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PILOT STUDY FOR A SHARK FISHERY SAMPLING PROGRAM IN CENTRAL AMERICA

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SUMMARY

A pilot study was initiated in April 2018 to collect additional shark fishery data and develop and test sampling designs for a long-term sampling program for the shark fisheries of Central America. This project was the second phase of a FAO-GEF Common Oceans program *Sustainable Management of Tuna Fisheries and Biodiversity Conservation in the Areas Beyond National Jurisdiction* (ABNJ) project to improve data collection for shark fisheries of Central America, originally funded in 2015. This second phase had two main components: identify landing sites of the small vessels, which fish in coastal waters (PNG fleet), obtain an order-of-magnitude of the shark catch by that fleet component, and produce a sampling designs for catch and effort (Task 1); and, for the longline fleet comprised of larger vessels fishing in both coastal and international waters (NPG fleet), produce sampling designs for estimating the size and sex composition of the catch to improve the information about total catch already available (Task 2). For the PNG fleet, landing sites were identified by combining a literature review, remote sensing information and *in situ* site visits. The methodology to obtain an order of magnitude estimate of shark landings was developed and an example of its implementation at several sites, based on data collected as part of this project, is presented. Additional data necessary to obtain an order of magnitude estimate for the entire

region will be collected up until the end of 2019 and global estimates for Central America will be computed. For the NPG fleet, it was found that the catch unloading process is not random with respect to species and size, and thus a super-sampling approach was implemented to collect detailed data on unloadings. With the super-samples collected, a simulator of the unloading process based on sequential Markov chains was built, which can be used to simulate PNG unloadings and test the performance of sampling designs for size composition. More super-samples will be collected during the remainder of 2019 to improve the representativeness of the simulator with respect to the main NPG trip types (dorado, shark) and to seasonality (rainy, dry seasons). With the additional super-samples, an improved simulator will be built to test the sampling designs. The sampling designs developed for both the PNG and NPG fleet components will form the basis for a long-term shark sampling program in Central American. It is recommended that the first phase of this long-term sampling program (Project C.4.b) assess the practicalities of the implementation and validate the assumptions of the proposed sampling designs, for fine tuning the sampling protocols.

INTRODUCTION

In 2015, the FAO-GEF Common Oceans program, and specifically the *Sustainable Management of Tuna Fisheries and Biodiversity Conservation in the Areas Beyond National Jurisdiction* (ABNJ) project, funded a project, carried out by the IATTC and OSPESCA[1], to improve shark data collection in the eastern Pacific Ocean (EPO), particularly in Central America[2], where much of the shark catch is landed and where the need for better data collection is greatest. For the purposes of this document, hereafter we will use the term “shark fishery” to refer to one or more groups of vessels landing any species of sharks in the Central American coast, independently of their target species.

During Phase 1 of the project (2015-2017), the data available for the shark fisherieswere identified and compiled, and recommendations were formulated for improving data collection. Also, three workshops were held, on data collection, assessment methods for shark species, and designing a pilot sampling program. After the last of these workshops, a pilot study was initiated in April 2018 to collect additional shark fishery data and develop and test sampling designs for a long-term sampling program for the shark fisheries in Central America (Phase 2 of the project).

At the workshop on designing the pilot study, held in September 2017, an external panel of experts in fisheries sampling provided advice and made recommendations, and a panel of scientific and technical experts from OSPESCA’s Regional Working Group on Sharks and Highly Migratory Species (GTEAM) provided advice on the feasibility and applicability of alternative sampling designs and input on relevant logistical aspects. It was agreed that, for the purposes of the project, and as recommended at the meeting of the Scientific Advisory Committee in 2016 (SAC-07-06b (iii)), the vessels that unload catches of sharks in Central America should be categorized into two groups, based on their length overall (LOA): “pangas” (PNG), defined as 10 meters or less (≤ 10 m) in length overall (LOA), and 3 m or less in beam; and “non-pangas” (NPG), defined as longline vessels over 10 m LOA and over 3 m in beam. This classification will be used for this project and may differ from the classification used in some countries.

A second important conclusion of the workshop was that more information on the various PNG shark fisheries was essential in order to design the sampling program for that fleet component. Specifically, all sites where shark catches are landed must be identified and, since one of the primary objectives was to estimate the total catch, a measure of the level of fishing activity (*e.g.*, the number of vessels) must be determined for each site, and the magnitude of catches must be obtained from a subset of all sites. This

[1] *Organización del Sector Pesquero y Acuícola del Istmo Centroamericano.*

[2] *The project covers the Pacific coasts of Costa Rica, El Salvador, Guatemala, Nicaragua, and Panama.*

is particularly important for countries in which the fishery is dominated by artisanal fleets, which have received little research focus by the IATTC staff. Sampling these fleets may be critical for monitoring population trends for species of high conservation concern, such as hammerhead sharks. Based on these conclusions and recommendations, the first task of Phase 2 of the project, **Task 1**, was to focus first on gathering data to map the location of potential shark landing sites on the Pacific coast of Central America; it would then focus on the on estimating catches and effort for the PNG component.

Information on how shark catches are unloaded is needed for designing the sampling of species, size and sex compositions. Another important conclusion of the workshop was that there is great diversity in unloading strategies for shark catches among companies, landing sites, and fleet components: for example, whether sharks are unloaded one-by-one or in groups, or unsorted or sorted by size, species, quality, or other criterion. The unloading strategies of individual companies and vessels will affect the accessibility of the catch to samplers and will determine the type of sampling design that will be needed to produce reliable estimates of the species, size and sex composition of the catch. Therefore, before sampling designs can be developed and tested, detailed data on unloading strategies must be collected and analyzed, since no such information is available.

Considering these conclusions and recommendations, a second task, **Task 2,** was initiated to focus on the larger NPG vessels, and on the development and testing of different designs for a sampling program to collect reliable data on the species, sex and size composition of shark catches. Sampling technicians surveyed NPG vessels (> 10 m) and their landing sites to identify these strategies; this took place in Costa Rica and Panama, where these vessels predominate.

To implement these two tasks, they were each broken down into a series of sub-tasks, as follows:

Task 1: Determine locations, catches, and effort of the *panga* (PNG) fleet

- 1.1: Identify and map all sites where shark catches are potentially landed along each country's EPO coastline;
- 1.2: Verify mapped landing sites *in situ*, and collect data on site characteristics and the level of fishing activity;
- 1.3: Collect data at selected landing sites on vessel operations and catch composition;
- 1.4: Compute order-of-magnitude estimates of shark catches landed at all sites, using information from 1.1-1.3;
- 1.5: Develop possible catch sampling designs and conduct simulations to evaluate performance.

Task 2: Testing sampling designs for composition data of the non-panga (NPG) vessels

- 2.1: *In-situ* surveys of vessels and landing sites to collect data on unloading practices;
- 2.2: Based on results of 2.1, collect catch species, size and sex composition data with which to develop and test sampling designs;
- 2.3: Develop sampling designs based on analysis of data collected in 2.1 - 2.2 and conduct simulations to evaluate performance.

The next sections detail the methods used to implement these tasks and the results up to date. The funding by ABNJ concluded in March 2019 and IATTC capacity building funds will be utilized to extend the pilot study to the end of December 2019. The work planned during 2019 is discussed in Section 3.

TASK 1: DETERMINE LOCATIONS, CATCHES, AND EFFORT OF THE PANGA (PNG) FLEET

1.1. IDENTIFY AND MAP ALL SITES WHERE SHARK CATCHES ARE POTENTIALLY LANDED

To identify fishing localities and catch landing sites (hereafter simply 'landing sites'), various sources of information were reviewed (e.g. annual catch reports published by fisheries agencies and NGOs, documents on censuses carried out by local fishing authorities, registers of companies and fishing cooperatives). The information, collected by country, was compiled to create the first-ever region-level summary of archived information for artisanal fisheries in Central America.

After compiling this historical information, satellite imagery available on Google Earth was reviewed to identify additional locations of interest. For this purpose, both locations with one or more vessels (assumed to be fishing vessels) and locations with characteristics that would make them suitable as landing sites were considered. Characteristics assumed to make a location suitable as a landing site included: a good road to reach the location, space to carry out the unloading of catch, existence of a nearby catch processing plant or fish market, and appropriate physical conditions for beaching or docking small vessels.

All locations of interest were assigned to one of three landing categories: a) **historical**, if the site location matched with a location previously reported in the literature; b) **new**, if vessels were observed in the satellite imagery and the site was not previously reported in the literature and; c) **potential**, if the site observed in the satellite imagery had characteristics of a landing site but no boats were observed and the site was not previously reported in the literature.

During the review of the satellite imagery, the coordinates (longitude and latitude) of each location of interest and a count of the number of vessels visible in the images were recorded. A unique numerical code ("ID") was assigned to each location of interest for the purpose of constructing a georeferenced database with the following fields: i) Site name, ii) Site ID, iii) Longitude, iv) Latitude, v) Number of vessels, and vi) landing category. This georeferenced database was the starting point for construction of a Google Earth spatial database (KML).

Because Google Earth satellite imagery is updated periodically, a review of newly available images for the region was conducted to evaluate the possibility of changes through time in site characteristics. This second review led to changes in the number of locations of interest identified, in part due to changes in the presence of vessels visible in the imagery. These changes highlighted the need for *in situ* verification of locations of interest, in addition to reinforcing the need to study satellite imagery over a more extended period.

1.2. VERIFY ALL LOCATIONS *IN SITU*, AND COLLECT DATA ON LANDING SITE CHARACTERISTICS AND THE LEVEL OF FISHING ACTIVITY

All locations of interest in the georeferenced database were visited to verify that the sites were in fact currently used for activities related to catch unloading. During this phase of the project, data also were collected on sites that could have been overlooked during the review of satellite imagery. There are two main reasons sites might have been overlooked are:

i. **Sites 'invisible'**: many sites were hidden in mangroves or under trees, rendering them invisible in satellite images (Figure 1).

ii. **Vessels not always present**: Many small landing sites were not identifiable in the satellite imagery when vessels were absent. If no vessels were present at a site when the satellite images were taken, its existence could only be established by a visit (Figure 2). In addition, during visits to locations of interest it was determined that some locations identified in the satellite imagery were not dedicated to fishing, despite the presence of vessels at the site. In particular, many places in Costa Rica, identified as locations of interest because of the presence of *pangas* in the satellite imagery, did not have landings of fisheries products, but instead were associated with marine transport, sportfishing, and/or tourism (Figure 3). Also, in some cases the vessels visible in the satellite images were no longer in use.

All locations of interest confirmed to be used for fish unloading were promoted to "landing points" (an isolated location covering an area of no more than 300 m in diameter) or "landing segments" (a group of locations covering an area of no more than 300 meters in diameter and with a distance less than 50 meters between locations). Hereafter, landing points and landing segments are collectively referred as "landing sites". A fishing locality is a community or geographical region whose population is primarily dedicated to marine fisheries. A fishing locality may contain one or more landing sites.

