMM 2018-04 (Sea Turtles)

8 and 10 April 2026 (Pohnpei)| 10 AM-2PM

Virtual Meeting

Trials Using Different Hook and Bait Types in the Configuration of the Surface Longline Gear Used by the Spanish Swordfish (*Xiphias gladius*) Fishery in the Atlantic Ocean

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STIIWG01-2026-IP-30[1]

4 April 2026

[1] Reference 30

SCRS/2007/113 Collect. Vol. Sci. Pap. ICCAT, 62(6): 1793-1830 (2008)

TRIALS USING DIFFERENT HOOK AND BAIT TYPES IN THE CONFIGURATION OF THE SURFACE LONGLINE GEAR USED BY THE SPANISH SWORDFISH (*XIPHIAS GLADIUS*) FISHERY IN THE ATLANTIC OCEAN

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SUMMARY

Three types of hooks and baits were tested on two swordfish longliners over a period of 480 days at sea in five zones of the North and South Atlantic Ocean. Nominal CPUE data would suggest that the overall catch rates in weight of the fish species in general were reduced with the alternate hooks and baits tested. Overall rates (+7% and –8%) and (+3% and –11%) were found for the swordfish and blue shark, respectively in relation to the hook and bait combination of reference. The shortfin mako exhibited substantial decreases (–9% and –61%). For the billfish group, however, the all rates underwent an increase (+7% and +49%). For the sea turtle species CAT (Caretta caretta) *and LOL* (Lepidochelys olivacea)*, the nominal catch rates using alternate hooks and baits tested were generally found to increase (+2%, +557%) and (+203%, –66%), respectively. Standardized log normal CPUEs showed that "zone" was the most important significant factor explaining the variability in the CPUE of all the species. "Hook type" was only significant in the billfish group, while "bait type" proved to be significant for the shortfin mako, several other fish and the sea turtle* C. caretta*. The interaction between bait and other factors were also significant for some species. The mean standardized CPUE data also suggest that the use of alternative hooks could cause variations in the CPUE of swordfish (+14% and – 11%) depending on the type of bait combined. The circle hook would lead to losses for this species (– 11% and –1%) depending on the type of bait combined. A comparison of the standardized CPUEs would suggest that changing the hook and maintaining the same type of bait could result in an increase in the level of sea turtles by-catch that become hooked in external or internal locations. The use of squid as bait instead of mackerel would cause a considerable increase in the number of some species of sea turtles being hooked either externally or internally, regardless of the type of hook used. No seabird interaction occurred during the whole experiment.*

RÉSUMÉ

*Trois types d'hameçons et d'appâts ont été testés sur deux palangriers d'espadon sur une période de 480 jours en mer dans cinq zones de l'océan Atlantique Nord et Sud. Les données de la CPUE nominale suggéreraient que les taux de capture en poids des espèces de poissons en général ont diminué avec les hameçons et les appâts alternatifs testés. Des réductions globales se produiraient en général de (+7% et -8%) et (+3% et -11%) pour l'espadon et le requin peau bleue, respectivement, en relation à la combinaison de référence hameçons et appâts. Des réductions plus considérables (-9% et -61%) seraient obtenues pour le requin taupe bleue. Or, il se produirait probablement des augmentations (+7% et +49%) pour le groupe d'istiophoridés. Pour les espèces de tortues caouanne (*Caretta caretta*) et tortue olivâtre (*Lepidochelys olivacea*), les taux de capture nominale se verraient en général augmentés (+2%, +557%) et (+203%, -66%), respectivement. Les estimations de CPUE standardisées (log normal) ont montré que la « zone » a été le facteur significatif le plus important pour expliquer la variabilité de la CPUE de toutes les espèces. « Type d'hameçon » n'a été significatif que dans le groupe istiophoridés, tandis que « type d'appât » s'est avéré significatif pour le requin taupe bleue, plusieurs autres poissons et la caouanne* C. caretta*. L'interaction entre le « type d'appât » et d'autres facteurs a également été significatif pour certaines espèces. Les données de la CPUE moyenne standardisée suggèrent aussi que l'utilisation d'hameçons alternatifs pourrait produire des variations dans la CPUE de l'espadon (+14% et -11%), en fonction de l'appât qui est combiné. L'hameçon circulaire produirait des pertes pour cette espèce (-11% et -1%) en fonction de l'appât qui est combiné. La comparaison entre les CPUE standardisées suggère que le changement d'hameçon, tout en maintenant le même type d'appât, pourrait donner lieu à une hausse du niveau des prises accessoires des tortues marines accrochées aux hameçons de façon externe ou interne. L'emploi du calmar comme appât au lieu du maquereau entraînerait une augmentation considérable du nombre de certaines espèces de tortues marines accrochées à l'hameçon de façon externe ou interne, quel que soit le type d'hameçon utilisé. Aucune interaction avec des oiseaux de mer ne s'est produite pendant toute l'expérimentation.*

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RESUMEN

Tres tipos de anzuelos y cebos fueron ensayados en dos buques palangreros de pez espada durante 480 días de mar en 5 zonas del Atlántico norte y sur. Los datos de CPUE nominal sugieren que las tasas de captura en peso del las especies de peces en general se verían mermadas con los anzuelos y cebos alternativos ensayados. Se producirían en general reducciones globales de (+7% y –8%) y (+3% y –11%) para el pez espada y la tintorera, respectivamente, en relación a la combinación anzuelo y cebo de referencia. Reducciones más considerables (–9% y –61%) se obtendrían para el marrajo dientuso. Sin embargo, para el grupo de peces de pico, probablemente se producirían incrementos (+7% y +49%). Para las especies de tortugas CAT (Caretta caretta) *y LOL* (Lepidochelys olivacea) *las tasas de captura nominal se verían en general incrementadas (+2%, +557%) y (+203%, –66), respectivamente. Las estimaciones de CPUE estandarizadas (log normal) mostraron que "zona" fue el factor significativo más importante para explicar la variabilidad de la CPUE de todas las especies. "Tipo de anzuelo" sólo se mostró significativo para el grupo billfish, mientras que "tipo de cebo" lo fue para el marrajo dientuso, otros peces y la tortuga marina* C. caretta*. La interacción del "tipo de cebo" con otros factores resultó significativa para algunas especies. Los datos de CPUE media estandarizada también sugieren que el empleo de anzuelos alternativos podría producir variaciones en la CPUE del pez espada (+14% y –11%), según el cebo que se combine. El anzuelo circular produciría perdidas para esta especie (–11% y –1%) según el cebo que se combine. La comparación entre las CPUE estandarizadas sugiere que el cambio de anzuelo, manteniendo el mismo tipo de cebo, podría producir incrementos en los niveles de enganches externos o internos de algunas tortugas marinas. El empleo de pota como cebo en vez de la caballa produciría incrementos sustanciales sobre los enganches externos e internos de algunas de las especies de tortugas marinas, independientemente de cual fuera el anzuelo usado. No ha habido ninguna interacción con aves marinas durante todo el experimento.*

KEYWORDS

Longline, CPUE, hook, bait, swordfish, sea turtles, sea birds

1. Introduction

The Code of Conduct for Responsible Fishery of the FAO supports the sustainable use of aquatic ecosystems and requires that fishery activities be carried out with due attention to the environment. The incidental capture of sea turtles and birds in pelagic longline fisheries has gained international attention in recent years as consequence of more responsible fishing practices, the ecosystem approach and the IPOAs/NPOAs (Anon. 2001, Anon. 2004a, Anon. 2004b, Anon. 2004c, Anon. 2004d, Anon. 2005a, Anon. 2005b). Fishery activity is one of many possible elements that may play a part in reducing the stocks of these species. It is therefore advisable to minimize this mortality due to interaction with fishing operations, regardless of the relative effect of the fishery on the total mortality of these species.

One goal of the research should be to investigate methods to minimize incidental by-catch and mortalities of these species, while retaining viable and sustainable fishing performance. Incidental by-catch of pelagic species is mostly affected by the area-time selection of the fishing operations linked to the local abundances and their specific oceanographic conditions. But the gear configuration and technology used for fishing can also produce effects on the catchability in relation to the different species-sizes. So, among other variables, it would be advisable to assess the effects of gear modifications on the incidental by-catch, evaluating whether modified gear would minimize incidental by-catch and also retain viable economic performance.

The ICCAT recommends promoting the release of sea turtles accidentally captured live and sharing all the available information including technical procedures that would be conducive to the reduction of these incidental catches, as well as guaranteeing the careful handling of the turtles to be released with the greatest possible chance of survival.

In this sense, some countries have promoted the use of different devices such as circle hooks, to try and limit the incidental by-catch of turtles, and once they have been caught, to be able to release them from the hook more easily. Moreover, the use of different types of bait, for which each species has different preferences, or a greater or lesser facility for ingesting these baits, could be important factors in determining the catchability of these species. Another factor would be the location of the hooks when swallowed and the severity of the wound.

Circle hooks ("G") have gained international notoriety in recent years because of the supposed advantages they offer in terms of conservation as compared with some types of "J" hooks (Watson 2004, Watson *et al*., 2002; 2005). Hence, they have been recommended for use by some forums despite the fact that the results of several studies have been rather inconsistent or even contradictory (Anon., *in press*). However, due to differences in environmental conditions, fishing practices and target species, it is unclear if it is appropriate to extrapolate local results to entire fisheries (Cooke & Suski, 2004). Some types of "G" hooks may be beneficial to the conservation of some species-areas, but these benefits are not necessarily cosmopolitan. This fact is relevant, insofar as credibility with fishermen may be lost in fisheries where "G" hooks do not work as expected or where the obligatory introduction of a type of hook does not produce the expected benefits or may even produce the opposite result of what was intended for some species. The U.S. WPRFM Council (Anon. 2005a) reports that it is necessary for each individual fleet to experiment with methods aimed at avoiding the accidental capture of sea turtles to determine the efficiency and economic feasibility of such methods. At the FAO Technical Consultation on Sea Turtles Conservation and Fisheries (ANON. 2004c) most participating nations expressed a wish to conduct experiments with sea turtle by-catch reduction technology prior to adopting any specific fishery management alternatives.

Offset hooks are hooks with the point bent sideways in relation to the shank. Offset hooks are believed to be more effective in hooking and retaining fish than a straight hooks and are probably easier to bait. Recent studies have suggested that circle style hooks ("G") with no offset or a minor offset (about 4^{o}) cause less physical damage to fish than "J" style hooks because of the tendency of circle hooks to hook fish in the mouth rather than in the pharynx, esophagous or stomach and also because "G" hooks minimize foul hooking (externally hooked) and bleeding (Prince *et al*. 2002, Skomal *et al*. 2002)

However, there is no generic description of a "G" hook. Hence, the broad variation in sizes, designs, offsets and manufacturers makes for a wide variety of types under the same name. A similar problem arises when discussing "J" hooks in the literature, where several sizes and designs are possible. It may be generally inferred from the literature that minor differences in the design and size of the "G" hook may affect the way these hooks work, which means that these two factors would be important in terms of the effectiveness of the different types of "G" hooks, and the varying degrees of effectiveness between the different types and as compared to other types of hooks. Therefore comparative studies dealing with these aspects are necessary. Factors such as local abundance and type of fishery, hook size, the feeding habits of the fish and the morphology of their mouths would appear to affect the efficiency of "G" hooks. Therefore, it is difficult to promote the use of "G" hooks as being a panacea for all the fisheries. A good knowledge of how fishes and other species get caught on the hook and their respective catch data are essential to be able to support planning recommendations. The general recommendations focusing on the use of "G" hooks should only be evaluated where there are sufficient scientific data to back them. Hence, there are a number of fishing elements that may affect incidental catch, such as local abundance, hook size and type, fishing depth, bait type, time and duration of hook setting, oceanographic and meteorological conditions, etc. In addition, biological parameters may affect the catch rate, including the turtle size frequency distribution encountered by the fleets, etc.

Some turtles generally get caught by the hook when trying to consume the bait or become entangled in suspended fishing tackle. Normally turtles are freed by cutting the line during collection operations. But, because it is in some cases difficult to lift the turtle on board, and due to the loss of time and the danger of being injured by the hook, some fishermen prefer to release these turtles with the hook. Thus the hook is left in the mouth or other parts of the body where it could cause serious injury or death to the turtle. Immediate mortality is very low since the length of the line enables the turtles to return to the surface to breathe, but medium and long-term mortality is not well known and could be significant (ANON. 2005b).

For decades the Spanish surface longline fishery targeting swordfish in the different oceans has used the traditional "J" hook types that are soaked at night predominantly with mackerel as the traditional bait. However, in more recent years, the introduction of a new monofilament longline called the "American" style gear has led to the use of hooks that have been adapted to this technology and to the sustained or sporadic use of squid (Illex spp.) as bait. Nevertheless, there are still very few scientific studies that can provide information to assess the possibility of adopting a type of "G" hook preferentially over other types of hooks.

Experiments done in areas where a high incidence of sea turtles in the Western Mediterranean Sea was observed suggest that there are other more important factors to consider than the type of hook used ("J" or "G" hooks) to reduce the accidental capture of sea turtles and the capture of juvenile swordfish in these Mediterranean areas (de la Serna *et al.* 2006). Experiments carried out in the Western Indian Ocean with different types of hooks did not generate any comparative results related to the respective capture of sea turtles, owing to the low interaction of these species in the fishing zone under experimentation (Ariz *et al*. 2005).

Another scientific goal of this study was to test the impact of using different bait types as a possible measure aimed at reducing the incidental catch of sea turtles in the Spanish longline fishery targeting swordfish, focusing on the efficiency of the baits for catching both target and by-catch species. The rationale for these fishing experiments is related to the need to develop longline fishing gear configurations and fishing strategies to reduce incidental capture rates of sea turtles.

The goal in this case was to test some types of the hooks and baits used and at the same time keeping other elements of the gear and fishing operations as constant as possible to be able to identify the impact of such selected factors in CPUE results more easily. This information could help in the recommendation of measures that would ensure that longline fisheries are able to minimize incidental sea turtle by-catch in the Atlantic and continue their operations in a manner that is compatible with the protection of threatened and endangered species.

To achieve this objective, 3 types of hooks were tested ("SG" semicircular, "G" circle and "J" conventional) along with two basic types of bait (mackerel and squid), to evaluate their effect on the accidental capture of sea turtles, by-catch species and swordfish, which is the target species. The conventional "J" hook, the "mackerel" bait and a combination of these were considered to be points of reference on the basis of which other hook-bait types and their combinations would be tested. Also assessed were the possible "gains" or "losses" produced in the CPUEs of each species in relation to these reference elements most commonly used by the fleet.

2. Material and methods

Fishing areas: The fishing areas covered by two boats during the experiment in the North and South Atlantic were located at around 47ºN–23ºS latitude. Temperate, subtropical and inter–tropical areas were surveyed during the experiment. The areas were analyzed considering 5 zones (**Figure 1**). The fishing zones were located in international waters that had been previously selected as being liable to produce a high incidence of interactions with sea turtles. Therefore the areas were selected to purposely try and force this interaction and they do not represent a random vision of the interaction rates obtained by the commercial fleet and should not be generalized. The areas of operation varied over the course of the experiment, which means that the spatial factor (zone) is linked to a time factor.

Longline used: The gear used by both commercial boats was the monofilament "American longline style" presently used by most of the Spanish longlining fleet with a mean number of around 1000–1400 hooks per set/vessel. The gear was adapted to test three different types of hooks and the utility of changing the bait from mackerel to squid to measure the yields of different species or groups caught. Only in some sets, was one of these two baits replaced by pieces of blue shark caught in the previous sets.

Gear configuration: A nylon monofilament main line was used, reaching around 55 nm per set. The gear was usually set between late afternoon and midnight to take advantage of the nocturnal near-surface feeding habits of swordfish. The line was kept close to the surface by numerous buoys which are attached to the mainline via separate buoy lines. Additional radio buoys were also used to locate the mainline. There were over 260 buoys on a line and on average, 5 branch lines between buoys. An average of 1300 (720–1440) hooked branch lines were attached to the mainline. Branch lines over 14 m long were spaced evenly along the mainline at a mean distance of roughly 80 m. The branchline may be made up of several parts; an upper section, a swivel, a plumb trace, another swivel, a steel line, an electric lightstick (green or blue) and a baited hook (baited by hand).