Table 1 and Figure 4 show the results of the study carried out to identify fishing localities and landing sites. The estimated number of PNG vessels per country is shown in Table 2, from four sources of data: a) national vessel registries[3]; b) satellite imagery; c) observations by sampling technicians; and d) interviews with fishers. There are significant variations in the numbers from these different sources.

During the visit to each landing site, a group interview was conducted with available fishers at the site to obtain information on the level of fishing activity and characteristics of fisheries operating there (Table 3). Following these visits and interviews, additional metadata were added to the georeferenced database, indicating the number of vessels observed *in situ* and whether the site was sampleable, with respect to logistical considerations and potential security concerns.

Four fishing gears were reported in the PNG fleet for sharks. The most widely used were gillnets (65%), followed by longlines (18%) and handlines (17%); purse-seine nets, although reported, were rarely used (≈ 0.1%). These proportions were essentially constant throughout the year, varying only slightly by season (dry season, November-April, *versus* rainy season, May-October) (Table 4).

1.3. COLLECT TRIP-LEVEL DATA AT SELECTED LANDING SITES ON VESSEL OPERATIONS AND CATCH COMPOSITION

After identifying the landing sites, and with the information obtained from the collective interviews, it is possible to make a map of the importance of each site for the landing of sharks, in terms of number of vessels and seasonality of the landings. For the purpose of obtaining order of magnitude estimates of effort and shark catch at the landing sites, a second visit was scheduled to each landing site that was considered sampleable. The objective of this second set of interviews was to collect information at the level of individual trips on catch composition, as well as information on variability in catch composition among trips, vessels, seasons and sites for purpose of modeling uncertainty. The catch and effort data were collected retrospectively for the dry and rainy seasons of 2018. It was decided to interview fishers about the most recent year because their activities in that year should be relatively accurate (compared to their recollection of activities in years prior) and to avoid possible biases due to different years of experience among fishers. The interviews were conducted with individual crew members of each vessel, usually the captain, and for several vessels at each landing point.

For sharks, catch information was collected by species and life stage (neonates, juveniles and adults), and interviewees were requested to provide estimates of the minimum, maximum and typical catch amounts per trip, for each season. The latter quantities will be used to apply "three-point" estimation methods, allowing for the construction of approximate probability distributions for catch amounts per trip (e.g. triangular and PERT distributions), and from those probability distributions, estimates of uncertainty (see Section 1.4).

Data collected show high seasonal variability in shark landings, with some sites having landings all year round and others only during certain months of the year, mainly between May and July (Figure 5). We were able to identify sites primarily dedicated to shark fishing (sharks as the only target species) and sites with mixed targets (Figure 6). The second round of interviews will continue during 2019, to increase the

[3] Panama has had a process of updating fishing licenses for the longline vessels which finalized 2019-04-29. This data is being analyzed and will be included in the final report of the project.

current coverage of 6.4% of landing sites and 10.1% of fishing localities with shark landings.

1.4. COMPUTE ORDER-OF-MAGNITUDE ESTIMATES OF SHARK CATCHES LANDED AT ALL SITES

The order of magnitude estimates of shark catch for the region will be based on site-specific order of magnitude estimates. The data available to estimate catch at a site are: catch per trip (minimum, typical, maximum) during the dry and rainy seasons, and the months of the year that correspond to the start, end and peak months for shark catches. In what follows it is explained how the order of magnitude estimate of catch is obtained for a given site.

The estimated catch at a site will be obtained by summing weekly estimates of catch over the year. Weekly estimates of catch for the site will be computed as the product of estimates of catch per week per vessel and the estimated number of active vessels. A Monte Carlo simulation will be used to obtain estimates of catch per week per vessel for every week of the year. For each species, life stage and week of the year, the Monte Carlo simulation involves implementation of the following steps:

Step 1. Simulate the number of trips per week per vessel: Draw a random number (n_{trips}) of trips per week per vessel from an appropriate distribution (e.g., a PERT, γ=2; Figure 7), for the corresponding season (dry or rainy) and environmental conditions (good or bad).

Step 2. Simulate n_{trips} catches: Take n_{trips} random draws from an appropriate distribution of catch per trip (e.g., PERT, γ=4; Figure 7), for the species, life stage and week of the year.

Step 3. Estimate catch per week per vessel: Sum the n_{trips} simulated catch-per-trip values (from Step 2) to obtain an estimate of catch per week per vessel for the current week.

The weekly distribution of catch per trip (Step 2 of the Monte Carlo simulation) were assumed to follow a PERT distribution (e.g., Figure 7). The catch related information necessary to define the PERT catch per trip distribution for a given week is the minimum, typical and maximum catch for the week. These three quantities are estimated from the seasonal information provide by fishers according to the following steps:

a) For the weekly estimates of the minimum and maximum catch per trip, the values provided by fishers for dry and rainy seasons were smoothed over the weeks of the year using cubic-splines, under the assumption of continuous and smooth change.

b) The weekly estimate of the typical catch per trip was assumed to follow a generalized PERT distribution from the start month to the end month provided by fishers, with the mode at the peak month provided by fishers (Figure 7). This seasonal distribution of typical catch per trip values was rescaled to the weekly range of variability from Step (a) before adding the minimum value to produce values of typical catch between the reported range of variability. Finally, these estimates were centered to the typical catch by season provided by fishers.

After implementing Steps (a)-(b), three-point estimates of catch per trip (minimum, maximum and typical) for each of the 52 weeks of the year were generated and used to parameterize the weekly PERT distributions of Step (2) in the Monte Carlo Simulation.

In order to estimate a distribution of the estimates of total catch for the site from which to calculate confidence intervals, the Monte Carlo simulation was replicated 1000 times. Analyses to calculate the optimal number of replicates will be conducted in the future. In addition, a sensitivity analysis of the catch estimates to the chosen three-point distributions will be conducted.

As an example of the above procedures, order of magnitude estimates of the catch of silky sharks (*Carcharhinus falciformis*) for four selected landing sites are presented in Figure 8, which illustrate the variability in landings by season and life stage, among landing sites.

Since detailed data are not likely to be available for all landing sites, an empirical model will be used to estimate the missing data. This model will use site-specific information such as fishing gears used, number of vessels, distance to major ports, rivers and cities, and if the site is associated with a beach or a mangrove, the latter seemingly important as a predictor of the species composition of the landings (e.g. hammerheads mainly landed in mangrove sites). Figure 9 shows the distribution of mangrove coverage and the classification of landing sites as beach (blue) and mangrove (red). A zoom of Figure 9 for El Salvador, including the river system is shown in Figure 10.

1.5. DEVELOP POSSIBLE CATCH SAMPLING DESIGNS AND CONDUCT SIMULATIONS TO EVALUATE PERFORMANCE.

To evaluate sampling designs for collecting data to estimate total catch of the PNG fleet, three steps are required:

1) Develop a simulator to generate "data" for catch composition for individual trips, during different times of the year at each site. This will be necessary to consider the observed high variability at both temporal and spatial scales in the landings.
2) For each candidate sampling design, sample the simulated data according to that design and estimate the species and life stage composition of the catch.
3) Rank the candidate sampling designs according to their bias, variance, and implementation feasibility.

The protocol implemented for the Monte Carlo simulation (Section 1.4) provides us with a simulator for generating landings data, since it simulates catch composition for individual trips for every week of the year at a particular site. With this approach, the simulator can be used to generate a time series of catch composition by trip for all the landing sites over the course of the year.

The data provided by the simulator allows testing of sampling designs based on specific rules describing the choices the samplers will have to make, related to when, where and for how long to collect samples at a particular landing point, given that the number of samplers is expected to be smaller than the number of sites. In a typical scenario, the simulation would start with a fixed number of samplers distributed randomly among landing sites. The samplers would then move and collect data following a set of rules (see Table 6 for examples). The activity and data collected by the samplers can be used to compute the total catch which can be compared with the "truth" to evaluate various performance measures (e.g. bias, variance, cost) and rank the different candidate sampling designs.

TASK 2: TESTING SAMPLING DESIGNS FOR COMPOSITION DATA OF THE NON-PANGA (NPG) VESSELS

Three phases were planned to carry out this part of the project, following the previously defined sub-tasks. The purpose of the first phase was to conduct a survey of vessels and landing sites to determine how NPG vessels process and unload their catch. The purpose of the second phase was to use information from the survey to guide the collection of data suitable for simulation testing of various sampling designs (collection of "super-sample" data). The purpose of the third phase was to develop a simulator based on the super-sample data and use the simulator to test various sampling designs for collecting size composition data. Each of these phases is described in detail below.

2.1. *IN-SITU* SURVEYS OF VESSELS AND LANDING SITES

The survey of unloading practices was conducted by IATTC staff and the staff of INCOPESCA and ARAP, the Costa Rican and Panamanian national fisheries authorities, respectively. The objective of the survey was to collect data on how catches are processed and unloaded by individual NPG vessels and whether those practices vary by landing site. The following data were collected:

1. **General:** fishing locality and landing site; name, registration, and length of vessel;
2. **Storage and processing:** how the catch is processed and stored aboard the vessel;
3. **Unloading methods:** how the catch is unloaded, in groups or individually, by species, size and/or quality;
4. **Catch accessibility for sampling:** catch handling and residence time of the catch on the dock.

A survey form was completed not only for each vessel, but also for each landing site where the vessel unloaded. Thus, if a vessel unloaded at three different sites, four forms were required, one for the vessel and one for each landing site. The survey was conducted at as many landing sites of NPG vessels as possible in Panama and Costa Rica, as those countries have the largest NPG fleets.

A total of 181 NPG vessels were surveyed, 119 in Costa Rica and 62 in Panama, at 25 landing sites distributed among 11 fishing localities (Table 7). Landings in Costa Rica are concentrated in Puntarenas, the main fishing port for that country, which contains ten landing sites, such as private and public docks. In Panama, landing locations are more widely distributed geographically, with a greater number of fishing localities but about the same number of landing sites.

The analysis of the survey data focused on answering several questions: can catch unloading be assumed to be random with respect to species/size/quality; will multiple protocols for catch measurement/weighting be necessary due to different preservation and processing procedures among vessels and/or landing sites; and, how accessible is the catch for sampling at various points during the unloading process. A preliminary summary of the main findings follows. This summary is based on 78% of all vessels surveyed in Costa Rica and 79% of all vessels surveyed for Panama. This summary will be updated in the near future when the remaining survey data is processed.

Unloading catches. Different methods were used to unload catches of sharks from NPG vessels in Costa Rica and Panama: in Costa Rica they are almost always unloaded one at a time, while in Panama they are usually unloaded in groups (Figure 11).

A more detailed analysis of the unloadings in Costa Rica revealed that unloading is rarely random. Most unloading practices took species into consideration and/or the catch was unloaded continuously in reverse order to the way it was loaded into the well (termed "well" in the following text) (Figure 12). However, 64% of the vessels that unloaded by well had loaded the catch into wells non-randomly, and often catch storage methods appear to separate species (Figure 12). Similar results were obtained in Panama (not shown), even though in Panama catches are generally unloaded in groups.

Preserving and processing catches. In Costa Rica, most vessels stored their shark catches on ice, whereas in Panama catches were as likely to be frozen as they were to be chilled (Table 8). Typically, sharks are stored in a vessel's wells headed, gutted, and with fins partially cut off[4]. This means that at the time of unloading, it will be impossible to obtain standard length measurements (*e.g.*, total length) or total weight.

Weighing catches. In both countries, most shark catches are weighed in groups after unloading (Table 9). Of the 63 Costa Rican vessels that reported weighing sharks in groups, 60 sorted the groups by species, while 21 of the 31 Panamanian vessels that weigh sharks in groups sorted them by length and weight, *i.e*. by size class.

Catch accessibility for measuring. The data collected indicate that, in general, more time is available if

[4] All National and Regional regulations related to finning in Central America are described in the document SAC-07-06 (ii).

the catch is unloaded in groups rather than one-by-one (Table 10); however, in practice, how much time is available to measure individual sharks will depend how many sharks are in the group; the larger the groups that are weighed, the more time available to measure fish. According to informal interviews with fishers, the best time to measure sharks is before they are weighed, regardless of condition (fresh/chilled or frozen), but this can still obstruct unloading operations.

In summary, the data collected by the project to date on NPG vessels unloading in Costa Rica and Panama indicate that:

a. Most vessels do not load or unload shark catches randomly with respect to species, size, or quality;
b. Unloading practices differ by country;
c. Access to shark catches for species- and size-composition sampling is very limited;
d. Shark catches are processed both when loaded aboard the vessel and when unloaded at the landing site.

These results imply that:

(i) sampling designs for species and size composition cannot assume random loading or unloading of the catch;

(ii) the sampling protocol will need to be adjusted for each country; and,

(iii) individual length and weight measurements collected must be robust to any processing of the catch aboard the vessel, and that other data will be needed to convert these measurements to typical measurements used for estimating size composition.

2.2 COLLECTION OF CATCH SIZE AND SEX COMPOSITION DATA WITH WHICH TO DEVELOP AND TEST SAMPLING DESIGNS

The data collected during the interviews showed that many NPG vessels do not load or unload catches of sharks randomly as regards species, size, or quality, and that unloaded sharks are often weighed in groups, although the definition of a 'group' was found to differ by country. This means that country-specific sampling protocols need to be developed, by length for Costa Rica, and by species and length in Panama. Since the sampling design cannot assume randomness, specialized sampling protocols need to be developed and tested. To test sampling protocols, a simulator needs to be developed, and for this, complete data from vessels unloading are necessary to parameterize a statistical model of the variability in the unloading process.

To this end, 'super-sample' data were collected; these contain very detailed information on the order in which the catches were unloaded and the size of the fish. The super-sampling protocol and preliminary results are presented for each unloading method (one-by-one, in groups) in the next sub-sections. To date the super-sampling for both type of unloading focused on trips that were thought to have some amount of shark catch. In the future (see below), super-sample data will be collected from both trips with and without shark catch.

2.2.1. 'One-by-one' super-sampling

Super-sampling of one-by-one unloading was conducted in two phases. The first phase focused on shark catch. The purpose of the first phase was to compare the order of unloading of the catch at the two possible sampling points (the deck of the vessel and the dock), determine whether it was possible to measure all sharks in the unloading, and evaluate the variability in the size composition of the shark catch. The purpose of the second phase was to expand the super-sampling to all taxa in the catch, guided by lessons learned in the first phase.

The super-sampling protocol for one-by-one unloading in the first phase involved the following three steps:

Step 1. Record when each individual shark was unloaded from the vessel (each shark was tagged with a unique identifier at the time it was unloaded from the well onto the deck);
Step 2. Record when each individual shark was landed on the dock from the deck of the vessel;
Step 3. Measure the inter-dorsal length (LID) of each shark, keeping track of the tag number.

To implement this method, three sampling technicians were necessary, as illustrated in Figure 13.

During October-November 2018, super-sample data were collected for six NPG unloadings in Puntarenas, Costa Rica. Data from five of the six super-samples have been processed. Little difference was found in the unloading order at the deck of the vessel compared to the dock. The length composition data for silky sharks from the five super-samples are shown in Figure 14. Although the unloadings occurred within weeks of each other, the average LID is very different among the unloadings, which may be due to differences in fishing locations among vessels. Even when the average LID is similar, the distribution of lengths over the course of unloading may be different (*e.g.*, Vessels A and B), which suggests that in some cases the unloading order may depend on the size of the individual sharks. These preliminary results also suggest that, with the possibility of trans-shipment of catches, it may be important to consider the variability in the size of the sharks in the catch, both within and among unloadings, when designing protocols for sampling size compositions. Measuring every shark was a time-consuming process and delayed the unloading of the catch, causing the fishers to incur additional costs.

Following the lessons learned in the first phase, the sampling protocol for the second phase was designed to minimize its impact on unloading operations, yet still provide adequate information for development of a simulator. The new protocol replaced measuring individual fish with recording the weight category of individual fish. Commercial weight categories were used for this purpose (Table 11). Also, for safety reasons, the sampling technicians could not always be on the deck of the vessel to record the unloading order at that point (Step 1 of the 1st phase protocol). Because little difference in order of unloading at the deck and arrival to the dock was observed in the 1st phase, the sampling protocol was therefore modified to record the unloading order (and weight category) of every fish unloaded at the dock.

By the end of December 2018, super-sample data for six NPG unloadings were collected using the new protocol. The data from those six super-samples are shown in Figure 15. Consistent with the results of the survey, these data illustrate that species/taxa are predominantly unloaded in blocks, although the order of the blocks differs among unloadings. The length of the species blocks, and the extent to which species blocks repeat during the unloading (*e.g.*, the first super-sample of Figure 15) differs by sample. For sharks, there is perhaps an indication of sorting by size within species (*e.g.*, second sample of Figure 15).

To provide a quantitative summary of the observations noted above, an analysis was conducted to define "unloading blocks" for each super-sample; i.e., groups of fish that were predominantly the same species within each individual unloading. Given the results of the survey (Figure 12), an unloading block was defined as the continuous unloading of species, however, in other applications, blocks could be based on other criteria (e.g., quality or size of the product). Blocks were allowed to contain some minor amount of unloading of other species, for practical reasons. To estimate the unloading blocks in each super-sample, the proportion of each species in a running fraction of the unloading (3%) was calculated and the dominant species (more than 50%) identified for each fraction. An unloading block was then defined as the sum of contiguous fractions with the same dominant species. Small blocks (less than 3% of total fish unloaded) dividing two blocks of the same dominant species were ignored to generate uninterrupted unloading blocks of the same species.

The unloading blocks identified for the six super-samples available (Figure 15) are described in Table 12 and indicated by gray and black bars below each super-sample in Figure 15. As a visual summary, the average distribution of the taxon blocks by fraction of the unloading was computed across super-samples (Figure 16). These results confirm that, at least for these six super-samples, the first part of the unloading is most likely to be dominated by dorado or sharks, with tunas and billfishes appearing later in the unloading. In other words, at the level of taxa, the order of unloading blocks appears to be non-random. The extent to which these results may vary by season and by trip type (shark or non-shark) will be investigated (see below). In addition, using both species and size to identify unloading blocks will also be investigated.

2.2.2 'Group' super-sampling

To conduct super-sampling of grouped unloadings, mainly occurring in Panama, it was necessary to revise the sampling protocol of Section 2.2.1. The main difficulties encountered with respect to the super-sampling of grouped unloadings (Figure 17) were the safety of the sampling technicians (due to the quantity of catch being unloaded) and access to the catch for the measuring. In the grouped unloadings, fish were grouped as they were removed from the vessel wells and unloading as a group onto an unloading platform on the dock that was next to a cargo container or the bed of a truck. The catch was then immediately loaded into the cargo container or truck bed. It was determined that it was unsafe for samplers to be on the deck of the vessel and near the unloading platform. A sampling protocol was therefore tested in which photographs were taken of the unloading process (Figure 18), from which the lengths of the unloaded sharks could be estimated. That protocol consisted of three steps:

Step 1. Placement of reference marks on the fish unloading platform;
Step 2. Photograph fish on the platform, using remotely-activated wireless cameras;
Step 3. From the photographs, using specialized computer software and the numerical methods of Chang *et al.* 2009, estimate trunk length of unloaded fish and species identification.

Although the camera system was determined to perform well, it was clear from the imagery that species identification would be impossible because of the catch processing that occurred prior to unloading, the size of the groups unloaded, and the position of individuals inside the cargo container/truck bed. Given these observations, it was determined that the funds and time to develop methods for species identification of grouped unloadings was beyond the project resources. Therefore, this part of the project was suspended.

2.3 DEVELOP SAMPLING DESIGNS FOR ONE-BY-ONE UNLOADINGS

To evaluate sampling designs for estimation of size composition of the NPG catch, three steps are required:

1) Develop a simulator to generate "data" for complete unloadings under scenarios that approximate the fishery. This is necessary when fishery data are limited (expected to be the case because super-sampling is a time-consuming process).

2) For each candidate sampling design, sample the simulated data according to that design and estimate the size composition of the catch.

3) Rank the candidate sampling designs according to their bias and variance, and implementation feasibility.

The super-sampling data were used to create a simulator (step 1), which is described in Section 2.3.1. Steps (2) - (3) have not yet been implemented because more super-sample data are necessary to refine the simulator (see below), however, important characteristics of candidate designs that will be tested are discussed in Section 2.3.2. The necessary additional super-sampling data are being collected from April to

December of 2019.

2.3.1 Simulator

Both the results of the survey and the preliminary analyses of the super-sample data suggest that catch is unloaded in blocks, the order of which is non-random. Moreover, the order of these blocks varies from unloading to unloading. This suggests that the order of unloading blocks is likely influenced by factors such as what the fishers caught and the current market demand, both of which may vary on a number of time scales (e.g., seasonal). Because of the apparent non-random nature of the unloadings and because we do not have prior information on the factors influencing the unloading process, we simulate the unloading process using Markov chains. Were the unloading of species to be random, we could have built a simulator using a series of multinomial distributions (e.g., for species, weigh category). In fact, if a transition matrix has identical rows, the distribution of the Markov Chain reduces to a multinomial distribution, meaning there is no structure and that component is random.

To model the structure of the unloading process, three Markov chain models were used in a sequential manner: (i) a chain to model the taxon blocks (*G*), (ii) a chain to model the species within a taxon block and (S_g), (iii) a chain to model the weight category (small, medium and large) of each species (L_s).

The parameterization of the Markov chain *G* depends on the length of the unloading (*N*), measured in number of fish, as given by:

$$G(N) = P(N) + [1 - P(N)]\,J,$$

where *N* is the number of fish, *G* is the transition matrix for the taxon blocks, *P* is the "persistence" matrix modelling the length of the unloading of a particular taxon block and J is the transition matrix for the jumps between taxon blocks. *P* is a diagonal matrix with components $P_{ii} = 1 - \frac{1}{p_i N}$, with p_i being the average fraction of fish unloaded for block *i*, considering each unloading block is occurring at most once per unloading. This means the transition between unloading blocks can be parameterized with the proportions p_i and the transition matrix of the jumps J. The former opens the possibility to improve the super-sampling experiments by including information on the proportion of individuals landed in each block. The Markov chain S_g, for species within taxon block *g*, is a matrix of order equal to the number of species observed, normally sparse since not all species will be present in a particular taxon block. The Markov chain L_s, for weight class with species *s*, is a matrix of order equal to the number of size or weight classes recorded for species *s* (assumed to be 3 for all species as per Table 11). The Markov chain *G* is started with the observed distribution of the first taxon block, while the Markov chains S_g and L_s are started with the equilibrium distribution of their transition matrices.