The gear was configured in sections or lengths and a combination of the hook-bait was placed on each section. The position of each hook-bait combination on the longline was rotated (**Table 1**) so that the position of a specific hook–bait combination on the longline would not influence the catch obtained and so that the different hook–bait combinations would be operating at the same time. The purpose of this was to prevent elements such as the drift of the different longline sections, the varying duration of the soaking time of a section or other uncontrolled factors, from systematically affecting the CPUEs obtained.

Depth: For the approximate determination of the maximum, minimum and mean depths at which the fishing gear operated, the vessel fishing in the North Atlantic used depth finders on the first and third hooks of each section between buoys, which provided an estimate of the maximum and minimum depths at which the longline was working.

Experimental vessel techniques and characteristics: The two boats selected are traditional or long distant units belonging to the Spanish fleet, normally fishing North or South of the of 5º N latitude, respectively. The vessel fishing in the North Atlantic is 25.7 m in length, with 93.6 GRT and 239 HP. The vessel operating in the South Atlantic is 31 m in length, with 149 GRT and 675 HP.

Time/area and duration: Each vessel operated for a total of 240 days at sea. Owing to the long duration of the experiment, the fishing activities were divided into sub-trips. Each vessel began to operate in October, 2005 in a previously selected zone and within this zone at a fixed point based on the criteria of each skipper. The experiment ended in August, 2006, after each vessel had completed 240 days at sea.

Characteristics of the experimental set-up for types of hooks and baits tested: Three types of hooks were tested with different degrees of offset and with the following measurements in mm (length – width – gape) (**Figure 2**). *A1*: Hook 18/O (10 º offset) new semicircular "SG" = 80 – 60 – 40 and bluish in color (proposed for testing by the fleet itself). *A2*: Hook 17/O (8º offset) circle style "G" = 60 – 50 – 30. *A3*: Hook 16/O (10 º offset) "J" or conventional = 60 – 45 – 30. The conventional A3 hook used in this experiment and by the fleet differs from other types of "J" hooks used in experiments by other authors. Here, the conventional type is larger in size and has an offset of 10º and the straightness of the design of the hooks is substantially different from both the one used by the fleet in the past and from the ones used in other experiments.

In addition, 2 different types of similar–sized bait were used alternately, the most common being as follows: bait 1= mackerel (*Scomber spp.*) weighing approximately 400-500 gr per fish and bait 6= squid (*Illex spp.*) around 200 gr per piece (**Figure 3**). The vessel fishing in the North Atlantic used pieces of blue shark (PGO) sporadically in their sets – called bait 10 – belonging to parts left over after dressing the individuals caught in the previous set. This bait 10 was used in combination with one of the other two baits, but the 3 different types of bait were never combined in the same set.

Experimental design: During the sets, each vessel maintained the characteristics of the gear, without changing the length flotation line, the section/length of the steel wire or rope with the sinker, the length of the gangions, the distance between them, etc. The experiment was based on the use of the most standardized gear possible in each vessel and between vessels to reduce the effects of factors other than the 3 hook types and 2 bait types, as described below.

Hooks: With each set an effort was made to set out the same number of hooks of each type. The total number of hooks per set was divided by 3 to calculate the total number of hooks of each type in each set. Then, the arrangement of the different hook types A1, A2 and A3 on the longline was established, alternating these positions every 3 sets. During the first set, the first type of hook, selected at random, was used. Next, the second type of hook, randomly selected, was fitted. Finally the third type of hook was used. After this arrangement had been defined, this combination was repeated in the next two sets.

In the next three sets, the position of the three types of hooks on the longline was changed. The first type of hook was moved to the position of the one that had been used in the middle in the 3 previous sets, followed by the hook type used last in the 3 previous sets, and finally, the first type. The position of the hooks kept on being moved successively –in a chain effect – every 3 sets (**Table 1**). The purpose of this was to reduce factors that might affect the CPUE as a consequence of the hook position on the longline.

Baits: Similar to the alternating combination by hook type, the two bait types proceeded to be combined. The position of the bait varied with each type of hook, in an attempt to prevent its position from affecting the catch obtained (**Table 1**). Pieces of blue shark were used sporadically, but always replacing one of the two above-mentioned bait types, so that only two different bait types were used in each set.

Species: An analysis was carried out on the results obtained for all the turtle species (TOR) captured: DER (*Dermochelys coriacea*), CAT (*Caretta caretta*) and LOL (*Lepidochelys olivacea*) as well as for fish species or groups: SWO (*Xiphias gladius*), PGO (*Prionace glauca*), IOO (*Isurus oxyrinchus*) and BIL (Istiophoridae). Results of the group other species (OTH) are also presented (TUN: *Thunnus spp*, CAO: *Carcharhinus spp.*, *Ruvettus pretiosus*, *Lepidocibium flavobrunneum*, etc). However this OTH group is not always analyzed since it groups together a wide variety of species. The results for the sea turtle DER was in some cases not discussed because its interaction is mostly produced by entangled or hooked by flippers.

Measurements of the species captured: The size of the billfish and swordfish were recorded to the lowest centimetre measured in a straight line from the lower jaw to the fork of the caudal fin (LJFL cm). For the rest of the fish species, the fork-length size (FL cm) was used. In turtles, the total carapace length was measured (TL cm). The dressed weight (DW) of the fishes was estimated in kg on the basis of different size-weight relationships. Incidental catches of turtles were expressed in number of individuals.

Effort and nominal yields: The nominal effort was calculated in thousands of hooks set by type of hook, bait and their combinations. Nominal CPUEs in weight (kg DW) per thousand hooks were used for SWO and the fish by-catch species. The incidental by-catch nominal CPUE of sea turtles was expressed in number of individuals. The nominal yields were obtained per hook and bait types and their combinations. The nominal CPUE was obtained by aggregation catch and effort data by factor or combination of factors described. The CPUE observations for standardized procedures were calculated from observations defined as the aggregation of the catch and effort data by factors bait-hook within each set.

Hook location in the incidental catch of turtles: During the experiment the location of the hook in each specimen of sea turtle caught was recorded (flipper, mouth, entangled in the gear, esophagus, stomach, lip, tongue and others). During the first two sub-trips carried out by the two vessels, the locations *lip and tongue* were not differentiated, with these two positions being included in the *mouth* group. Later these two new positions were described and recorded separately. In the descriptive analyses, the hook locations of *lip, tongue* and *mouth* were summed up in the category called *mouth*. The locations *stomach* and *esophagus* were also grouped together within the category *swallowed*. Additionally, during the trips the observers carried out a visual survey in the fishing area to obtain some complementary data on sightings of sea turtles.

Analysis: The analyses were focused on different aspects such as species composition, catch in number and dressed weight (DW), size classes, severity of the injuries caused by each type of hook in the sea turtles and other factors that enhance entanglement or hooking. Analyses were carried out to obtain nominal and standardized catch data of all the species captured and the target species (*Xiphias gladius*), in particular, as well as the most important species and groups from a commercial standpoint.

To evaluate the significance of the factors tested, a preliminary standardization of the CPUEs was carried out using GLM, calculated in weight for the fish species and in number for the sea turtles. The following factors were considered: hook (A1, A2, A3), bait (1 and 6), zone (1,2,3,4,5) and the interactions hook*bait, bait*zone, hook*zone, hook*bait*zone. Records with bait 10 were not used in the analyses. In the LN transformation (CPUE+1), a lognormal distribution was assumed. The significance of each factor was evaluated at confidence intervals of 95% and 90%. GLM results were tested using both *StatGraphics* and *SAS* software under identical premises. In addition, the significant differences between the mean CPUEs obtained by species and factors were tested by applying an ANOVA–Multiple Range Test (*StatGraphics Plus 5.1)*.

3. Results

Fishing effort: The two vessels deployed a total of 430,299 hooks during a total of 342 sets, with an average number of 1,258 hooks per set. The total number of hooks used by hook type, bait and zone, in addition to their combinations, are presented in **Tables 2** and **3**. Alternative bait type 10 was only used in a few sets in the North Atlantic.

Set depth: The set depth of a total of 298 hooks was observed (102 in the 1st hook and 196 in the 3rd hook), although it was only possible to record the depth for a total of 284 hooks (98 in the 1st and 186 in the 3rd hook). The mean depth was 38.8 m. The depth recorded in the first hook ranged between 1-106 m, with a mean depth of 30 m. The third hook reached a depth range of 17-135 m, with a mean depth of 47 m.

Total catches and nominal yields: **Tables 4, 6** and **8** show the total accumulated catch in weight (kg DW) and in number of specimens in addition to the respective catch rates per thousand hooks, for each species-group, by zone and hook and bait type used. The total weight of the specimens of the different fish species captured, regardless of the use assigned to the catch, was 461 t. A total of 194 t was obtained by one of the vessels with 188,569 hooks and 267 t by the other vessel with 241,730 hooks.

Catches, nominal yields and average sizes by zone: The catch levels in weight (kg DW) resulting from the different fish species–groups point to a wide variability in catches between zones and species (**Tables 4** and **5, Figures 4** and **6**). The largest catches of SWO and PGO in weight were observed in zones 5 and 4. Catches of IOO were mainly recorded in zone 1 of the North Atlantic and practically the only catches of BIL appeared in the South Atlantic, especially in zone 5. Zone 5 provided the highest yields in weight of SWO and BIL, also showing the largest mean sizes of both species (149 cm and 225 cm, respectively), as well as the lowest yields in weight of PGO and IOO. Zone 3 presented intermediate yields for the species SWO, PGO and IOO. Zone 2 exhibited the lowest yield of SWO and the highest of PGO, in relation to the smallest individuals of both species (122 and 149 cm respectively). Zone 1 had the highest yields of IOO with specimens of the smallest mean size.

Catch data, incidental catch rates and mean turtle (TOR) sizes would also suggest important differences between species and zones. The highest interaction rates with CAT occurred in zone 1, while interactions with DER and LOL were found in zone 4. Zones 2 and 3 showed intermediate incidental catch rates for CAT and DER. In Zone 4 there was no interaction with CAT, but this was the only zone presenting an interaction with LOL (mean size 76 cm) as well as showing the highest interaction rates with DER (mean size 117 cm). (**Tables 4** and **5**, **Figures 4, 5** and **6**).

Catch, nominal yields and average sizes by hook type: In general, the catches obtained using different types of hooks do not differ substantially in magnitude. The three hook types yielded similar levels of SWO catches, although the largest catches were had with the conventional A3 hook and the semicircular A1 and the smallest with the A2 circle hook. However in PGO, the largest catch was obtained with the circle style A2 hook. The conventional A3 hook yielded the largest catches of IOO and the lowest BIL catches.

The highest catch rates in weight for SWO and IOO were obtained with the conventional A3 hook, while the greatest yields of PGO resulted from the use of the A2 circle hook and for BIL they were had with the semicircular style A1 and the A2 circle hook.

The greatest interaction for CAT occurred with the conventional A3 hook and for DER with the semicircular A1 hook. The rates were similar for LOL with the three hook types, although this species only appeared in zone 4. (**Tables 6** and **7, Figures 6** and **7**).

Catch, nominal yields and average sizes by bait type: The catch levels in weight obtained for the different fish species were relatively similar for baits type 1 (mackerel) and 6 (squid), with the exception of IOO and OTH. In general, bait type 1 showed somewhat higher catches and yields in most of the species-groups than the other two bait types, particularly in the case of IOO. The OTH group, however, exhibited a higher CPUE with bait 6 (squid), which would imply that there was a higher percentage of by-catch belonging to this group (**Tables 8** and **9, Figures 6** and **8**).

The level of interaction with turtle (TOR) specimens was generally lower with bait type 1 (mackerel) and higher with bait 6 (squid) for species CAT and LOL, around +239% +450% in relation to bait 1 (mackerel), respectively. This would suggest that these two species have either a greater ability to locate bait 6 (squid), or a preference for this bait, or, simply that bait type 6 is more conducive to the hook being swallowed and the turtles being caught. Curiously, bait 10 also appears to be more effective (+289%) than bait 1 (mackerel) in causing the incidental capture of CAT, possibly as a consequence of the structure of the bait itself, which leads to the progressive biting and hooking of the turtle. Bait type 10, however, was only used sporadically in some of the sets carried out in the North Atlantic, for which reason its effect on LOL was not evaluated.

Retaining the catch: The total catches of all the fish species combined and retained on board amounted to 407 t (DW), accounting for 88.3% of the total catch of the two vessels. The catch amount retained on board the two vessels was 178 t of SWO (96.7%), 140 t of PGO (97.3%), 25 t of IOO (95.6%), 20 t of BIL (83.1%) and 53.1% of the group OTH. All fish specimens were retained on board, with the exception of some individuals belonging to the group OTH or specimens of different species that were released live or marked with conventional tags and released.

Gains-losses in nominal catch rates: "*Gain*" is understood to be an increase in CPUE, in both the target species and by-catch species caught incidentally, in relation to the combination selected as a reference. Therefore it represents increments in mortality. In sea turtles, the term "*gain*" should be interpreted as increments in incidental catch rates, and therefore, an undesirable effect on this species. The term "*loss*" should be interpreted in the opposite sense.

Hooks: Gains or losses in catch rates in terms of percentage as a result of using semicircular or circle hooks (type A1 or A2) as opposed to the conventional hook used as a reference (type A3) are summarized in **Tables 10** and **11, Figure 9**. The use of any of the alternative hooks tested suggests losses in the nominal catch rate in weight for most of the fish species, in relation to the conventional type A3 hook. However PGO showed moderate gains when the circle type A2 hook was used (+6.7%). In the BIL group gains were suggested with either of the alternative hooks tested, A1 and A2 (+33.1% and +15.6%, respectively) as compared with the conventional hook (A3). On the basis of data from hooks A1 and A2, incidental (nominal) catch rates appeared to decrease in number of turtles (TOR) as compared with the conventional A3 type hook, except for DER, where gains were obtained with the semicircular A1 type hook (+18%). Nevertheless, it must be taken into account that the interaction of this latter species with the longline usually occurs as a result of the animals becoming hooked externally, in the flippers, the axillae or from becoming entangled in the lines, which means that the interaction would probably have very little to do with the type of bait or hook used (**Figure 11**).

Baits: Gains or losses in catch rates in terms of percentage as a result of using baits type 6 (squid) and type 10 (blue shark) as opposed to the reference bait 1 (mackerel) are summarized in **Tables 12** and **13, Figure 10**. The use of alternative baits would result in a lower catch rate in weight for almost all of the fish species as compared to bait 1 (mackerel), except for the OTH group. In contrast, the use of the two alternative baits would imply considerable increases in the incidental catch rates of turtles CAT and LOL, between +242% and +483% depending on the species and alternative bait used (**Table 12, Figure 10**).

*Hooks*baits*: **Tables 14** and **15** summarize the gains and losses in the catch rates in weight and number of fishes caught, as well as the incidental catch rates in number of specimens of turtle species that interacted with the fishing gear, in accordance with the different hook-bait combinations in relation to the reference combination (A3/1), consisting of the conventional hook A3 (straight) and bait 1 (mackerel).

The combination of any type of alternative hook with bait type 10 (blue shark) was found to produce substantial reductions in fishery yields in weight and number of all the fish species (ranging from –42% and –90% in weight and from –13% and –85% in number), depending on the species and hook combination used. However this type 10 bait considerably increased the incidental catch rate of turtles. The yields of SWO in weight using bait 10 (blue shark) were found to decrease between –46% and –73%, depending on the combined hook type. Although bait type 10 has only been used in several sets in the North Atlantic, the results would suggest that any combination using this bait type would not be very effective in catching either target or by-catch species of fishes, but it would, in contrast generally increase the incidental catch rate of sea turtles, present in the interaction areas and enticed by the bait.