Estimation of parameters for the SMC is a sequential process. First it is necessary to define taxon blocks, e.g., using the procedure described in Section 2.2.1. Once taxon blocks are defined for each super-sample, it is necessary to estimate the transition probabilities for transiting from one taxon block to the next during the unloading (transition matrix J). Then for each taxon block, the estimated transition rates within a taxon block are used to estimate a species transition matrix S_g, and for every species s, transition rates are used to estimate a size-category transition matrix, L_s. All the probabilities are estimated using the maximum likelihood estimator for the transition matrix of a Markov Chain, based on the counts of the observed transitions.

The results of the parameter estimation are shown in the Table 13, showing sharks and dorado are the more abundant groups in the unloadings. Particularly, sharks are the more abundant taxon, explained by the fact that the unloadings used to parameterize the SMC were expressly sampled because they contained shark catch. Figure 19 shows Dorado tend to be the first block to be unloaded except when sharks are dominant, being second. In addition, we found all species and size transition matrices (not shown because they are too numerous.) have rows with statistically significant differences (*p*-values from a Chi-squared test less than 0.05), being consistent with the results of the survey and justifying the use of a Markov Chain to model the unloading process.

Prior to using of the SCM to generate unloadings data, it is important to evaluate whether there are enough super-sample data to adequately characterize the unloading process. Therefore, a simulation study using the current estimated parameters was done to analyze the ability to recover the original parameter values during the estimation process. A total of 5000 super-samples were generated, each one simulating the unloading of 500 fish. From all 5000 simulated super-samples, a random subset of 200 was taken to calculate the error in the expected proportion of unloaded species and its variance across the 200 replicates. The values of 5000, 500 and 200 were selected arbitrarily, and can be varied in the future once a final simulator is built with additional super-sample data.

The results of this experiment are shown in Figure 20. We observe a large initial reduction in the estimation error comes after 25 super-samples (or around 5000 fish sampled), meaning the current 6 are not enough to properly carry out a simulation experiment and more data need to be collected. Additionally, given the proportion in number of species landed are related to the parameters estimated for the taxon block transition matrix, using additional sources of information, such as landing records per trip, and fitting different models for different types of trips (e.g. targeting sharks, targeting dorado or targeting billfishes) will be important to consider in the future. Improvements in the parameter estimation and taxon block identification will be further investigated.

2.3.2 Sampling designs considerations

Several lessons learned from the various stages of data collection conducted to date have immediate bearing on the characteristics of candidate sampling designs. For example, from the survey results and from practical experience gained during the collection of the super-sample data it was learned that unloading speed varies mainly with the size of the fish (smaller fish are unloaded faster) and the preservation method (frozen fish are unloaded faster than fresh fish because the frozen fish are not washed as they are unloaded). In addition, it was learned that measuring every fish is not possible in practice, so some fish will need to be skipped when sampling. Thus, the number of fish that will need to be skipped during sampling will need to be a function of the size of the fish and the preservation method. Possible skipping scenarios to be tested with the final simulator could be to skip m fish, where m = 2, 3, …, 10.

Skipping fish to be measured may introduce error into the estimates of size composition because samplers may lose count of the number of fish skipped. The impact of error in m-skipping sampling can be evaluated for the various sampling designs using data from the simulator. We will consider the error in the in m-skipping as “jumps” in the counting, being positive if we skip more fish than required and negative if we skip less. Additionally, we will consider that the sampler may realize the error in the skipping process and evaluate the impact of catching up the original schedule or not doing it.

Another consideration for sampling designs is whether the entire unloading should be sampled or if it will be possible to sample only part of an unloading. The extent to which sampling only part of the unloading will be a viable option depends on the variability in catch composition within versus among unloadings, which may vary seasonally. This is something that will be evaluated with the simulator once additional super-sample data have been collected.

FUTURE WORK AND PERSPECTIVES

The remaining months of this pilot study (through December 2019) will be dedicated to the completion of the work plan for the Tasks 1 and 2, as outlined below.

For Task 1, the main priority is to increase the proportion of landings sites surveyed for catch and effort information (sub-task 1.3) in order to produce robust estimates for the order-of-magnitude of the catch of sharks (using the methods described in section 1.4) and build the simulator to test candidate sampling designs for the catch composition of the PNG fleet (using the ideas outlined in section 1.5). Additionally, trip-level sampling by trained samplers will be carried out using the data form shown in the Appendix to collect information for validating some answers given by the crew in the interviews, and also to evaluate the feasibility of data collection. Information on the duration of each stage of the unloading (landing, filleting and weighting) will be collected in order to estimate the possible number of samples that can be collected during a typical work day.

For Task 2, the main priority is to increase the number of super-samples, aiming for at least 25 for each main group (dorado-oriented trips, shark-oriented trips) for each season (dry and rainy). Additionally, with information on landing frequency and catch composition of the NPG fleet provided by Costa Rica, a sampling design for estimating the species composition of the catch of NPG vessels will be developed. Currently, 100% of landings in Costa Rica are monitored for species composition and total catch amounts.

The main results from this pilot study will be sampling designs which can be implemented as part of a long-term sampling program to monitor the shark fisheries in Central America (see Proposal C.4.b). However, it is important to consider that an initial phase of such program should focus on assessing the practicalities of the implementation and validating the assumptions of the proposed sampling designs, which may lead to fine tuning of the sampling protocols for the long term. Additionally, alternatives for increasing the quality and quantity of data available should be explored; particularly the ones not increasing the sampling effort (i.e. number of samplers) like logbooks for vessels of the PNG fleet.

ACKNOWLEDGMENTS

We acknowledge the support of the Technical links from each Central American country (ARAP, CENDEPESCA, DIPESCA, INCOPESCA, INPESCA) in the completion of this stage of the project. We also extend a special thank you to the Central American longline fishing sector whose motivation and willingness to collaborate provided this project with invaluable information leading to a successful completion of the project objectives.

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Chang, S-K., Lin, T-T., Lin, G-H., Chang, H-Y., and Hsieh, C-L. 2009. How to collect verifiable length data on tuna from photographs: an approach for sample vessels. – ICES Journal of Marine Science, 66: 907–915.

FIGURE 1. Unloading site in mangroves.
FIGURA 1. Sitio de descarga en manglares.

FIGURE 2. Landing site found during site visit.
FIGURA 2. Sitio de desembarque encontrado durante las visitas.

FIGURE 3. Sites dedicated to purposes other than fishing.
FIGURA 3. Sitios dedicados a propósitos diferentes a la pesca.

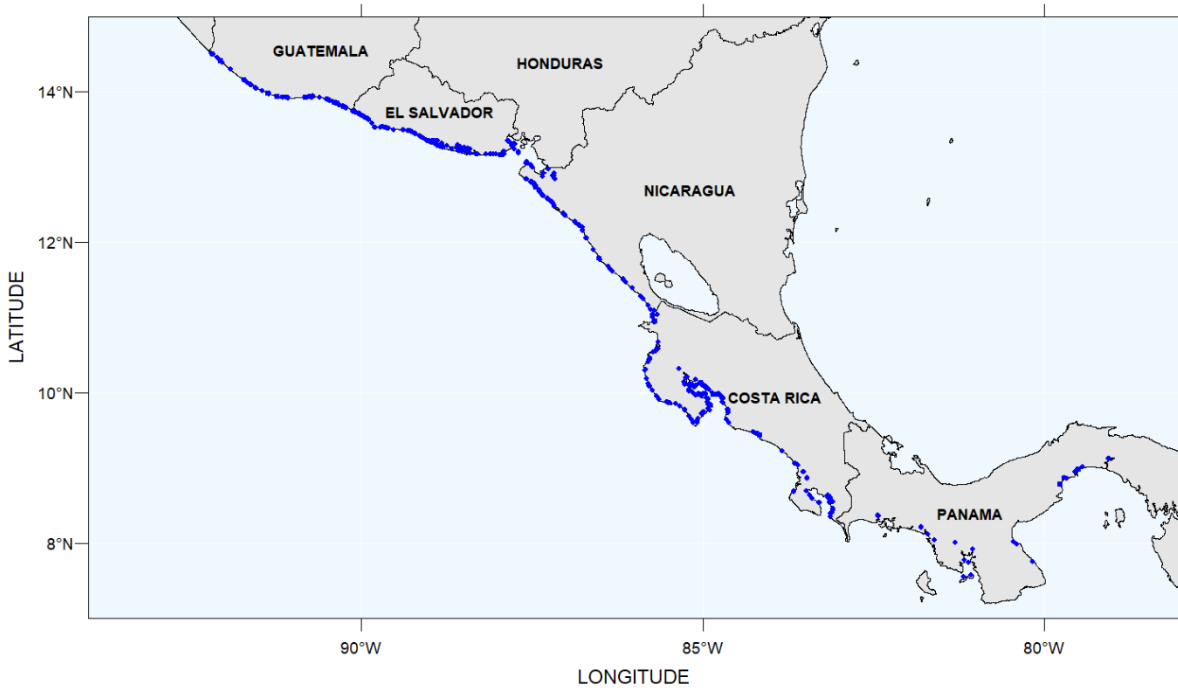

FIGURE 4. Landing sites identified under sub-tasks 1.1 and 1.2.
FIGURA 4. Sitios de desembarque identificados durante las sub-tareas 1.1 y 1.2.

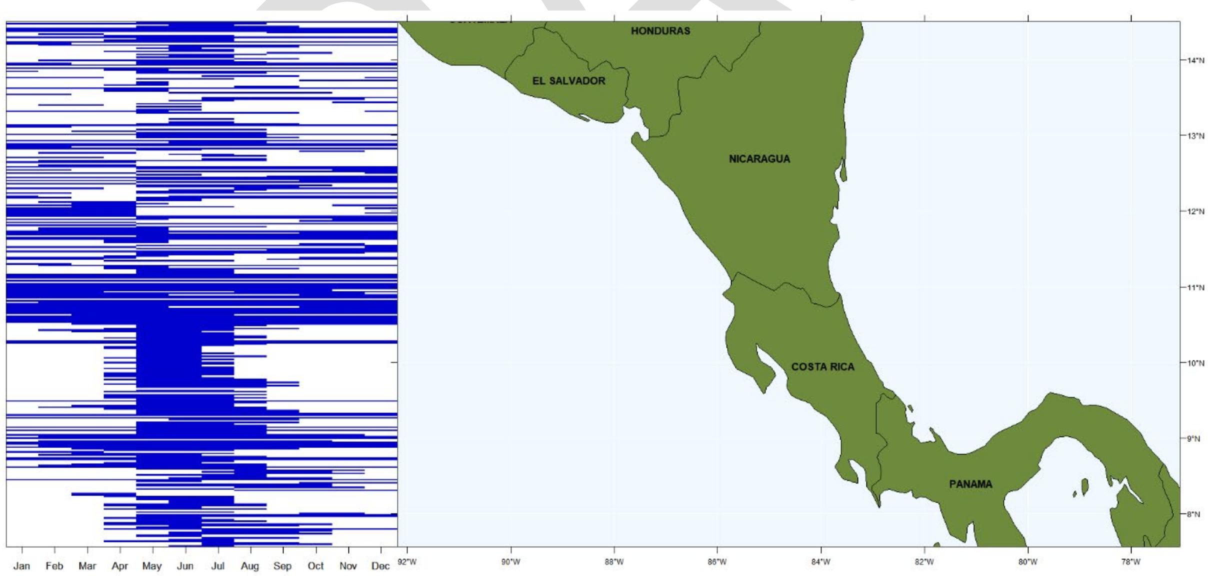

FIGURE 5. Shark fisheries seasonality. The blue area indicates shark landings reported at the site corresponding the latitude observed in the map.

FIGURA 5. Estacionalidad de las pesquerías de tiburones. El área azul indica los desembarques de tiburones reportados en los sitios correspondientes con a latitud observada en el mapa.

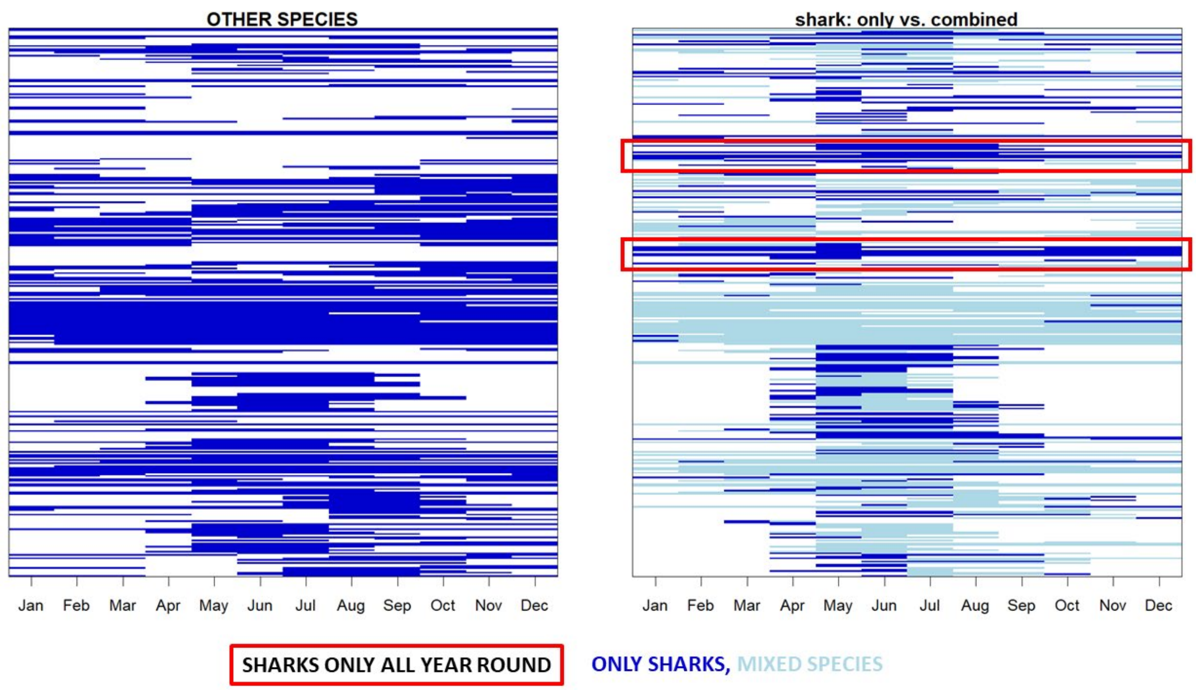

FIGURE 6. Fishing seasonality. In the left panel, the blue area indicates landings for species other than sharks. In the right panel, colored areas indicate shark landings reported at the site as in Figure 5, but distinguishing when landings are primary sharks (blue) or mixed with other species (light blue). The order of the landing sites (north at the top) match the order shown in Figure 5.

FIGURA 6. Estacionalidad de la pesca. En el panel de la izquierda, el área azul indica los desembarques de especies diferentes de los tiburones. En el panel derecho, las áreas coloreadas indican las capturas de tiburones reportadas en el sitio, como en la Figura 5, pero diferenciando cuando los desembarques son principalmente tiburones (azul) o en combinación con otras especies (celeste). El orden de los sitios de desembarque (norte arriba) concuerdan con el orden mostrado en la Figura 5.

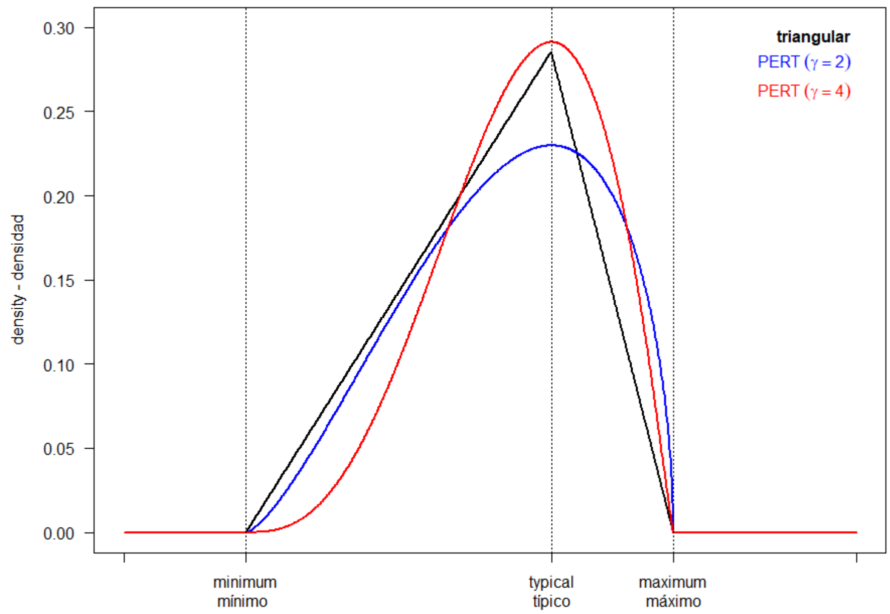

FIGURE 7. Examples of the distributions (triangular and PERT) used in the Monte Carlo simulations, for the same “three-point” estimates. See details in the text.

FIGURA 7. Ejemplo de las distribuciones (triangular y PERT) usadas en las simulaciones de Monte Carlo, para los mismo estimados de “tres puntos”. Ver los detalles en el texto.

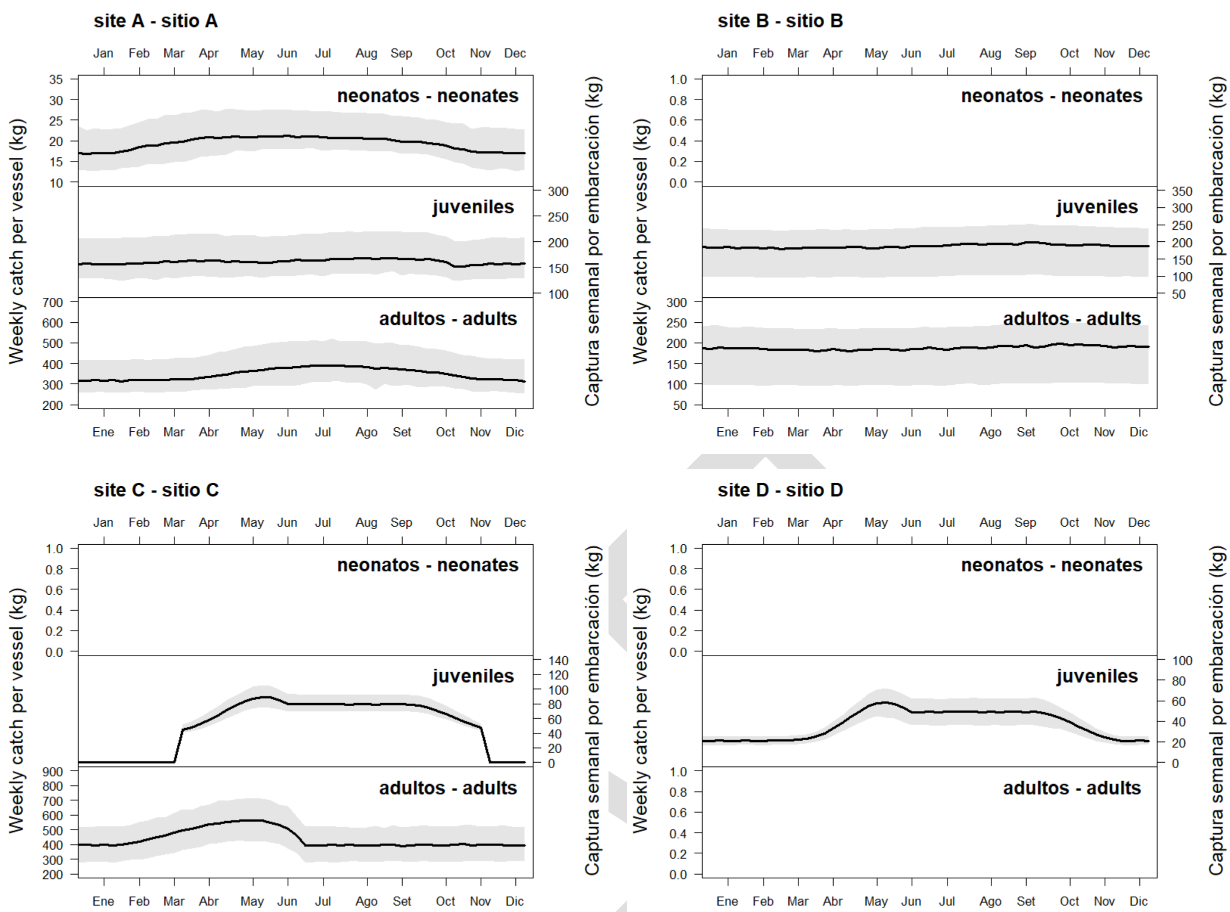

FIGURE 8. Seasonality of the landings of silky sharks (*Carcharhinus falsiformis*) by life stage (neonates, juveniles and adults) for four landing sites. Solid lines represent the mean of the catch and grey bands the 90% confidence interval based on Monte Carlo simulations.

FIGURA 8. Estacionalidad de los desembarques de tiburón sedoso (*Carcharhinus falsiformis*) por estadio (neonatos, juveniles y adultos) para cuatro sitios de desembarque. Las líneas sólidas representan la media de las capturas y las bandas grises el intervalo de confianza al 90% basado en las simulaciones de Monte Carlo.