The results of all the other combinations except bait type 10 indicate that the catch rates *in weight* of the total fish species would generally decrease as compared to the alternative combinations tested. Moderate variations in yield were observed in SWO, with losses in 60% of the combinations tested, with catch rates in weight ranging from +7% and –8% in relation to the combination of reference. In PGO losses were found in 60% of the alternative combinations tested, with catch rates in weight ranging from +3% and –11%. In species IOO there were losses in 100% of the alternative combinations tested, with a drop in catch rates ranging from –9% and –61%. However, in the BIL group, gains were obtained in 100% of the combinations tested with positive catch, with catch rates ranging between +7% and +49%. In the OTH group there were gains in 60% of the alternative combinations, with catch rates of between +32% and –11%.

Moreover, according to the results, with the exception of bait type 10, there was a decrease in the catch rates in *number* for all of the fish species in 65% of the alternative combinations tested. Species SWO exhibited gains in the number of fishes in 60% of these combinations, with rates ranging between +12% and –6% in relation to the reference combination. On comparing these data with those related to weight for the same species, it might be assumed that these gains would be attributed to smalle-sized fishes. In PGO, 80% of the alternative combinations tested produced losses in the catch rates in number of between +11% and –19%. Species IOO suffered losses in 100% of the alternative combinations tested with catch rates ranging from –1% to –69 %. In the BIL group losses occurred in 80% of the combinations tested, with catch rates of between +12% and –22%. In the OTH group there were gains in 70% of the alternative combinations tested, with catch rates of between +52% and –7%.

With the exception of bait type 10, the nominal catch rates in *number* of individuals in turtle (TOR) species was generally seen to increase in 79% of the alternative combinations tested, for the three species as a whole. In the CAT species incidental catches rose in 100% of the alternative combinations tested with incidental catch rates in number ranging from +2% and +557%, depending on the hook-bait combination. Species LOL was subject to rose incidental catches in 75% of the alternative combinations tested, with incidental catch rates in number of between +203% and –66%.

If the same hook types (with different types of bait) and the different hooks (with identical baits) are compared, the results suggest that bait may be the most important factor affecting the incidental catch rates of species CAT and LOL. The use of hook A1 combined with bait 6 (squid) could lead to increases of between +144% and +209% in the respective incidental catch rates of the two turtle species in relation to the same hook, if combined with bait 1 (mackerel). However the use of hook A1 with bait 1 (mackerel) would account for incidental catch rates in these species of +2% and –66%, respectively, in relation to the standard configuration. The use of the reference hook (A3) with bait type 6 (squid) may result in an increase in the incidental catch in number of up to +557% and +141% for the species CAT and LOL, respectively, in relation to the same type of hook combined with reference bait type 1 (mackerel).

The combined nominal data would suggest that, overall, a change in hook does not appear to be the factor that contributes most to reducing the incidental catch rates of turtles, but rather that it might even lead to increased incidence rates, even when the same bait type 1 is used. In species CAT, changing the hook type but using the same bait type, in all cases, led to an increase in incidental catch rates between +2% and +49% of the standard combination. If bait is also changed, these rates rise to +194%. In LOL, only with the combination of hook A1 and bait 1 (mackerel) was there a reduction on the effect of the incidental catches of this species, but this benefit was not observed when hooks A1 or A2 were combined with bait 6 (squid), which led to an increase in incidental catch rates of +143% and +203%, respectively in relation to the standard combination. Hook A2 (circle) does not appear to reduce the incidental catch rate of the two species of turtles, and the incidence rate increases to a greater or lesser extent depending on the bait with which this hook is combined.

Significance of the factors analyzed and a comparison of the standardized CPUEs: The preliminary results obtained by means of GLM suggest that most of the factors tested were not significant in explaining the variability of the CPUE of the different species-groups considered (**Table 16**). “Zone” was the only or most important significant factor that was able to explain most of the variability in the CPUE of the species-groups. Hook type was only significant, although with minor importance, in the case of IOO. Bait type was found to be significant, although of moderate or little importance, in species-groups IOO, OTH and CAT. The hook*bait combination was not significant for any of the species. The bait*zone combination proved to be significant and relatively important in species-groups IOO, OTH, CAT and LOL. The hook*zone combination was not significant for any of the species. The hook*bait*zone combination was only significant and moderately important in the CAT species. Identical results were obtained by using the ANOVA multiple range test to evaluate the similarity between means.

The preliminary results of the standardized mean CPUEs by species and for each of the principal factors are shown in **Table 17**. The high variability in the CPUE between zones for the different species was confirmed. For SWO, the mean standardized CPUEs indicate that a change in hook could lead to mean yield losses in weight of between –7 and –15% for hooks A1 (semicircular) and A2 (circle), respectively, as compared to the reference hooks (A3). For PGO, a change in hook could lead to gains ranging from +6 to +18%. For IOO this would generate mean losses of between –43% and –35%, and for BIL gains of between +5% and +14%.

Although the experiment attempted to standardize and balance the type and number of observations between combinations, the hook and bait factors are not easy to separate, since neither one is able to produce a capture by itself. Only the combination of the two factors enable a capture to take place, except in cases where animals become entangled in the gear or when sporadic accidents occur. The olfactory stimulus appears to be fundamental in the swordfish to the final attack on prey–bait (MEJUTO *et al*. 2005). Similar behaviour is known in other large pelagics species. The hook*bait interaction was not significant for any of the species under the assumptions put forth, whereas bait was significant in several species. However, the mean standardized CPUE estimations for the hook*bait combination proved to be of some interest when compared (**Table 18**). In SWO, the use of alternative hooks could cause gains or losses, depending on the bait combined, with the CPUE values fluctuating between +14% and –11% in relation to the combination of reference. Hook A2 would cause mean yield losses in weight of between –11% and –1%, depending on whether it was combined with mackerel (bait 1) or squid (bait 6). In PGO, hook A2 could lead to yield gains in weight of between +1 and +13% depending on whether it is combined with mackerel or squid, respectively. Hook A1 would cause the mean yield to decrease with both baits. In IOO, the use of alternative hooks and baits could lead to declining mean CPUEs in all the combinations, fluctuating between –35% and –77%, according to the combination used. The greatest losses in this species would occur by combining the hooks tested with bait 6 (squid). The use of reference hook A3 combined with squid could bring about mean losses of –55% in this species.

For the remaining species, the results are considered to be extremely sensitive to the preliminary methodological approach used, since they are species with a low prevalence. Under these circumstances, a lognormal approach would probably not be the best option, and it would be advisable to test other alternatives in the near future. Nonetheless, the preliminary results are of some interest, even in consideration of these limitations. In the BIL group, the use of alternative hooks and bait could lead to increasing or decreasing CPUEs depending on the combination used, fluctuating between +23% and –19%. However, since we are dealing with a combination of species, it would not be appropriate here to draw conclusions. For the CAT turtle, all the alternative combinations tested suggest that there are increases in the mean incidental catch rate, ranging from +66% to +433% as compared to the combination of reference. The highest increases took place when the alternative hooks (A1 or A2) were combined with bait 6 (squid), with the rate rising by +205% and +433%, respectively. By changing only the hook type, the rate also appeared to increase, but more moderately (+66%, +72%). The use of the reference hook (A3) combined with bait 6 (squid) increased the mean incidence rate by around +434% over reference bait type 1 (mackerel).

For LOL, the majority of the alternative combinations tested suggested possible increments in the mean CPUE of between –59 and +111% over the reference combination. The highest increases were generated when different hooks were combined with bait 6 (squid), ranging between +40% and +106%. Only hook A1 combined with mackerel inferred possible mean decreases in the incidental catch rates, but it must be remembered that this species only appeared in zone 4.

Levels of sea turtle interaction and releases: An interaction effect on a total of 435 sea turtles (species combined) was achieved. Of these 93.3% were released alive apparently good condition for survival (**Table 19**). Owing to the relatively low interaction observed with turtles in commercial fishery practices in the Atlantic, the areas selected for the experiment and the strategy maintained throughout its duration were conducive to the procurement of high interaction rates. However the fishery practices and the treatment of the incidental captures were the same as the ones applied during commercial activities, with the exception of the test carried out on hooks and baits. Hence, the release rates could be similar to those that would occur in strictly commercial operations.

Hook location by turtle species and species combined: The different locations of the hooks on a total of 409 turtles caught were observed. As regards the DER species, it was not possible to observe the hook location on 26 individuals (4.8% of the total). The prevalence of the different locations observed on the 409 turtles, regardless of the hook or bait type used can be broken down as follows: 45.7 % by the flipper, 40.3% in the mouth (mouth+lip+tongue), 6.1% swallowed (5.6% in the esophagus and 0.5% in the stomach), 5.1% entangled, and 2.7% other types of hooking. As regards the specimens of CAT and LOL, 78.0 % and 66.7% were hooked in the mouth while 81.8% of the individuals belonging to the DER species were hooked by the flippers. In the case of LOL specimens, 25.9% were wounded in the esophagus (**Table 20, Figure 11**).

Hook location on turtles by hook type: The highest percentage of hookings (41.1%) took place with the A3 hooks (straight), followed by hook A1 (semicircular) 30.4% and A2 (circle hook) 28.4%. Eighty-six percent of the hookings were observed on the external part of the animals (flippers+mouth+entangled), while roughly 11.3% were caught internally (esophagus+stomach) (**Table 21, Figure 12**). Hook A1 (semicircular), which is larger in size, was mainly caught in the flippers (18.1%) and in the mouth (8.2%). The A2 circle hook was primarily caught in the flippers and mouth at similar levels (13.1% and 12.6% respectively). With the conventional hook A3, the greatest number of hook locations were in the mouth and flippers (18.8% and 15.1%), respectively.

Hook location on turtles by species and hook type: The CAT species was the most prevalent (39.4%), caught in the mouth with the A3 type hook (conventional). In contrast the highest percentages of species LOL (29.2%) were caught with the A2 hook (circle). The DER species was found, in most cases, to be caught by the flipper or entangled, but never to have swallowed the hook, (**Table 22, Figure 13**).

Hook location on turtles by bait type: The prevalences of the different hook locations by bait type combined would suggest that most of the interactions (60.6%) occurred with bait type 6 (squid), while nearly half (36.7%) were had with bait 1 (mackerel) and 2.6% with bait 10 (blue shark), although the latter bait type was subject to very few trials. Bait 6 (squid) was involved in 54.2% of the external hookings and 4.8% of the internal hookings observed, which would suggest that this bait is probably one of the most important factors leading to the increase in incidental catches and the CAT and LOL turtles' swallowing the prey (**Table 23, Figure 14**).

The highest percentage of turtles hooked in the mouth (29.3%) took place with bait type 6 (squid), whereas bait type 1 (mackerel) resulted in only 9.8% of turtles caught by the mouth. The percentages of animals being hooked in the flipper or entangled were similar with both bait types 1 and 6. In 4.8% of the cases, the hook was swallowed in association with bait type 6 (squid), while the percentage amounted to only 0.9% when associated with bait type 1 (mackerel).

When relating hook location to bait type in each turtle species (**Table 24, Figure 15**), we observed that CAT demonstrated a clear preference for bait type 6 (squid) with 59.0% of the hook locations being found in the mouth and 7.5% swallowed, as opposed to only 16.2% of the hooks caught in the mouth and 2.3 % swallowed when the conventional bait type 1 (mackerel) was used. For the CAT turtle, the use of bait 6 (squid) increased the probability of the animals being hooked in the mouth by about 4 times as compared to the use of the conventional bait type 1 (mackerel). In the species LOL the use of bait 6 (squid) also increased the probability of the animals being hooked in the mouth by about 4 times as compared to the use of the conventional bait type 1 (mackerel). Moreover, the rate of hooks swallowed by LOL rose to +25.9%, compared to a rate of zero with the conventional type 1 bait (mackerel). The results of the interactions with bait type 10 were not considered since only a few fishing operations were carried out with this bait, all of which took place in the North Atlantic. Therefore, there were no interactions with LOL and only at a moderate rate with CAT and DER.

*Prevalences in turtles of each hook location, species and hook*bait combinations*: For the total number of turtles, the highest percentage of hook locations were found in the mouth (14.7%) with the combination of conventional hook–squid bait (A3/6), followed by the flippers (9.3%) with the combination semicircular style hook–squid bait (A1/6) and lastly, 3.4% of the turtles were found to have swallowed the hooks which were caught in the esophagus with the combination conventional hook–squid bait (A3/6) (**Table 25**). To facilitate the description, the prevalences in percentages of the different hook locations were combined and then classified into “external” (flipper+mouth+entangled) and “internal” wounds (esophagus+stomach), according to the different combinations of hooks A1, A2, A3 (semicircular, circle and straight) and baits 1 and 6 (mackerel and squid). The differences between their respective combinations were also computed (**Table 26, Figure 18**).

The results obtained for the species DER must be interpreted with caution, since when these turtles are hooked on the longline, it has relatively little to do with the hook-bait type used, as the interaction mostly occurs with the lines. In species CAT and LOL, the greatest accumulated prevalences are related to the hooks that use bait type 6 (squid) in their respective combinations. The combined use of hook type A3 (conventional) with bait 6 (squid) led to increases in the external and internal hookings of CAT (+34.1% and +5.8%) and LOL (+11.1% and +14.8%), as compared to the same hook when used in combination with bait 1 (mackerel). This results are consistent with other experiences done in the Atlantic (WATSON *et al*., 2005)

4. Discussion

A comparison of the different mean CPUEs obtained (nominal and standardized) with the different hook types indicates that by changing hooks and retaining the same type of bait, there would generally be moderate mean variations –both positive and negative– in the level of external or internal hook location in sea turtles as a whole. By contrast, the use of bait type 6 (squid) would account for the highest mean increases of external hook locations as well as internal hookings, particularly in some of the sea turtles, regardless of the hook selected for use. The data do not in general show significant CPUE differences between hook types alone and additional studies are needed. However the nominal an standardized data would, however, suggest that the use of alternative hooks could lead to a general decrease in the catch rate in weight of most fish species in comparison with the conventional hook A3. Nevertheless, moderate increases could be had in PGO with the use of circle hook type A2 (+6.7%). The BIL group could be subject to gains with either of the alternative hooks tested, A1 and A2, (+33.1% and +15.6%, respectively) in comparison with the conventional hook (A3).

The use of alternative baits would generally lead to a lower catch rate in weight for practically all of the fish species, as compared to bait 1 (mackerel). But it would generate an overall increase in the incidental capture of sea turtles CAT and LOL (+242% and +483%), depending on the turtle species and on the bait used. The interaction rates with turtle specimens were generally lower with bait type 1 (mackerel) and higher with bait 6 (squid) for CAT and LOL, roughly +239% and +450% over bait 1 (mackerel), respectively.

The results obtained help us to understand the nature and the complexity of the problem. It is not advisable to simplify the debate and reduce it to the use of one or more hook types based on studies whose designs oftentimes lack standardization. Despite the fact that statistical significance was not achieved in some of the CPUE analyses presented and that additional methodological approaches are needed, the mean standardized and nominal CPUE values would suggest that the combination of the different hook*bait types could have a substantial effect on the catch rate of sea turtles and hook location. The use of squid as a bait could contribute considerably to the overall increase in the accidental capture of some of the most characteristic turtles, as well as to the seriousness of the wounds produced by the hooks, regardless of the type of hook used. In this sense, the recent experience of observers and fishermen with “G” hooks indicates that it is more difficult to release turtles caught with “G” hooks than with more traditional "J" and tuna hook types especially when the hook had already been swallowed or a "piercing type hooking" happen on its mouth. This was also suggested by scientific observers during this experiment. The hook locations should also be taken into account to quantify their significance in the mortality caused by the wounds (Epperly & BoggS, 2004) as well as other factors such us the portion of branch line attached to the hook kept on the released sea turtles, etc. These factors are especially relevant in fisheries like the one described here, where roughly 93% or more of the total incidental turtle catches are released alive.

Previous studies have indicated a small degree of offset (=<4^{o}) in the hook does not increase the rate of gut hooking, but an offset of 15^{o} or larger does result in gut hooking comparable to that of "J" hooks (Malchoff *et al*. 2002, Prince *et al*. 2002, Skomal *et al*. 2002). Hook size and shape are probably only one of the key issues in terms of the efficient conservation of the species. More studies are needed in this direction. In any case, there is a clear need for a consensus to standardize the terminology of these fishing devices and their products.