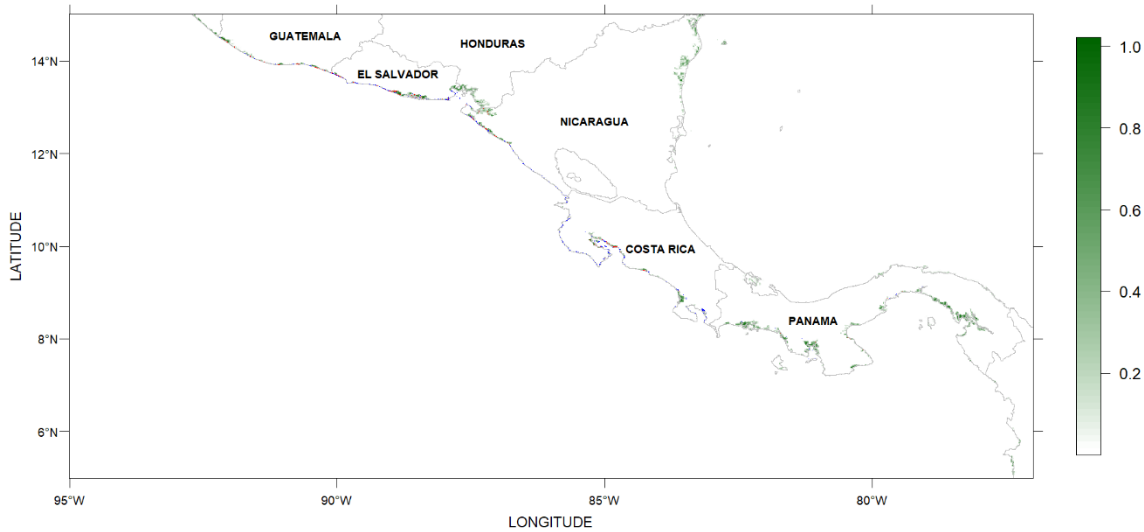

FIGURE 9. Landing sites (red, blue) and mangrove coverage (green). Landing sites in areas with more than 10% of mangrove coverage were classified as mangrove sites (red); the remaining landing sites were classified as beach sites (blue).

FIGURA 9. Sitios de desembarque (rojo, azul) y cobertura de manglares (verde). Los sitios de desembarque con más de 10% de cobertura fueron clasificados como sitios de manglar (rojo), el resto de sitios de desembarque fueron clasificados como sitio de playa (azul).

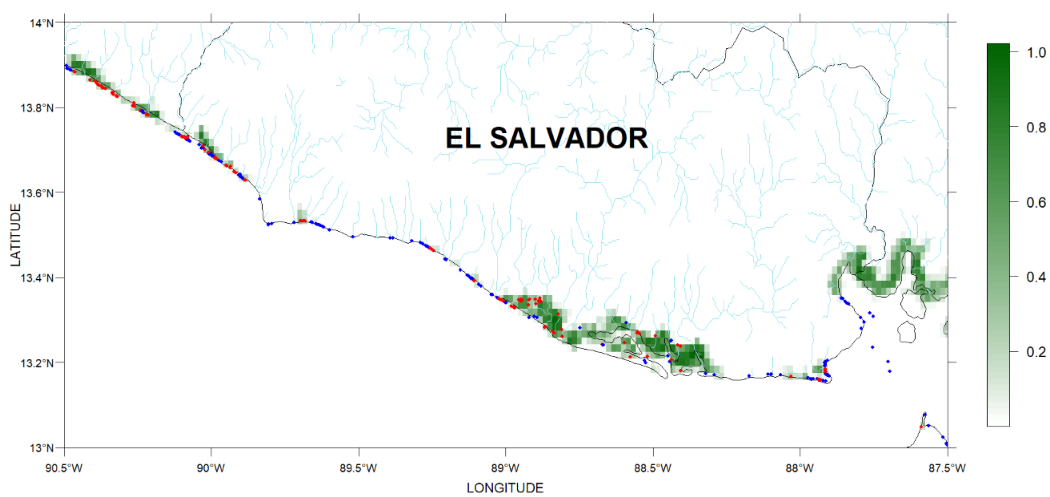

FIGURE 10. Landing sites, mangrove coverage (green) and rivers in El Salvador. Landing sites in areas with more than 10% of mangrove coverage were classified as mangrove sites (red); the remaining landing sites were classified as beach sites (blue).

FIGURA 10. Sitios de desembarque, cobertura de manglares (verde) y ríos en El Salvador. Los sitios de desembarque con más de 10% de cobertura fueron clasificados como sitios de manglar (rojo), el resto de sitios de desembarque fueron clasificados como sitio de playa (azul).

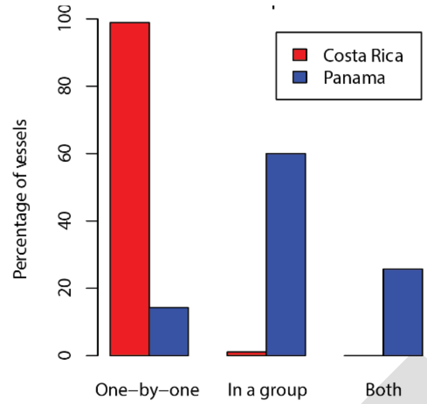

FIGURE 11. Unloading methods for sharks by the NPG fleets of Costa Rica and Panama.
FIGURA 11. Métodos de descarga para tiburones por la flota NPG de Costa Rica y Panamá.

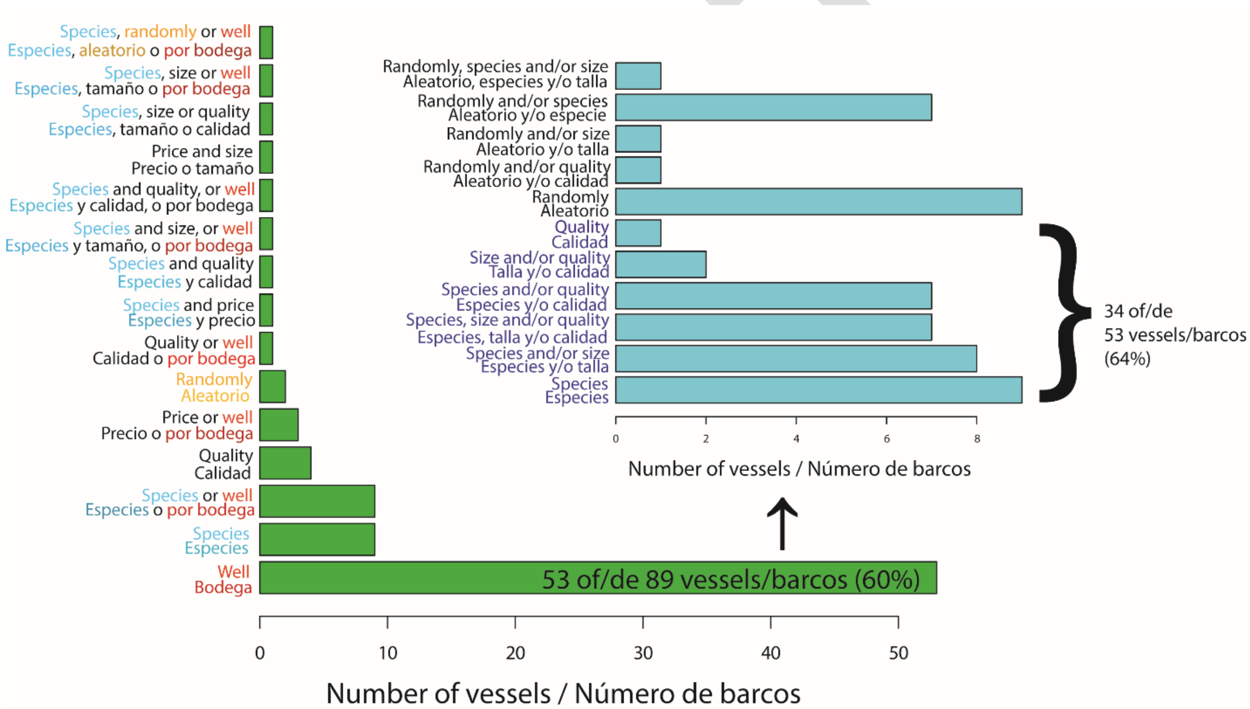

FIGURE 12. Frequency of unloading (main figure) and loading (inset) methods used by NPG vessels in Costa Rica.
FIGURA 12. Frecuencia de métodos de descarga (figura principal) y carga (recuadro) usados por la flota NPG en Costa Rica.

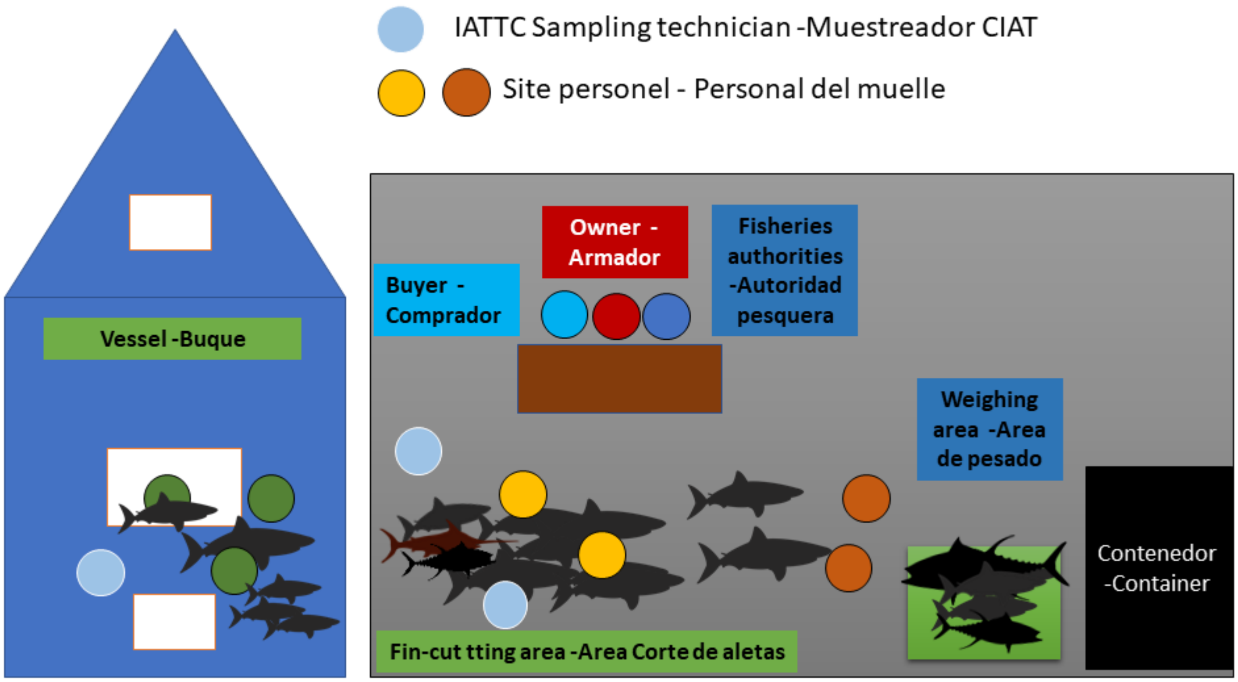

FIGURE 13. Schematic of super-sampling for 'one-by-one' unloading.
FIGURA 13. Esquema de super-muestreo para descarga "uno por uno".