The identification of factors of the fishing gear that may favor the incidental capture of sea turtles would allow changes to be made in the gear's configuration to reduce these interactions. However, the introduction of changes in fishing strategy must be assessed with caution for all of the species subject to capture as a whole and then validated, establishing appropriate scientific monitoring methods, since the implications of these findings may have important repercussions on other species as well as on the CPUE indicators used to assess fish stocks. Improving the identification of areas-times exhibiting a higher interaction with sea turtles could help fishermen take action and effectively carry out practices to avoid accidental captures, since these catches are unwanted, interfere with fishing operations and oftentimes put fishermen at risk when attempting to release the turtles retained under adverse sea conditions.

During this experiment, interaction with sea turtles was deliberately sought after by selecting specific fishing grounds. However, contrary to what would have been expected, the frequent and abundant sightings of turtles in the zone western of Azores Islands did not produce rates of turtles being hooked. This indicates that the areas-times of high local abundance may not necessarily correspond to those that produced the greatest number of interactions with the fishing gear. Any interaction with sea birds had happened during the whole experiment.

Further research is needed to develop more effective fishing practices to mitigate accidental captures. Investigations need to focus on the reason why turtles are attracted by certain types of bait and the extent to which the effect of attraction takes place, what makes it easier or more difficult for the animals to swallow each type of bait, the oceanic distribution areas and the seasonality of these turtle species, their real interaction with the fishery, associated environmental factors, etc. In any event, the aim must be to develop more selective fishing practices, but without losing sight of the fact that fishing is just another part of a more complicated issue related to sea turtles, whose reproduction habitats have been destroyed and degraded as a result of practices of land development and economic activities which have had a huge impact on these species in the great majority of the coastal areas where they nest.

Acknolwledgements

The authors are grateful to the skippers and crews of the longline vessels AMEL and CEDES for their cooperation during 2005 and 2006 thanks to whom this experiment was made possible, as well as scientific observers A. Carmona, E. González, A. León, G. Mucientes and P. Quelle for their efforts and professional assistance. Special thanks go out to all the people involved in Program 04 of the IEO of the Centro Oceanográfico of A Coruña (A. Carroceda, I. González, M. Quintans y J.L. Torres) who have provided assistance. This work was carried out within the framework of projects SHKLL03, SWOATL and SWOATL0710 of the *Instituto Español de Oceanografía.*

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Table 1. Experimental combination of three different hook types (A1, A2, A3) and two bait types (C1, C2) by set (lance).

	100	100	100	100	100	100	100	100	100	100	100	100	1200
Lance 1	A1 C1	A1 C1	A1 C1	A1 C1	A2 C2	A2 C2	A2 C2	A2 C2	A3 C1	A3 C1	A3 C1	A3 C1	
Lance 2	A1 C2	A1 C2	A1 C2	A1 C2	A2 C1	A2 C1	A2 C1	A2 C1	A3 C2	A3 C2	A3 C2	A3 C2	
Lance 3	A1 C1	A1 C1	A1 C1	A1 C1	A2 C2	A2 C2	A2 C2	A2 C2	A3 C1	A3 C1	A3 C1	A3 C1	
Lance 4	A2 C2	A2 C2	A2 C2	A2 C2	A3 C1	A3 C1	A3 C1	A3 C1	A1 C2	A1 C2	A1 C2	A1 C2	
Lance 5	A2 C1	A2 C1	A2 C1	A2 C1	A3 C2	A3 C2	A3 C2	A3 C2	A1 C1	A1 C1	A1 C1	A1 C1	
Lance 6	A2 C2	A2 C2	A2 C2	A2 C2	A3 C1	A3 C1	A3 C1	A3 C1	A1 C2	A1 C2	A1 C2	A1 C2	
Lance 7	A3 C1	A3 C1	A3 C1	A3 C1	A1 C2	A1 C2	A1 C2	A1 C2	A2 C1	A2 C1	A2 C1	A2 C1	
Lance 8	A3 C2	A3 C2	A3 C2	A3 C2	A1 C1	A1 C1	A1 C1	A1 C1	A2 C2	A2 C2	A2 C2	A2 C2	
Lance 9	A3 C1	A3 C1	A3 C1	A3 C1	A1 C2	A1 C2	A1 C2	A1 C2	A2 C1	A2 C1	A2 C1	A2 C1	
Lance 10	A1 C2	A1 C2	A1 C2	A1 C2	A2 C1	A2 C1	A2 C1	A2 C1	A3 C2	A3 C2	A3 C2	A3 C2	
Lance 11	A1 C1	A1 C1	A1 C1	A1 C1	A2 C2	A2 C2	A2 C2	A2 C2	A3 C1	A3 C1	A3 C1	A3 C1	
Lance 12	A1 C2	A1 C2	A1 C2	A1 C2	A2 C1	A2 C1	A2 C1	A2 C1	A3 C2	A3 C2	A3 C2	A3 C2	
Lance 13	A2 C1	A2 C1	A2 C1	A2 C1	A3 C2	A3 C2	A3 C2	A3 C2	A1 C1	A1 C1	A1 C1	A1 C1	
Lance 14	A2 C2	A2 C2	A2 C2	A2 C2	A3 C1	A3 C1	A3 C1	A3 C1	A1 C2	A1 C2	A1 C2	A1 C2	
Lance 15	A2 C1	A2 C1	A2 C1	A2 C1	A3 C2	A3 C2	A3 C2	A3 C2	A1 C1	A1 C1	A1 C1	A1 C1	
Lance 16	A3 C2	A3 C2	A3 C2	A3 C2	A1 C1	A1 C1	A1 C1	A1 C1	A2 C2	A2 C2	A2 C2	A2 C2	
Lance 17	A3 C1	A3 C1	A3 C1	A3 C1	A1 C2	A1 C2	A1 C2	A1 C2	A2 C1	A2 C1	A2 C1	A2 C1	
Lance 18	A3 C2	A3 C2	A3 C2	A3 C2	A1 C1	A1 C1	A1 C1	A1 C1	A2 C2	A2 C2	A2 C2	A2 C2	
Lance 19	A1 C1	A1 C1	A1 C1	A1 C1	A2 C2	A2 C2	A2 C2	A2 C2	A3 C1	A3 C1	A3 C1	A3 C1	
Lance 20	A1 C2	A1 C2	A1 C2	A1 C2	A2 C1	A2 C1	A2 C1	A2 C1	A3 C2	A3 C2	A3 C2	A3 C2	
Lance 21	A1 C1	A1 C1	A1 C1	A1 C1	A2 C2	A2 C2	A2 C2	A2 C2	A3 C1	A3 C1	A3 C1	A3 C1	
Lance 21	A2 C2	A2 C2	A2 C2	A2 C2	A3 C1	A3 C1	A3 C1	A3 C1	A1 C2	A1 C2	A1 C2	A1 C2	
Lance 22	A2 C1	A2 C1	A2 C1	A2 C1	A3 C2	A3 C2	A3 C2	A3 C2	A1 C1	A1 C1	A1 C1	A1 C1	
Lance 23	A2 C2	A2 C2	A2 C2	A2 C2	A3 C1	A3 C1	A3 C1	A3 C1	A1 C2	A1 C2	A1 C2	A1 C2	

etc...

C1 = bait 1. C2 = bait 6 or 10.

Table 2. Total number of hooks set during the experimental survey in the North and South Atlantic (5º North boundary), by hook type, bait type and zone, as well as average number of hooks by set, total number of sets and total catch of total fish species combined, in dressed weight.

	NORTH ATL.	SOUTH ATL.	TOT. ATL.
HOOK A1 (18/0)	62775	80578	143353
HOOK A2 (17/0)	62897	80576	143473
HOOK A3 (16/0)	62897	80576	143473
BAIT 1 (mackerel)	90851	120834	211685
BAIT 6 (squid)	87717	120896	208613
BAIT 10 (PGO)	10001	0	10001
ZONE 1	85876	0	85876
ZONE 2	38385	0	38385
ZONE 3	38028	0	38028
ZONE 4	26280	119520	145800
ZONE 5	0	122210	122210
AVE _HOOK / SET	1084	1438	1258
TOT_HOOK	188569	241730	430299
TOT_SET	174	168	342
TOT CATCH w	194186	266945	461132

Table 3. Total number of hooks set during the experimental survey, by zone and hook–bait combinations.

		TOT_HOOKS					
		ZONE					
HOOK Type	BAIT Type	1	2	3	4	5	TOTAL
A1	1	13733	6500	6910	22620	20578	70341
	6	12783	5545	4984	25230	20160	68702
	10	2028	750	782	750	0	4310
Total A1		28544	12795	12676	48600	40738	143353
A2	1	14886	4765	5346	24330	20576	69903
	6	12088	7670	6550	24270	20160	70738
	10	1692	360	780	0	0	2832
Total A2		28666	12795	12676	48600	40736	143473
A3	1	13815	7340	5376	24750	20160	71441
	6	13104	4735	6908	23850	20576	69173
	10	1747	720	392	0	0	2859
Total A3		28666	12795	12676	48600	40736	143473
TOTAL		85876	38385	38028	145800	122210	430299

Table 4. Catch in dressed weight (Cw), catch in number (Cn), catch rates in weight (CPUEw), catch rates in number (CPUEn) and average size (Ave_SIZE) obtained for the fish species-groups and sea turtles species, by zone.

	ZONE	1	2	3	4	5
Cw	BIL	4	9	0	7527	16597
	IOO	12803	2295	2744	5102	3413
	OTH	4983	4222	10013	44487	18614
	PGO	34773	25463	16995	51400	15667
	SWO	29134	6906	7896	57140	82947
Cn	BIL	1	1	0	168	183
	IOO	891	160	148	92	73
	OTH	364	268	1097	1442	765
	PGO	3802	3108	790	2004	774
	SWO	1489	372	360	1812	2371
	CAT	151	4	16	0	2
	DER	30	15	24	153	13
	LOL	0	0	0	27	0
CPUEw	BIL	0,05	0,23	0,00	51,62	135,81
	IOO	149,08	59,78	72,16	34,99	27,93
	OTH	58,02	109,99	263,31	305,13	152,31
	PGO	404,92	663,36	446,91	352,54	128,20
	SWO	339,25	179,91	207,64	391,91	678,73
CPUEn	BIL	0,01	0,03	0,00	1,15	1,50
	IOO	10,38	4,17	3,89	0,63	0,60
	OTH	4,24	6,98	28,85	9,89	6,26
	PGO	44,27	80,97	20,77	13,74	6,33
	SWO	17,34	9,69	9,47	12,43	19,40
	CAT	1,758	0,104	0,421	0,000	0,016
	DER	0,349	0,391	0,631	1,049	0,106
	LOL	0,000	0,000	0,000	0,185	0,000
Ave_SIZE	BIL	130	155	—	190	225
	IOO	123	122	129	189	180
	OTH	115	113	98	125	130
	PGO	150	149	206	209	193
	SWO	125	122	130	144	149
	CAT	59	79	52	—	39
	DER	181	191	145	117	117
	LOL	—	—	—	76	—

Table 5. Qualitative comparison of the nominal catch rates within species, in weight for the fish species–groups and in number for sea turtle species, by zone. (+: low rate, ++: intermediate rate; +++: high rate; NC= no catch).

	Species :	SWO	PGO	IOO	BIL	CAT	DER	LOL
CPUE Zone	1	++	++	+++	+	+++	++	NC
	2	+	+++	++	+	++	++	NC
	3	++	++	++	NC	++	++	NC
	4	++	++	++	++	NC	+++	+++
	5	+++	+	+	+++	+	+	NC

Table 6. Catch in dressed weight (Cw), catch in number (Cn), catch rates in weight (CPUEw), catch rates in number (CPUEn) and average size (Ave_SIZE) obtained for the fish species–groups and sea turtles species, by hook type.

	HOOK TYPE	A1	A2	A3
Cw	BIL	9207	8006	6924
	IOO	7751	8559	10046
	OTH	26741	26611	28968
	PGO	46718	50367	47213
	SWO	62106	58719	63197
Cn	BIL	113	121	119
	IOO	389	481	494
	OTH	1169	1439	1328
	PGO	3282	3825	3371
	SWO	2150	2082	2172
	CAT	38	48	87
	DER	91	67	77
	LOL	8	9	10
CPUEw	BIL	64,23	55,80	48,26
	IOO	54,07	59,65	70,02
	OTH	186,54	185,48	201,90
	PGO	325,89	351,06	329,07
	SWO	433,24	409,27	440,48
CPUEn	BIL	0,79	0,84	0,83
	IOO	2,71	3,35	3,44
	OTH	8,15	10,03	9,26
	PGO	22,89	26,66	23,50
	SWO	15,00	14,51	15,14
	CAT	0,27	0,33	0,61
	DER	0,63	0,47	0,54
	LOL	0,06	0,06	0,07
Ave_SIZE	BIL	218	206	199
	IOO	218	128	131
	OTH	114	113	119
	PGO	164	159	163
	SWO	139	138	140
	CAT	61	58	59
	DER	131	132	133
	LOL	82	82	76

Table 7. Qualitative comparison of the nominal catch rates within species, in weight for the fish species–groups and in number for sea turtles species, by hook type. (+: low rate, ++: intermediate rate: +++: high rate)

	Species:	SWO	PGO	IOO	BIL	CAT	DER	LOL
CPUE Hook	A1	++	+	+	+++	+	+++	+
	A2	+	+++	++	++	++	+	+
	A3	+++	++	+++	+	+++	++	++

Table 8. Catch in dressed weight (Cw), catch in number (Cn), catch rates in weight (CPUEw), catch rates in number (CPUEn) and average size (Ave_SIZE) obtained for the fish species–groups and sea turtles species, by bait type.

	BAIT TYPE	1	6	10
Cw	BIL	12274	11863	0
	IOO	17115	9036	205
	OTH	34222	47366	731
	PGO	75123	67887	1288
	SWO	93906	88350	1767
Cn	BIL	190	163	0
	IOO	946	407	11
	OTH	1664	2217	55
	PGO	5407	4975	96
	SWO	3268	3046	90
	CAT	38	128	7
	DER	121	109	5
	LOL	4	23	0
CPUEw	BIL	57,98	56,87	0,00
	IOO	80,85	43,31	20,50
	OTH	161,67	227,05	73,08
	PGO	354,88	325,42	128,79
	SWO	443,61	423,51	176,68
CPUEn	BIL	0,90	0,78	0,00
	IOO	4,47	1,95	1,10
	OTH	7,86	10,63	5,50
	PGO	25,54	23,85	9,60
	SWO	15,44	14,60	9,00
	CAT	0,18	0,61	0,70
	DER	0,57	0,52	0,50
	LOL	0,02	0,11	0,00
Ave_SIZE	BIL	205	211	–
	IOO	127	135	133
	OTH	119	113	110
	PGO	162	161	161
	SWO	139	139	125
	CAT	58	59	58
	DER	133	129	182
	LOL	80	78	–

Table 9. Qualitative comparison of nominal catch rates within species-group, in weight for the fish species–groups and in number for sea turtles species, by bait type. (+: low rate, ++: intermediate rate; +++: high rate; NC= no catch).

	Species:	SWO	PGO	IOO	BIL	CAT	DER	LOL
CPUE Bait	1	+++	+++	+++	+++	+	+++	+
	6	++	++	++	+	++	++	+++
	10	+	+	+	NC	+++	+	NC

Table 10. Gains and losses (%) of catch rates in weight and number for ach species–group and hook type tested –A1 (semicircular) and A2 (circler)– as compared to the conventional reference hook type A3 (J) used by the Spanish fleet.

	HOOK TYPE			
	CPUEw		CPUEn	
SPECIES	**A1**	**A2**	**A1**	**A2**
BIL	33,1	15,6	-5	2
IOO	-22,8	-14,8	-21	-3
OTH	-7,6	-8,1	-12	8
PGO	-1,0	6,7	-3	13
SWO	-1,6	-7,1	-1	-4
CAT	-	-	-56	-45
DER	-	-	18	-13
LOL	-	-	-20	-10

Table 11. Qualitative comparison among catch rates within each species–group, in weight for the fish species–groups and in number for sea turtle species, by hook type tested in relation to the hook of reference (A3). (–: yield below reference , +: yield above reference).