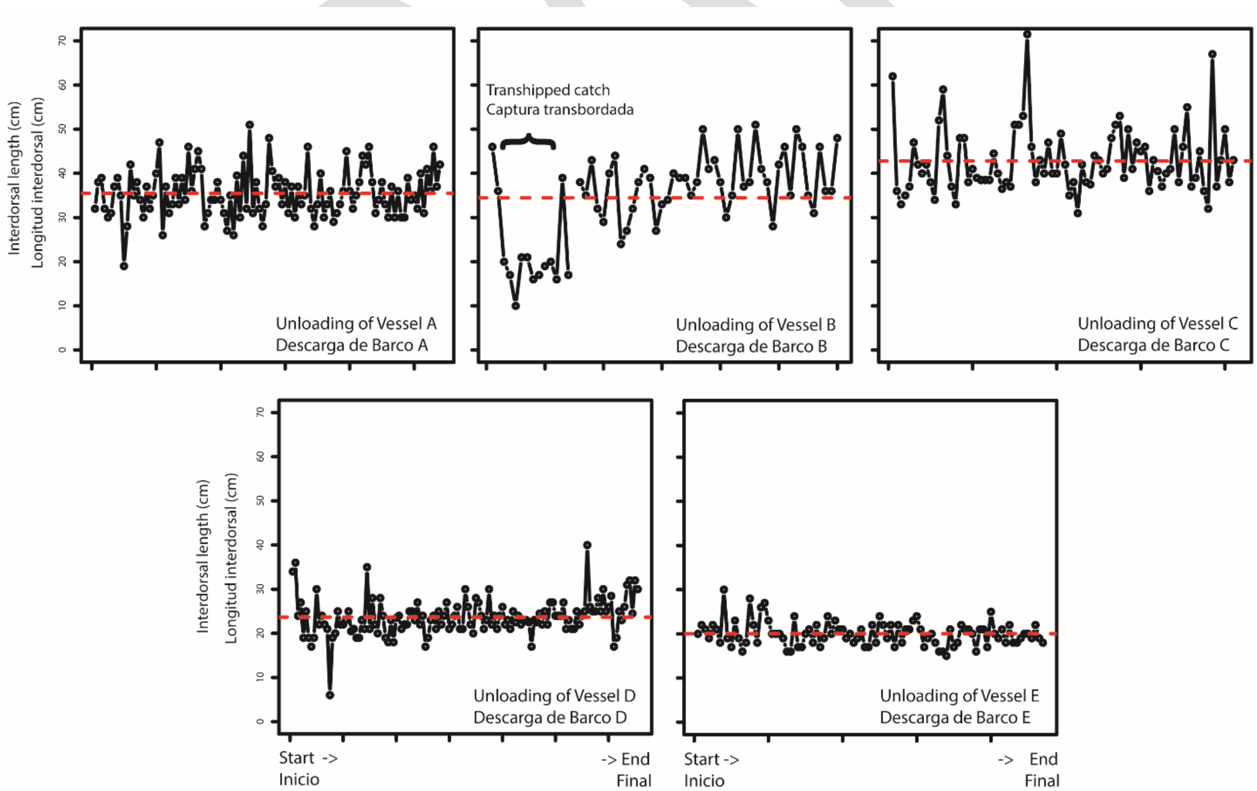

FIGURE 14. LID of silky sharks (cm), according to the order in which they were unloaded from the vessel, for 5 of the 6 super-samples collected with the initial super-sampling protocol.

FIGURA 14. LID del tiburón sedoso (cm), de acuerdo al orden en que fueron descargados de las embarcaciones, para 5 de 6 de los supermuestras colectados con el protocolo de supermuestreo inicial.

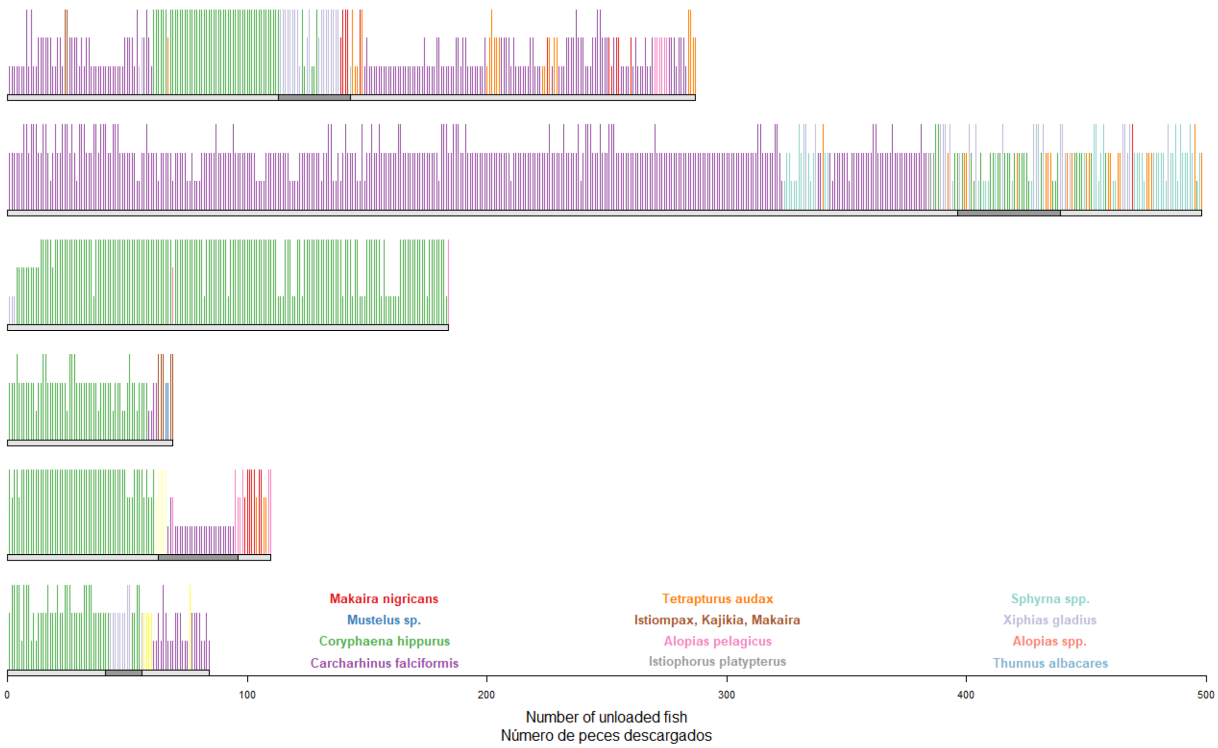

FIGURE 15. Species and size composition of the 6 super-samples collected with the simplified protocol, according to the order in which they were unloaded from the vessel. Color codes species and the vertical size of the bar the weight class (see Table 11). The gray and black horizontal bar at the bottom of each super-sample indicates the "unloading blocks" that were identified (see text).

FIGURA 15. Especies y composición de tamaños de 6 de los supermuestras colectadas con el protocolo simplificado, de acuerdo al orden en que fueron descargados de la embarcación. El color representa las especies y el tamaño de la barra vertical la categoría de peso (ver Tabla 11). Las barras horizontales negras y grises en la parte inferior de cada supermuestra indica los "bloques de descarga" que fueron identificados (ver texto).

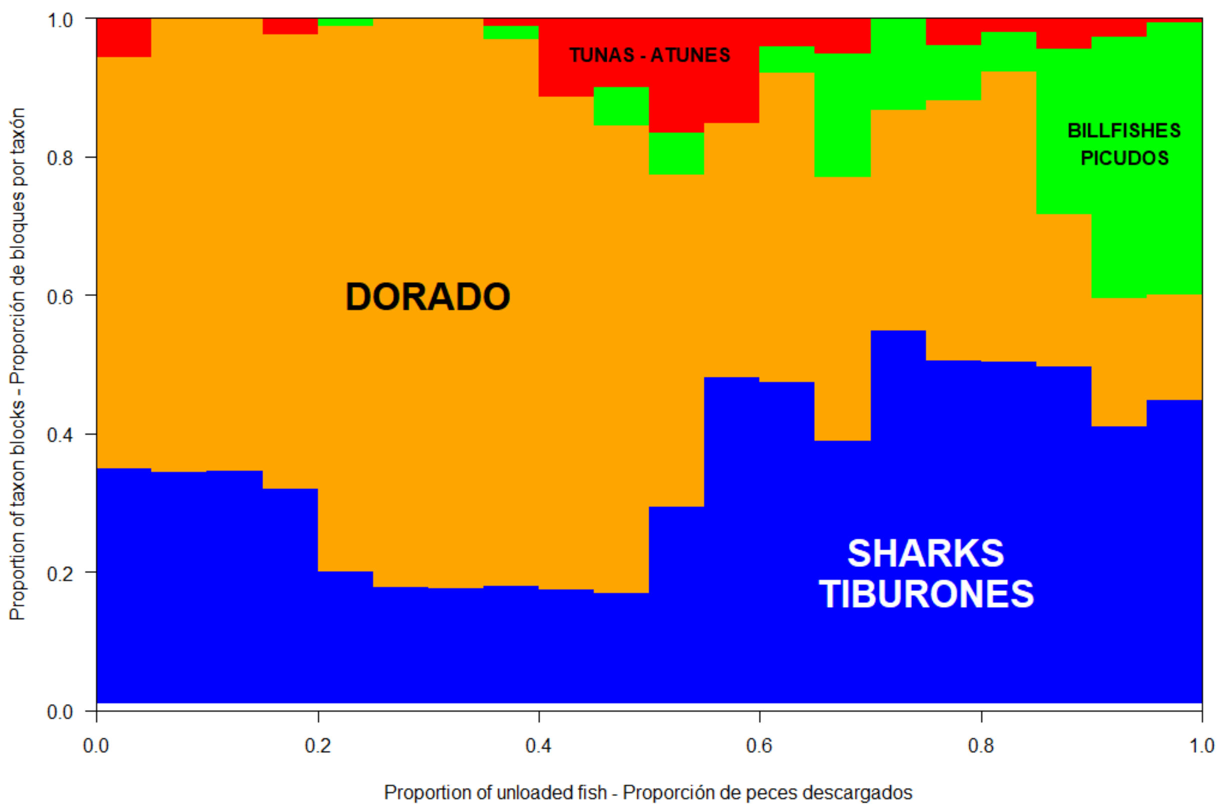

FIGURE 16. Average species composition of the six unloadings shown in Figure 8, in 5% fractions, from the start to the end of unloading. The x-axis corresponds to the timeline of unloading, from a proportion of 0 (the start) to a proportion of 1 (the end).

FIGURA 16. Composición de especies promedio de las seis descargas mostradas en la Figura 8, en fracciones de 5%, del inicio al final de la descarga. El eje x corresponde a la línea de tiempo de la descarga, desde la proporción 0 (inicio) hasta la proporción 1 (final).