	Species:	SWO	PGO	IOO	BIL	CAT	DER	LOL
CPUE Hook	A1	-	-	-	+	-	+	-
	A2	-	+	-	+	-	-	-
	A3	ref	ref	ref	ref	ref	ref	ref

Table 12. Gains and losses (%) of catch rates in weight and number for each of the species–groups and bait type: mackerel (1), squid (6), blue shark (10). (NC= no catch).

	BAIT TYPE			
	CPUEw		CPUEn	
SPECIES	**6**	**10**	**6**	**10**
BIL	-2	NC	-13	NC
IOO	-46	-75	-56	-75
OTH	40	-55	35	-30
PGO	-8	-64	-7	-62
SWO	-5	-60	-5	-42
CAT	-	-	242	290
DER	-	-	-9	-13
LOL	-	-	483	NC

Table 13. Qualitative comparison among catch rates within each species–group, in weight for the fish species–groups and in number for sea turtle species, by bait type tested in relation to the bait of reference (type 1). (–: yield below reference , +: yield above reference, NC= no catch).

	Species:	SWO	PGO	IOO	BIL	CAT	DER	LOL
CPUE Bait	1	ref	ref	ref	ref	ref	ref	ref
	6	-	-	-	-	+	-	+
	10	-	-	-	NC	+	-	NC

Table 14. Gains and losses (%) of catch rates in weight and number for each of the species-groups and hook type (A1, A2, A3) and bait type (1, 2), in relation to the combination of reference (ref:A3/1). (NC= no catch).

	HOOK + BAIT				
	CPUEW				
HOOK+ BAIT/SPECIES	BIL	IOO	OTH	PGO	SWO
A1/1	30	-15	-11	1	7
A1/6	49	-61	27	-11	-6
A1/10	NC	-68	-45	-77	-73
A2/1	36	-9	-14	3	-5
A2/6	3	-52	27	-1	-8
A2/10	NC	-90	-79	-42	-53
A3/1	**ref**	**ref**	**ref**	**ref**	**ref**
A3/6	7	-39	32	-10	2
A3/10	NC	-77	-58	-64	-46

	HOOK + BAIT							
	CPUEn							
HOOK+ BAIT/SPECIES	BIL	IOO	OTH	PGO	SWO	CAT	DER	LOL
A1/1	-16	-15	-7	-1	12	2	18	-66
A1/6	-6	-69	11	-19	-6	146	26	143
A1/10	NC	-70	-22	-80	-62	51	-56	NC
A2/1	12	-1	0	-4	1	49	5	NC
A2/6	-22	-55	52	11	-4	194	-26	203
A2/10	NC	-85	-47	-35	-31	NC	NC	NC
A3/1	**ref**	**ref**	**ref**	**ref**	**ref**	**ref**	**ref**	**ref**
A3/6	-14	-53	32	-17	5	557	-5	141
A3/10	NC	-78	-30	-65	-13	1263	163	NC

Table 15. Qualitative comparison among catch rates within each species–group, in weight for the fish species–groups and in number for sea turtle species, by hook–bait combinations in relation to the combination of reference (ref:A3/1). (–: yield below reference , +: yield above reference, NC= no catch).

	Species :	SWO	PGO	IOO	BIL	CAT	DER	LOL
Hook/Bait	A1/1	+	+	-	+	+	+	-
	A1/6	-	-	-	+	+	+	+
	A1/10	-	-	-	NC	+	-	NC
	A2/1	-	+	-	+	+	+	NC
	A2/6	-	-	-	+	+	-	+
	A2/10	-	-	-	NC	NC	NC	NC
	A3/1	ref	ref	ref	ref	ref	ref	ref
	A3/6	+	-	-	+	+	-	+
	A3/10	-	-	-	NC	+	+	NC

Table 16. Results of the statistical significance (confidence interval 90%) of each factor considered in the preliminary GLM obtained on the basis of CPUE observations recorded for each factor during each set. Hook (A1, A2, A3), baits (1,6,) and interactions. Superindice 1 to 4 indicate the importance, from high to low, of each factor considered to be significant (in accordance with type III SS).

		Species							
Factor	***Levels***	***SWO***	***PGO***	***IOO***	***BIL***	***OTH***	***CAT***	***DER***	***LOL***
Hook type	A_1,A_2,A_3	no	no	yes^4	no	no	no	no	no
Bait type	1, 6	no	no	yes^2	no	yes^3	yes^4	no	no
Zone	1,2,3,4,5	yes	yes	yes^1	yes	yes^1	yes^1	yes^1	yes^1
Hook*bait	Interaction	no	no	no	no	no	no	no	no
Bait*zone	Interaction	no	no	yes^3	no	yes^2	yes^2	no	yes^2
Hook*zone	Interaction	no	no	no	no	no	no	no	no
Hook*bait*zone	Interaction	no	no	no	no	no	yes^3	no	no

Table 17. Standardized mean CPUEs by species obtained using GLM (in weight for fishes and in number for turtles) for each of the principal factors. Gains and losses in percentage (ratio%) in relation to the type factor of reference (ref). Note that many of the factors were not statistically significant at the 90% level (see table 16 for more detail).

Species	*Factor*	*Type*	*Stand CPUE*	*Ratio%*	*Species*	*Factor*	*Type*	*Stand CPUE*	*Ratio%*
SWO	THOOK	A1	170,35	-6,70	OTH	THOOK	A1	40,14	-10,62
SWO	THOOK	A2	155,50	-14,83	OTH	THOOK	A2	40,77	-9,20
SWO	THOOK	A3	182,58	ref	OTH	THOOK	A3	44,90	ref
SWO	TBAIT	1	166,13	ref	OTH	TBAIT	1	32,92	ref
SWO	TBAIT	6	171,50	3,23	OTH	TBAIT	6	52,97	60,91
SWO	ZONE	1	197,92	-60,69	OTH	ZONE	1	9,94	-85,46
SWO	ZONE	2	65,41	-87,01	OTH	ZONE	2	11,81	-82,73
SWO	ZONE	3	142,82	-71,63	OTH	ZONE	3	120,11	75,69
SWO	ZONE	4	150,49	-70,11	OTH	ZONE	4	125,22	83,16
SWO	ZONE	5	503,43	ref	OTH	ZONE	5	68,37	ref
PGO	THOOK	A1	198,66	6,04	CAT	THOOK	A1	0,43	-19,42
PGO	THOOK	A2	222,03	18,51	CAT	THOOK	A2	0,50	-6,51
PGO	THOOK	A3	187,35	ref	CAT	THOOK	A3	0,53	ref
PGO	TBAIT	1	205,23	ref	CAT	TBAIT	1	0,27	ref
PGO	TBAIT	6	198,43	-3,31	CAT	TBAIT	6	0,74	178,21
PGO	ZONE	1	275,42	323,24	CAT	ZONE	1	2,89	13516,30
PGO	ZONE	2	619,24	851,60	CAT	ZONE	2	0,17	692,15
PGO	ZONE	3	257,37	295,51	CAT	ZONE	3	0,57	2574,62
PGO	ZONE	4	119,52	83,67	CAT	ZONE	4	NC	NC
PGO	ZONE	5	65,07	ref	CAT	ZONE	5	0,02	ref
IOO	THOOK	A1	6,48	-43,21	DER	THOOK	A1	1,66	28,34
IOO	THOOK	A2	7,43	-34,92	DER	THOOK	A2	1,32	2,05
IOO	THOOK	A3	11,41	ref	DER	THOOK	A3	1,29	ref
IOO	TBAIT	1	12,08	ref	DER	TBAIT	1	1,54	ref
IOO	TBAIT	6	5,46	-54,83	DER	TBAIT	6	1,29	-15,75
IOO	ZONE	1	47,13	2081,88	DER	ZONE	1	1,23	229,53
IOO	ZONE	2	12,54	480,36	DER	ZONE	2	0,81	116,24
IOO	ZONE	3	10,11	368,13	DER	ZONE	3	2,43	551,28
IOO	ZONE	4	1,99	-7,83	DER	ZONE	4	3,50	835,07
IOO	ZONE	5	2,16	ref	DER	ZONE	5	0,37	ref
BIL	THOOK	A1	1,13	4,77	LOL	THOOK	A1	0,04	-41,39
BIL	THOOK	A2	1,23	13,75	LOL	THOOK	A2	0,05	-31,64
BIL	THOOK	A3	1,08	ref	LOL	THOOK	A3	0,07	ref
BIL	TBAIT	1	1,23	ref	LOL	TBAIT	1	0,02	ref
BIL	TBAIT	6	1,06	-14,48	LOL	TBAIT	6	0,09	301,05
BIL	ZONE	1	0,02	-99,80	LOL	ZONE	1	NC	NC
BIL	ZONE	2	0,05	-99,48	LOL	ZONE	2	NC	NC
BIL	ZONE	3	NC	NC	LOL	ZONE	3	NC	NC
BIL	ZONE	4	3,36	-62,22	LOL	ZONE	4	0,31	NA
BIL	ZONE	5	8,89	ref	LOL	ZONE	5	NC	NC

NC= catch not observed. NA = data not available.

Table 18. Mean standardized CPUEs by species observed using GLM (in weight for fishes and in number for turtles) for the hook∗bait interactions and gains or losses in percentage (ratio%) of each combination in relation to the combination of reference (ref). Note that this interaction was not statistically significant at the 90% level in some of the species (see table 16 for more detail).

Species	***Factor***	***Type***	***Stand CPUE***	***Ratio%***	***Species***	***Factor***	***Type***	***Stand CPUE***	***Ratio%***
SWO	HOOK*BAIT	A1*1	189.72	13.76	OTH	HOOK*BAIT	A1*1	32.90	-12.19
SWO	HOOK*BAIT	A1*6	154.72	-7.23	OTH	HOOK*BAIT	A1*6	49.63	32.45
SWO	HOOK*BAIT	A2*1	148.22	-11.12	OTH	HOOK*BAIT	A2*1	29.78	-20.52
SWO	HOOK*BAIT	A2*6	165.02	-1.05	OTH	HOOK*BAIT	A2*6	56.51	50.82
SWO	HOOK*BAIT	A3*1	166.77	ref	OTH	HOOK*BAIT	A3*1	37.47	ref
SWO	HOOK*BAIT	A3*6	202.16	21.22	OTH	HOOK*BAIT	A3*6	54.56	45.61
PGO	HOOK*BAIT	A1*1	201.13	-3.49	CAT	HOOK*BAIT	A1*1	0.31	66.74
PGO	HOOK*BAIT	A1*6	198.44	-4.78	CAT	HOOK*BAIT	A1*6	0.57	205.02
PGO	HOOK*BAIT	A2*1	210.85	1.17	CAT	HOOK*BAIT	A2*1	0.32	72.22
PGO	HOOK*BAIT	A2*6	236.44	13.45	CAT	HOOK*BAIT	A2*6	0.71	280.83
PGO	HOOK*BAIT	A3*1	208.41	ref	CAT	HOOK*BAIT	A3*1	0.19	ref
PGO	HOOK*BAIT	A3*6	170.29	-18.29	CAT	HOOK*BAIT	A3*6	0.99	432.66
IOO	HOOK*BAIT	A1*1	10.90	-35.90	DER	HOOK*BAIT	A1*1	1.60	-14.81
IOO	HOOK*BAIT	A1*6	3.79	-77.73	DER	HOOK*BAIT	A1*6	1.78	-4.96
IOO	HOOK*BAIT	A2*1	9.81	-42.30	DER	HOOK*BAIT	A2*1	1.27	-32.16
IOO	HOOK*BAIT	A2*6	5.68	-66.56	DER	HOOK*BAIT	A2*6	1.42	-24.35
IOO	HOOK*BAIT	A3*1	17.00	ref	DER	HOOK*BAIT	A3*1	1.87	ref
IOO	HOOK*BAIT	A3*6	7.71	-54.66	DER	HOOK*BAIT	A3*6	0.87	-53.73
BIL	HOOK*BAIT	A1*1	1.06	-13.06	LOL	HOOK*BAIT	A1*1	0.02	-58.90
BIL	HOOK*BAIT	A1*6	1.24	1.49	LOL	HOOK*BAIT	A1*6	0.07	39.97
BIL	HOOK*BAIT	A2*1	1.50	23.15	LOL	HOOK*BAIT	A2*1	NC	NC
BIL	HOOK*BAIT	A2*6	1.02	-16.84	LOL	HOOK*BAIT	A2*6	0.10	111.57
BIL	HOOK*BAIT	A3*1	1.22	ref	LOL	HOOK*BAIT	A3*1	0.05	ref
BIL	HOOK*BAIT	A3*6	0.98	-19.83	LOL	HOOK*BAIT	A3*6	0.10	106.38

NC= catch not observed.

Table 19. Number and percentage of sea turtles released alive or discarded dead, by species, hook and bait types (NC = no catch). Note: Bait 10 was only used in some North Atlantic sets.

Hook type	*Bait type*	*Data /Species*	*CAT*	*DER*	*LOL*	*Total*
1	1	Number alive	8	43	0	51
		Number dead	3	1	1	5
		Total number	11	44	1	56
		% alive	72.7	97.7	0.0	91.1
		% dead	27.3	2.3	100.0	8.9
	6	Number alive	25	42	2	69
		Number dead	1	4	5	10
		Total number	26	46	7	79
		% alive	96.2	91.3	28.6	87.3
		% dead	3.8	8.7	71.4	12.7
	10	Number alive	1	1	NC	2
		Number dead	0	0	NC	0
		Total number	1	1	NC	2
		% alive	100.0	100.0	NC	100.0
		% dead	0.0	0.0	NC	0.0
2	1	Number alive	16	37	NC	53
		Number dead	0	2	NC	2
		Total number	16	39	NC	55
		% alive	100.0	94.9	NC	96.4
		% dead	0.0	5.1	NC	3.6
	6	Number alive	30	27	6	63
		Number dead	2	1	3	6
		Total number	32	28	9	69
		% alive	93.8	96.4	66.7	91.3
		% dead	6.3	3.6	33.3	8.7
	10	Number alive	NC	NC	NC	NC
		Number dead	NC	NC	NC	NC
		Total number	NC	NC	NC	NC
		% alive	NC	NC	NC	NC
		% dead	NC	NC	NC	NC
3	1	Number alive	11	38	3	52
		Number dead	0	0	0	0
		Total number	11	38	3	52
		% alive	100.0	100.0	100.0	100.0
		% dead	0.0	0.0	0.0	0.0
	6	Number alive	68	34	4	106
		Number dead	2	1	3	6
		Total number	70	35	7	112
		% alive	97.1	97.1	57.1	94.6
		% dead	2.9	2.9	42.9	5.4
	10	Number alive	6	4	NC	10
		Number dead	0	0	NC	0
		Total number	6	4	NC	10
		% alive	100.0	100.0	NC	100.0
		% dead	0.0	0.0	NC	0.0

Table 20. Prevalence (%) of each hook location within each sea turtle species and sea turtles species combined.

Location	%CAT	%DER	%LOL	% TOT
Flipper	8,1	81,8	7,4	45,7
Mouth	78,0	5,7	66,7	40,3
Entangled	1,2	9,1	0	5,1
Esophagus	9,2	0	25,9	5,6
Stomach	1,2	0	0	0,5
Other	2,3	3,3	0	2,7

Table 21. Prevalence (%) of each hook locations by hook type and sea turtles species combined.

Loc. / Hook	A1	A2	A3
Flipper	18,1	13,1	15,1
Mouth	8,2	12,6	18,8
Entangled	2,0	1,5	1,7
Esophagus	0,7	0,5	4,5
Stomach	0,2	0,2	0
Other	1,2	0,5	1,0

Table 22. Prevalence (%) of each hook location within each sea turtle species and turtles combined, by hook type.

Location	Hook type	%CAT	%DER	%LOL	%TOR
Flipper	A 1	2,4	32,5	4,2	18,1
Mouth	A 1	15,3	1,9	12,5	8,2
Entangled	A 1	0,6	3,3	0	2,0
Esophagus	A 1	0,6	0	8,3	0,7
Stomach	A 1	0,6	0	0	0,2
Other	A 1	1,2	1,4	0	1,2
Flipper	A 2	3,5	22,0	4,2	13,1
Mouth	A 2	22,9	2,4	29,2	12,6
Entangled	A 2	0	2,9	0,0	1,5
Esophagus	A 2	0,6	0	4,2	0,5
Stomach	A 2	0,6	0	0	0,2
Other	A 2	0,6	0,5	0	0,5
Flipper	A 3	2,4	27,3	0	15,1
Mouth	A 3	39,4	1,4	20,8	18,8
Entangled	A 3	0,6	2,9	0	1,7
Esophagus	A 3	8,2	0	16,7	4,5
Stomach	A 3	0	0	0	0
Other	A 3	0,6	1,4	0	1,0

Table 23. Prevalence (%) of each hook location by bait type for the species of turtles combined.

Loc. / Bait type	1	6	10
Flipper	22,5	22,2	1,0
Mouth	9,8	29,3	1,2
Entangled	2,2	2,7	0,2
Esophagus	0,7	4,6	0,2
Stomach	0,2	0,2	0
Other	1,2	1,5	0

Table 24. Prevalence (%) of the hook locations within each sea turtle species by bait type.

Location	Bait type	%CAT	%DER	%LOL
Flipper	Mackerel	1,7	42,6	0
Mouth	Mackerel	16,2	3,8	14,8
Entangled	Mackerel	0,6	3,8	0
Esophagus	Mackerel	1,7	0	0
Stomach	Mackerel	0,6	0	0
Other	Mackerel	1,2	1,4	0
Flipper	Squid	6,4	37,3	7,4
Mouth	Squid	59,0	1,9	51,9
Entangled	Squid	0	5,3	0
Esophagus	Squid	6,9	0	25,9
Stomach	Squid	0,6	0	0
Other	Squid	1,2	1,9	0
Flipper	PGO	0	1,9	0
Mouth	PGO	2,9	0	0
Entangled	PGO	0,6	0	0
Esophagus	PGO	0,6	0	0
Stomach	PGO	0	0	0
Other	PGO	0	0	0

Table 25. Prevalence (%) of the hook location within each sea turtle species and species combined, for each combination hook*bait used.

Location	Hook/Bait	CAT	DER	LOL	TOT. TOR.
Flipper	A1/1	0,6	15,8	0	8,3
Mouth	A1/1	3,5	1,4	3,7	2,5
Entangled	A1/1	0,6	1,0	0	0,7
Esophagous	A1/1	0	0	0	0
Stomach	A1/1	0,6	0	0	0,2
Other	A1/1	0,6	0,5	0	0,5
Flipper	A1/6	1,7	16,3	3,7	9,3
Mouth	A1/6	13,3	0,5	14,8	6,6
Entangled	A1/6	0	2,4	0	1,2
Esophagous	A1/6	0,6	0	7,4	0,7
Stomach	A1/6	0	0	0	0
Other	A1/6	0,6	1,0	0	0,7
Flipper	A1/10	0	0,5	0	0,2
Mouth	A1/10	0,6	0	0	0,2
Entangled	A1/10	0	0	0	0
Esophagous	A1/10	0	0	0	0
Stomach	A1/10	0	0	0	0
Other	A1/10	0	0	0	0
Flipper	A2/1	0,6	12,9	0	6,9
Mouth	A2/1	8,1	1,4	0	4,2
Entangled	A2/1	0	1,4	0	0,7
Esophagous	A2/1	0	0	0	0
Stomach	A2/1	0	0	0	0
Other	A2/1	0,6	0	0	0,2
Flipper	A2/6	2,9	9,1	3,7	6,1
Mouth	A2/6	13,9	1,0	25,9	8,1
Entangled	A2/6	0	1,4	0	0,7
Esophagous	A2/6	0,6	0	3,7	0,5
Stomach	A2/6	0,6	0	0	0,2
Other	A2/6	0	0,5	0	0,2
Flipper	A2/10	0	0	0	0
Mouth	A2/10	0	0	0	0
Entangled	A2/10	0	0	0	0
Esophagous	A2/10	0	0	0	0
Stomach	A2/10	0	0	0	0
Other	A2/10	0	0	0	0
Flipper	A3/1	0,6	13,9	0	7,4
Mouth	A3/1	4,0	1,0	11,1	2,9
Entangled	A3/1	0	1,4	0	0,7
Esophagous	A3/1	1,7	0	0	0,7
Stomach	A3/1	0	0	0	0
Other	A3/1	0	1,0	0	0,5
Flipper	A3/6	1,7	12,0	0	6,9
Mouth	A3/6	32,4	0,5	11,1	14,7
Entangled	A3/6	0	1,4	0	0,7
Esophagous	A3/6	5,8	0	14,8	3,4
Stomach	A3/6	0	0	0	0
Other	A3/6	0,6	0,5	0	0,5
Flipper	A3/10	0	1,4	0	0,7
Mouth	A3/10	2,3	0	0	1,0
Entangled	A3/10	0,6	0	0	0,2
Esophagous	A3/10	0,6	0	0	0,2
Stomach	A3/10	0	0	0	0
Other	A3/10	0	0	0	0

Table 26. Accumulated prevalence (%) of hook location in turtles, classified as external hooking (flipper+mouth+entangled) and internal hooking (esophagous+stomach) resulting from the different combinations of hook types A1, A2, A3 (semicircular, circle and straight) and bait types 1 and 6 (mackerel and squid) and the differences found between the respective combinations, according to data summarized from table 25 (see **Figure 18**).

Hook/bait	***Hooked***	***CAT%***	***DER%***	***LOL%***	***Total%***
A1/1	external	4.7	**18.2**	3.7	**11.5**
A1/1	internal	0.6	0.0	0.0	0.2
A1/6	external	**15.0**	**19.2**	**18.2**	17.1
A1/6	internal	0.6	0.0	7.4	0.7
A2/1	external	8.7	**15.7**	0.0	**11.8**
A2/1	internal	0.0	0.0	0.0	0.0
A2/6	external	**16.8**	**11.5**	**29.6**	14.9
A2/6	internal	1.2	0.0	3.7	0.7
A3/1	external	4.6	**16.3**	**11.1**	**11.0**
A3/1	internal	1.7	0.0	0.0	0.7
A3/6	external	**34.1**	**13.9**	**11.1**	**22.3**
A3/6	internal	5.8	0.0	**14.8**	3.4
(A1/6)-(A1/1)	external	+**10.3**	+1.0	**+14.8**	+5.6
(A1/6)-(A1/1)	internal	0.0	0.0	+7.4	+0.5
(A2/6)-(A2/1)	external	+8.1	-4.2	**+29.6**	+3.1
(A2/6)-(A2/1)	internal	+1.2	0.0	+3.7	+0.7
(A1/1)-(A3/1)	external	+0.1	+1.9	-7.4	+0.5
(A1/1)-(A3/1)	internal	-1.1	0.0	0.0	-0.5
(A2/1)-(A3/1)	external	+4.1	-0.6	***-11.1***	+0.8
(A2/1)-(A3/1)	internal	-1.7	0.0	0.0	-0.7
(A1/6)-(A3/1)	external	**+10.4**	+2.9	+7.4	+6.1
(A1/6)-(A3/1)	internal	-1.1	0.0	+7.4	0.0
(A2/6)-(A3/1)	external	**+12.2**	-4.8	**+18.5**	+3.9
(A2/6)-(A3/1)	internal	-0.5	0.0	+3.7	0.0
(A3/6)-(A3/1)	external	+**29.5**	-2.4	0.0	**+11.3**
	internal	+4.1	0.0	**+14.8**	+2.7

Note: Values and differences greater than or equal to +10% are shown in boldface. Values and differences less than or equal to –10% are shown in boldface italics

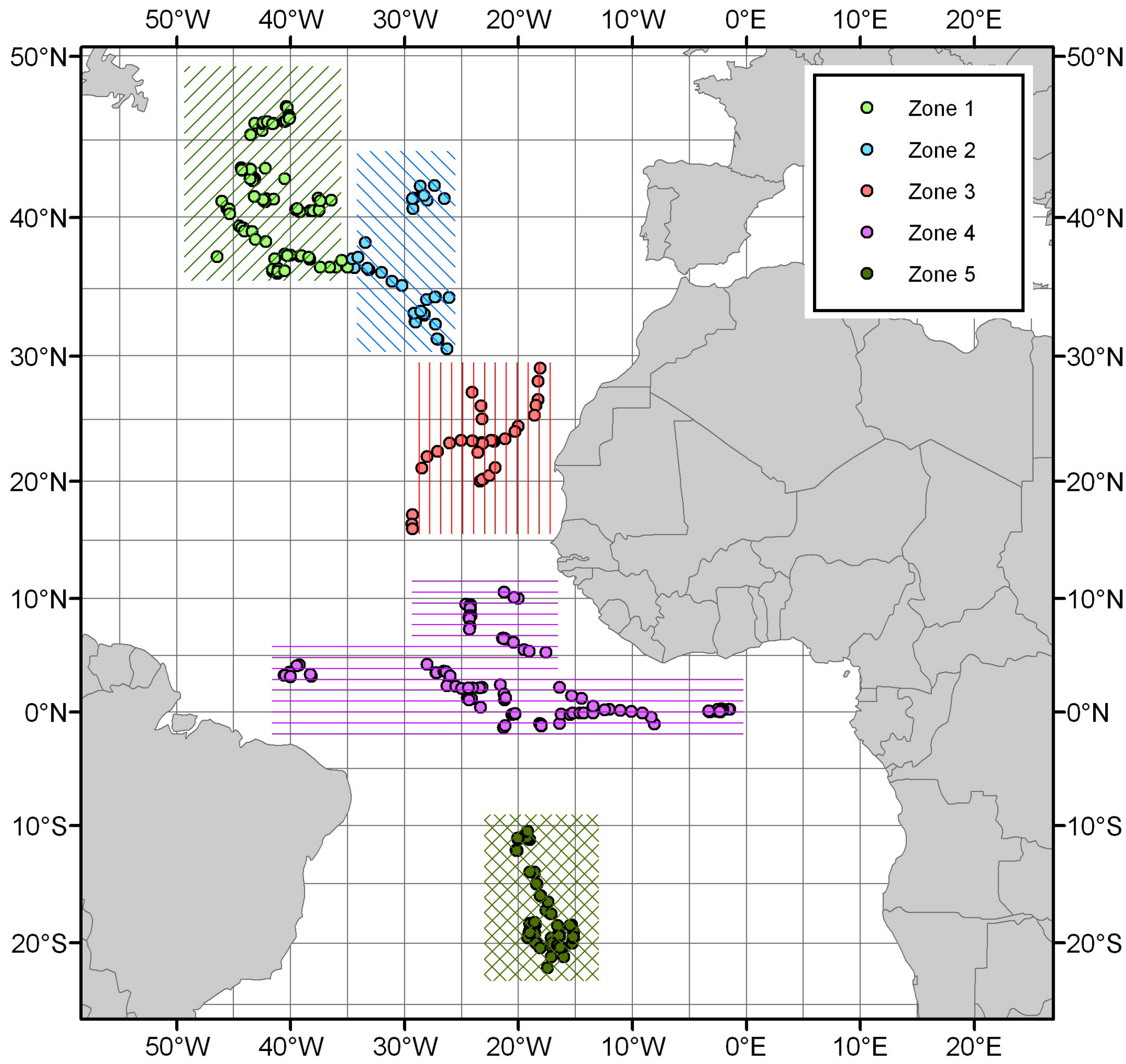


Figure 1. Map of the fishing areas in the North and South Atlantic where the sets were carried out (dots) and definition of the five zones considered in the analyses (striped).

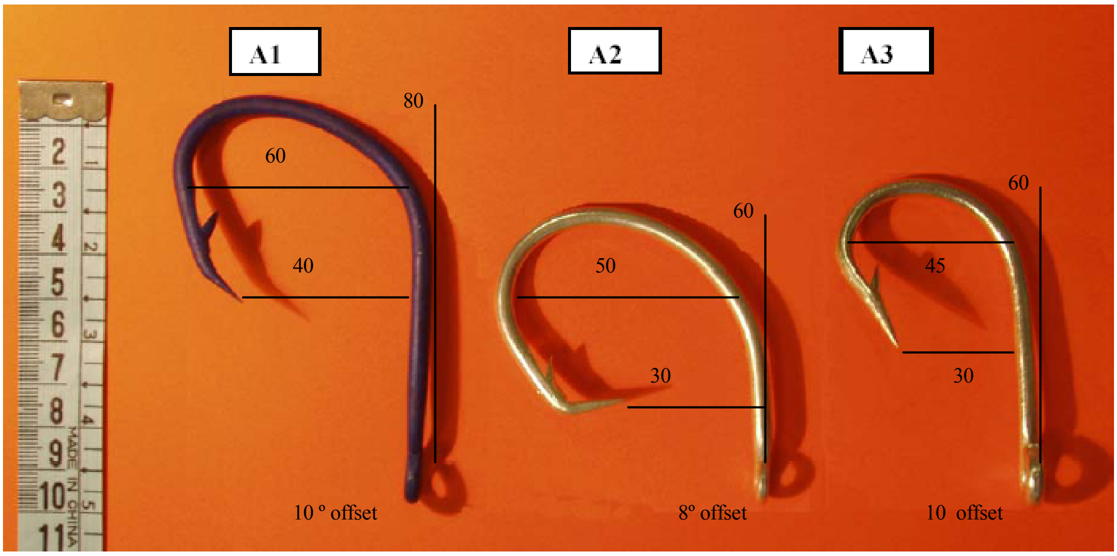


Figure 2. Three types of hooks tested during the survey, sizes (mm) and offset (degrees). ***A1***: the new semicircular “SG” hook 18/O (10 º offset) = 80 – 60 – 40 and blue in colour (as proposed by the fleet itself). ***A2***: Circle “G” hook 17/O (8º offset) = 60 – 50 – 30. ***A3***: Conventional “J” hook 16/O (10 º offset) “J” = 60 – 45 – 30.

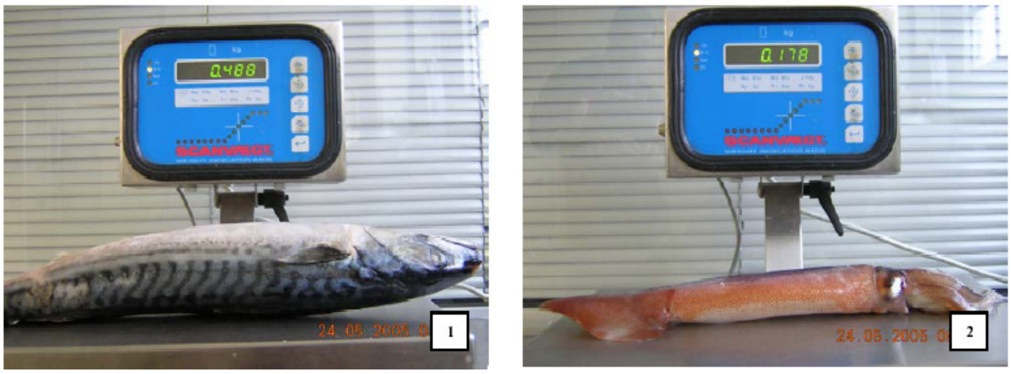


Figure 3. Weight of the two main baits tested during the survey. Bait 1: mackerel weighing about 500 g (Scomber spp.). Bait 6: Squid weighing about 200g (Illex spp.).

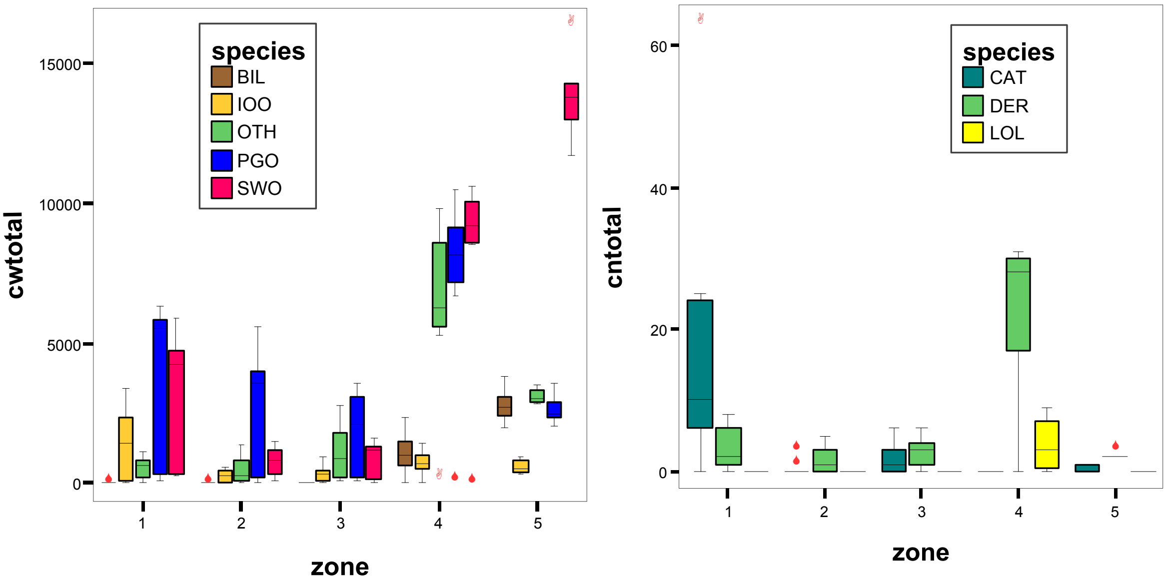


Figure 4. Box-plots of the observations recorded by zone. Catch in weight (kg DW) of the different fish species (left) and catches in number of turtles (only positive records included in this plot), (right panel).

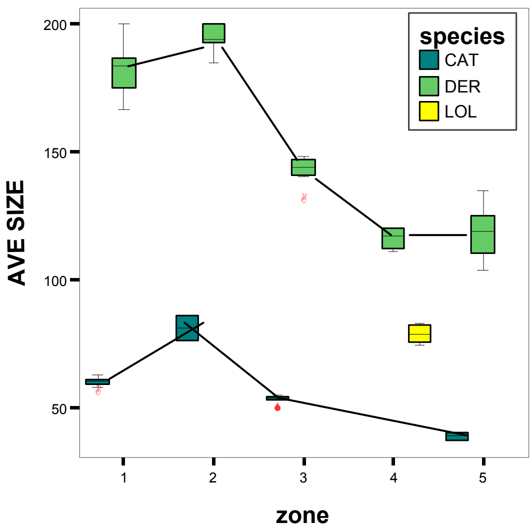


Figure 5. Mean size (cm) of sea turtle species found to interact with the longline by zone. Note: LOL species was only detected in zone=4.

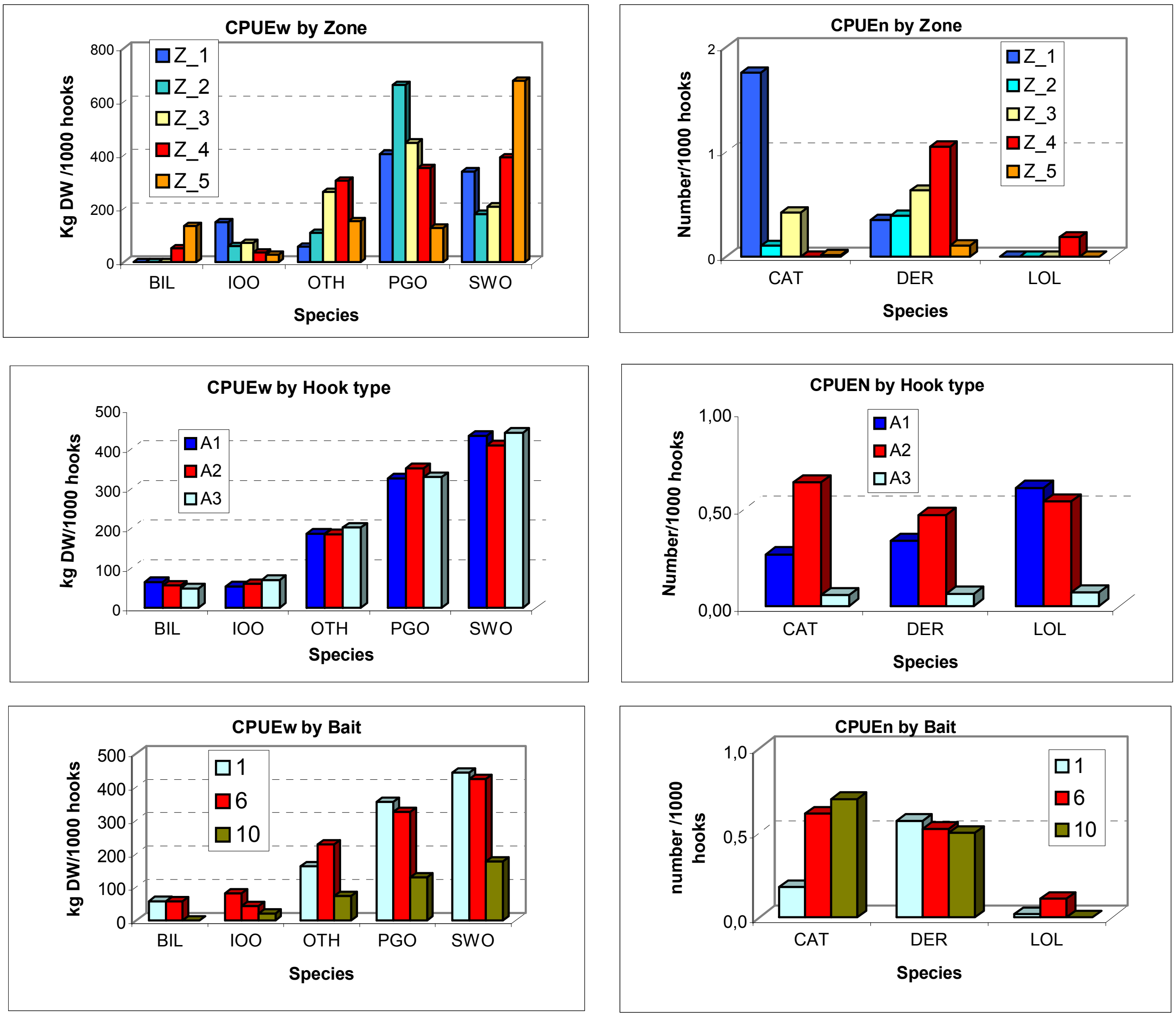


Figure 6. Nominal catch rates (CPUE) recorded during the experiment, expressed in weight kg DW – dressed weight– (CPUEw) for fish species and number of individuals (CPUEn) for turtle species by zone (upper panels), hook type (central panels) and bait type (lower panels).

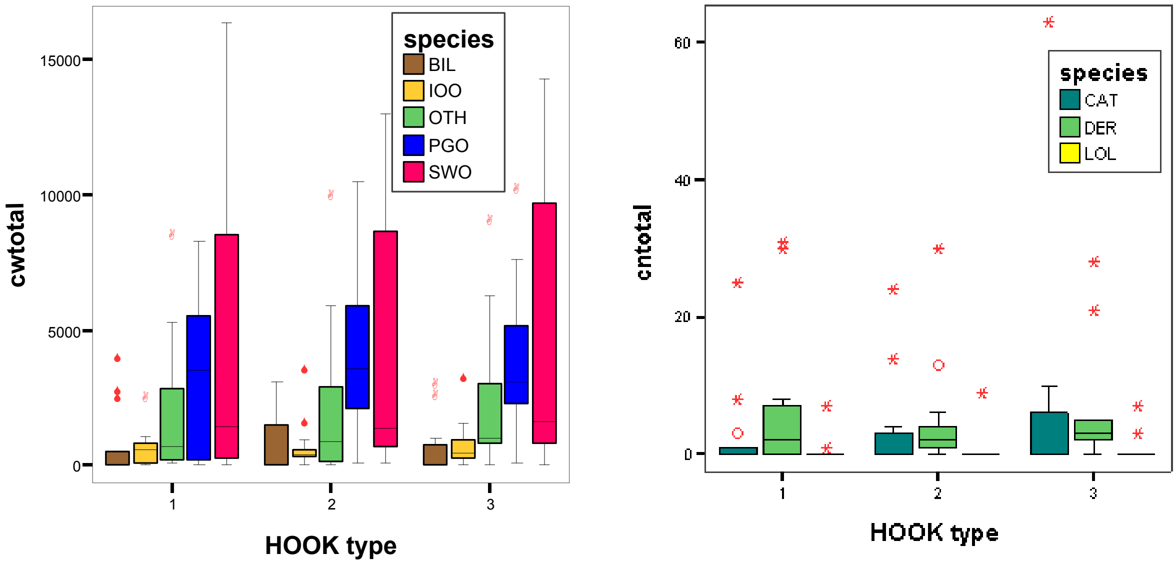


Figure 7. Box-plots of the observations recorded by hook type. Catches in weight (kg DW) of the different fish species (left) and catches in number of turtles (only positive records included in this plot), (right panel).

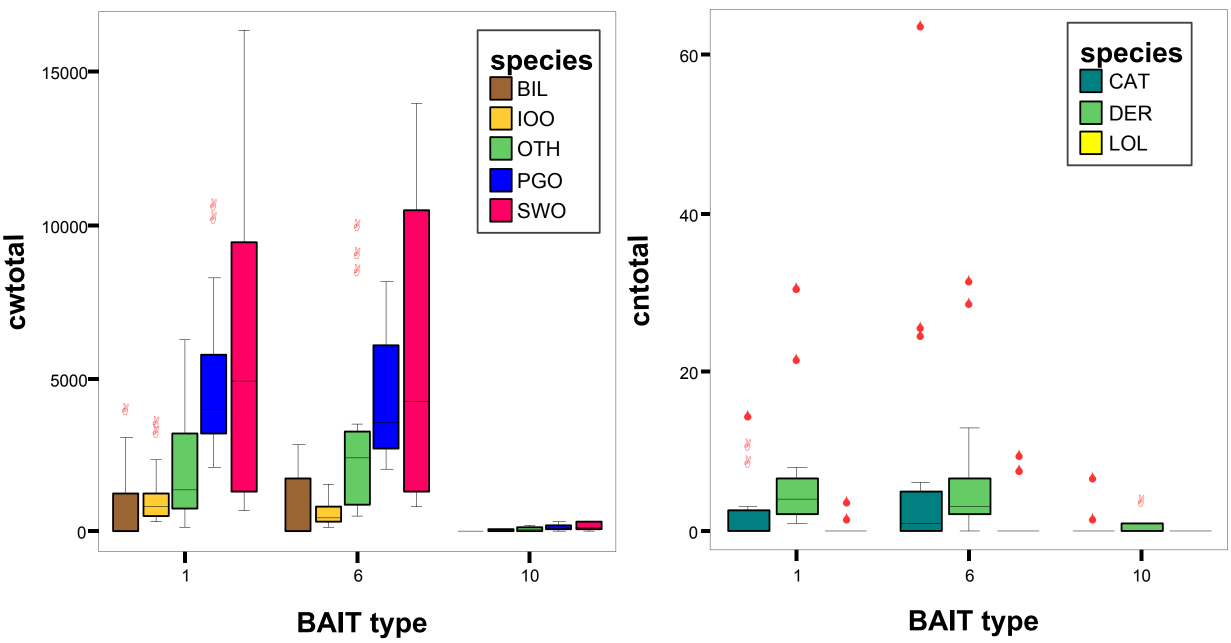
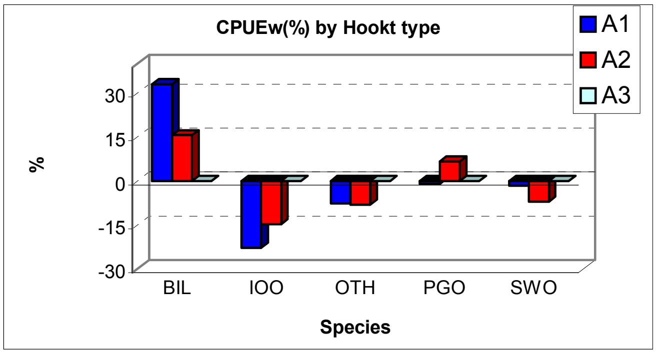


Figure 8. Box-plots of the observations recorded by bait type. Catches in weight (kg DW) of the different fish species (left) and catches in number of turtles (only positive records included in this plot), (right panel).



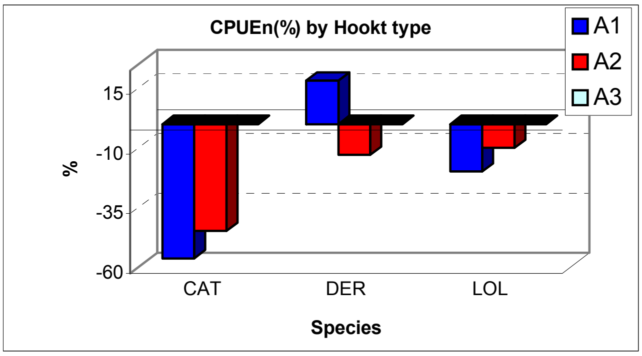
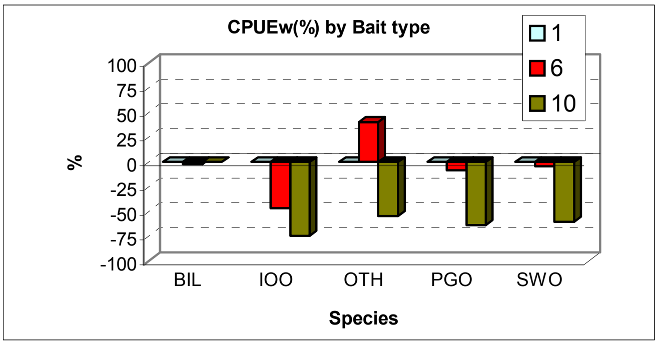


Figure 9. Gains and losses in nominal catch rates in weight for fish species and in number of turtles caused by type A1 hooks (semicircular) and type A2 (circle hooks), as compared to type A3 hooks (conventional) used as a reference.



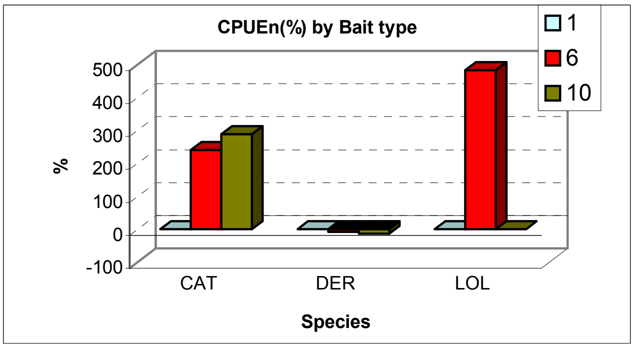


Figure 10. Gains and losses in nominal catch rates in weight for fish species and in catch rates in number of turtles caused by bait types 6 (squid) and 10 (blue shark) as compared to bait 1 (mackerel) used as a reference.

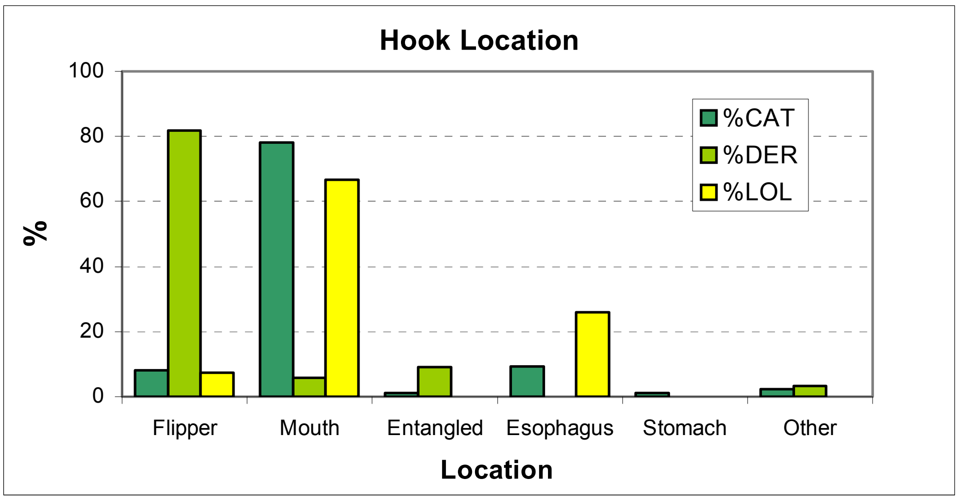


Figure 11. Prevalence (%) of each hook location by species of turtle.

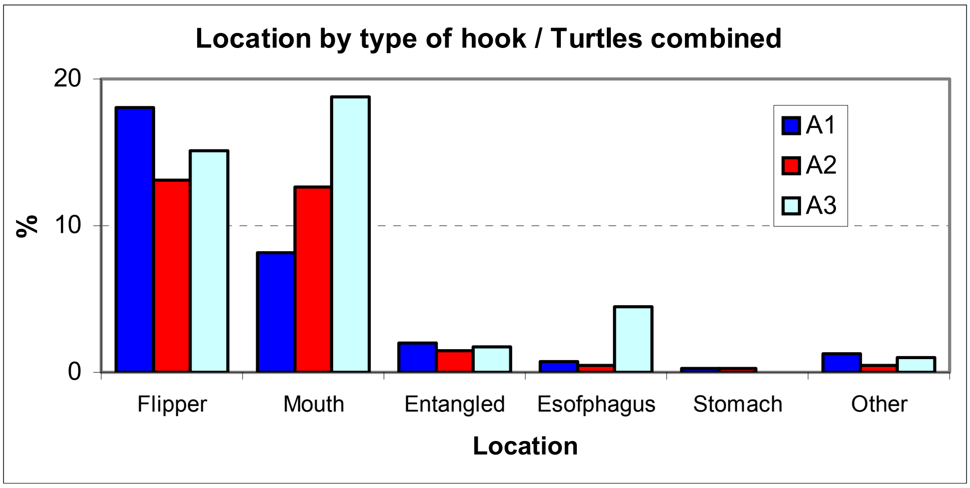


Figure 12. Prevalence (%) of each hook location for all species of turtles combined by hook type.

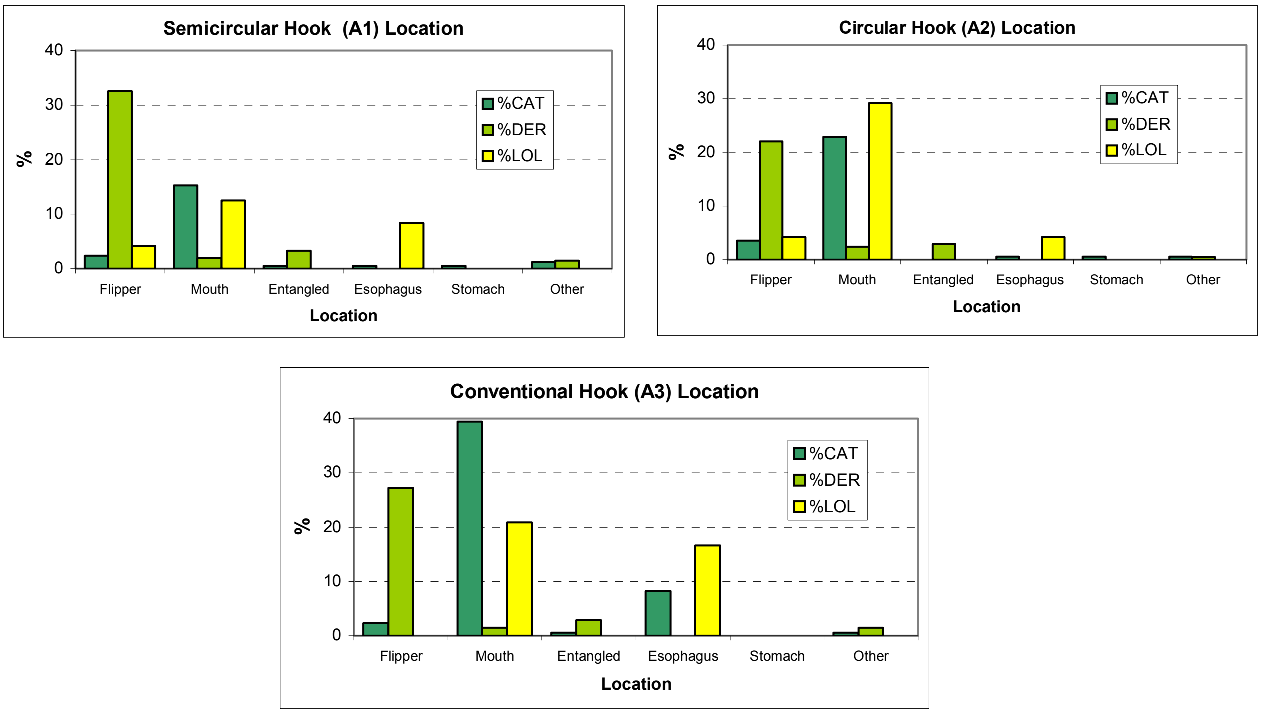


Figure 13. Prevalence (%) of each hook location by species of sea turtle and by hook type.

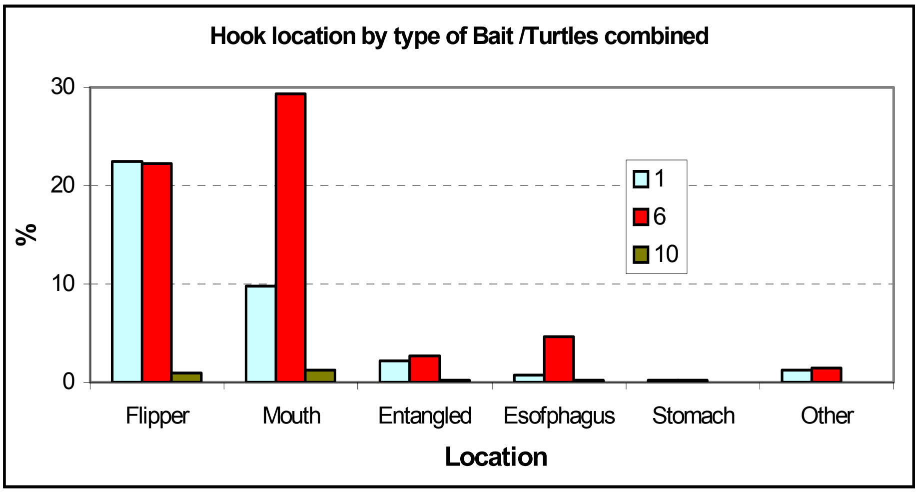


Figure14. Prevalence (%) of each hook location by species of turtles combined and by bait type.

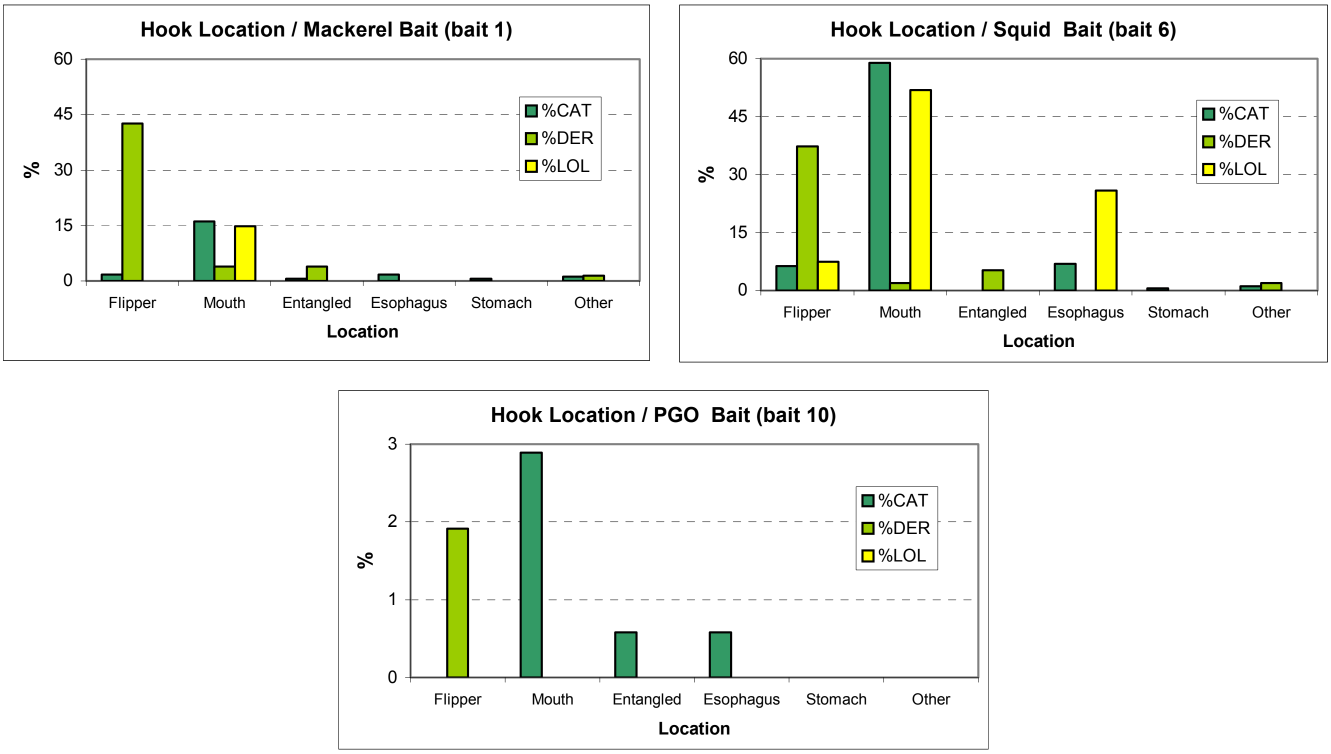


Figure15. Prevalence (%) of hook locations by species of turtles and by bait type (Note that the scale for bait10 is not the same as for the other baits).

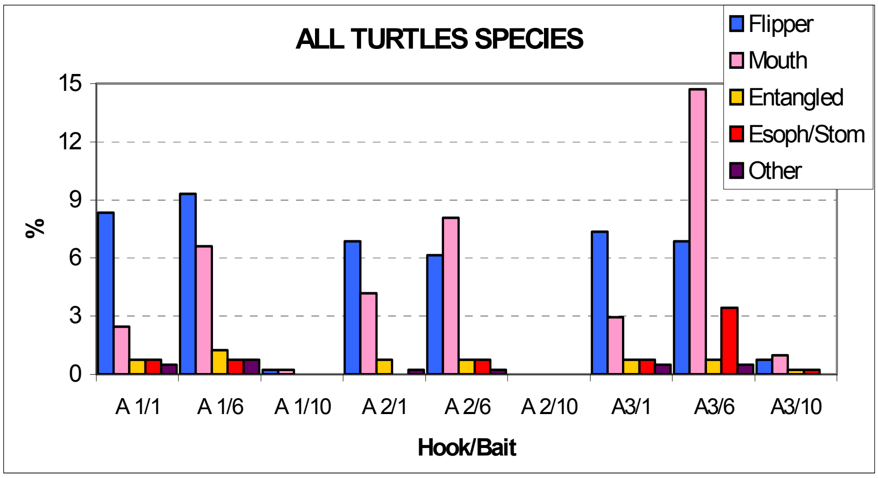


Figure16. Prevalence (%) of hook locations by species of sea turtles combined and by different hook and bait type combinations.

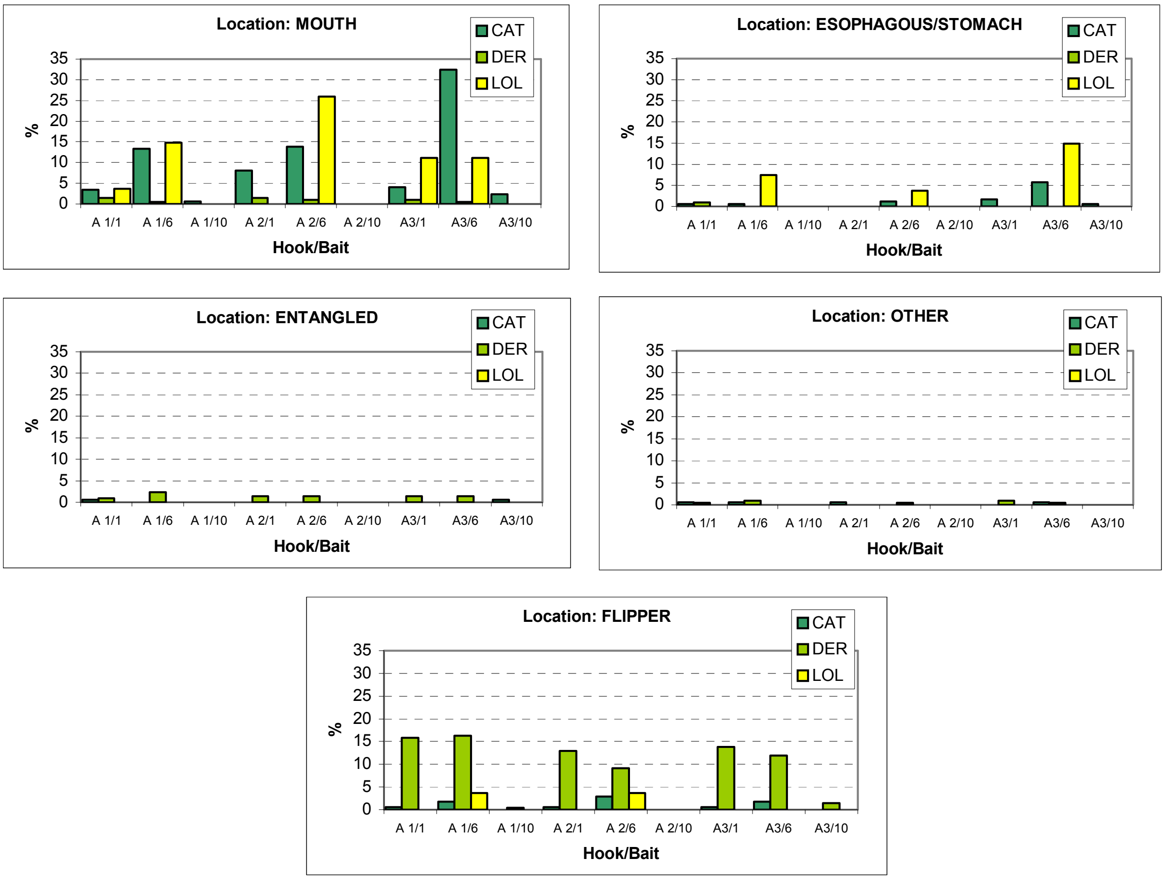


Figure 17. Prevalence (%) of each hook location for sea turtle species by hook and bait type combinations.

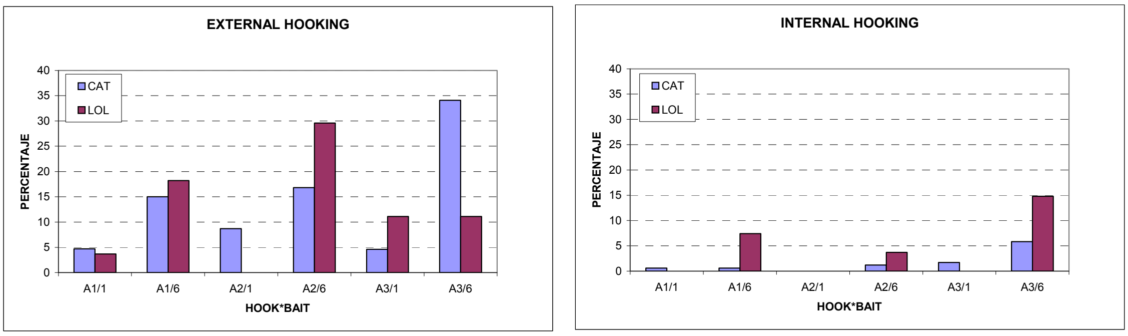


Figure 18. Prevalence (%) of each group of hook location (external or internal) for the sea turtles *Caretta caretta* (CAT) and *Lepidochelys olivacea* (LOL) by hook and bait combinations. The lack of vertical bar in a hook-bait combination indicates null catch (see table 26 for more details).