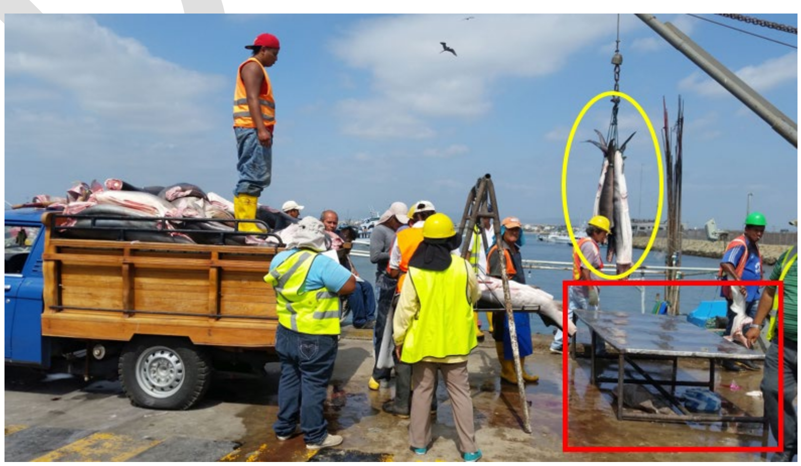

FIGURE 17. An example of a 'group' unloading.

FIGURA 17. Ejemplo de descarga “en grupo”.

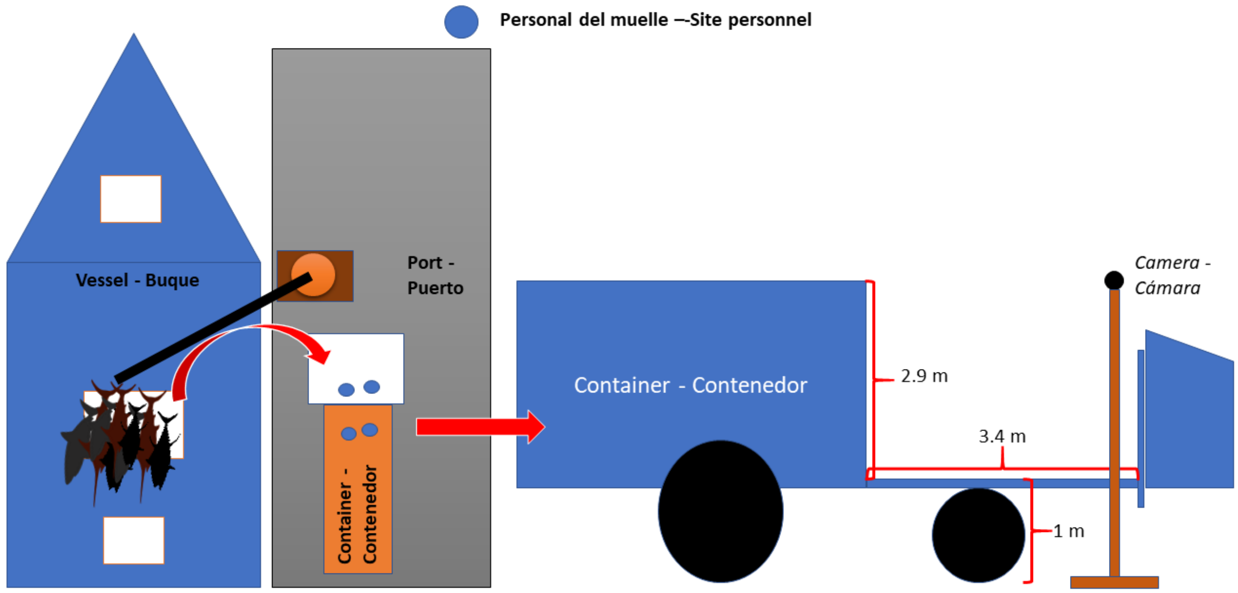

FIGURE 18. Schematic of super-sampling for ‘group’ unloading.
FIGURA 18. Esquema del supermuestreo para la descarga “en grupo”.

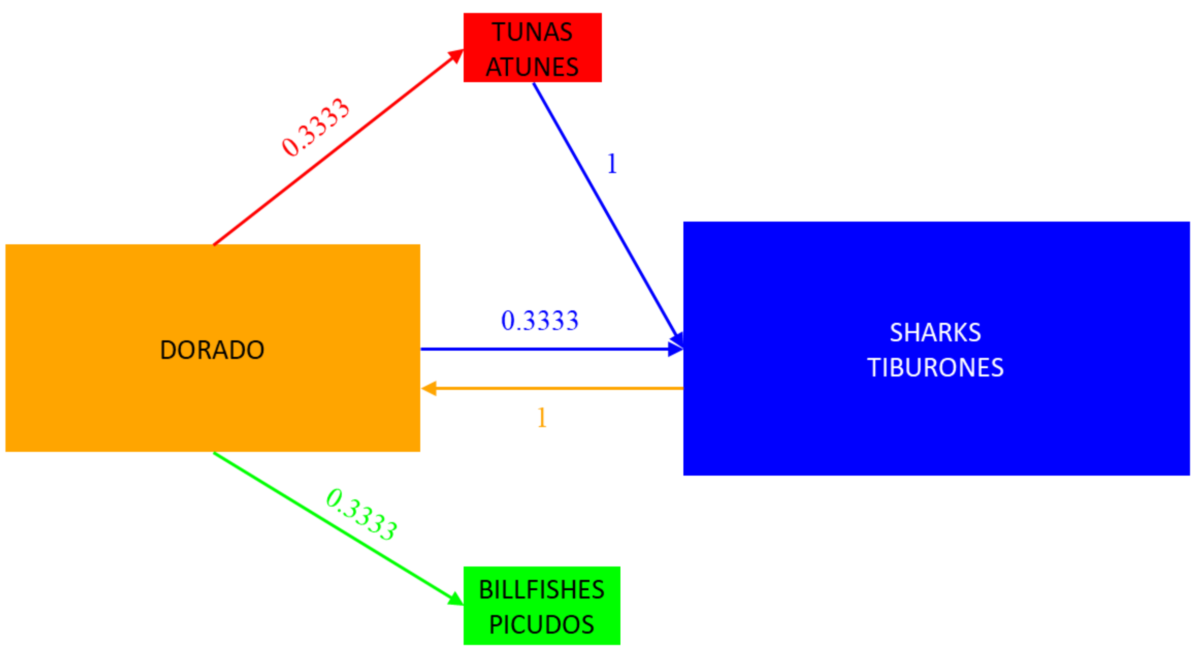

FIGURE 19. Diagram representing the transition between taxon blocks. The size of the box is proportional to the estimated proportion of fish in the catch (in numbers) and the arrows show the probability of jumping to other unloading blocks, the color representing the next unloading block.

FIGURA 19. Diagrama representando la transición entre bloques de taxones. El tamaño de la caja es proporcional a la proporción estimada de los peces en la captura (en número) y las flechas muestran la probabilidad de saltar a otro bloque de descarga, el color representando el siguiente bloque de descarga.

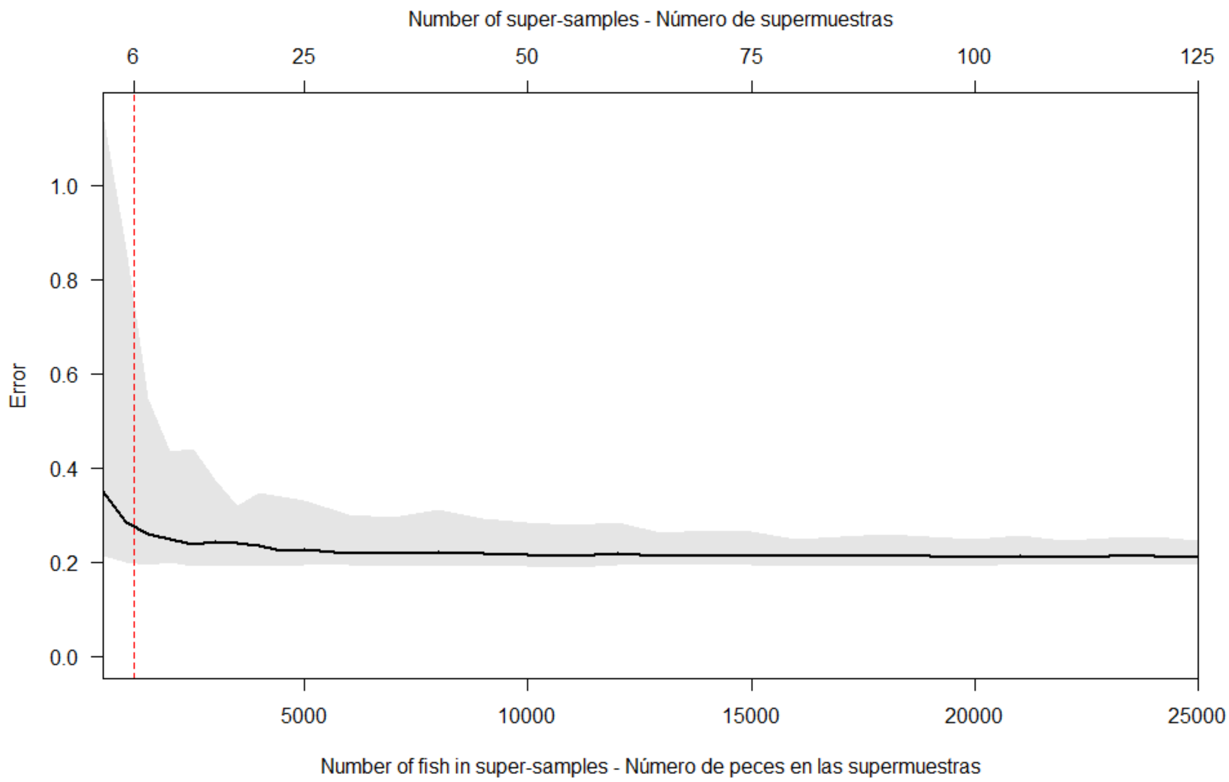

FIGURE 20. Estimation error for the SMC (solid black line), and estimation error variance (shaded gray region), as a function of the number of super-samples and the number of fishes in the super-sample. The dashed red line indicates the number of super-samples currently available.

FIGURA 20. Estimación del error para el CMS (línea negra sólida), y varianza del error en la estimación (área gris), como función del número de supermuestras y el número de pescados en la supermuestra. La línea guionada roja indica el número de supermuestras actualmente disponibles.

TABLE 1. Fishing localities and landing sites (identified from historical data, satellite imagery and after in situ verification), in total and with shark fisheries.
TABLA 1. Localidades pesqueras y sitios de desembarque (identificados a partir de datos históricos, imágenes satelitales y después de las verificaciones *in situ*), en total y con pesquerías de tiburones.

	Fishing localities – Localidades pesqueras		Landing sites – Sitios de desembarque	
	Total	With shark landings – Con desembarques de tiburones	Total	With shark landings – Con desembarques de tiburones
Costa Rica	121	41	152	102
El Salvador	89	55	244	183
Guatemala	51	32	182	133
Nicaragua	39	34	149	109
Panama	39	36	68	52
Total	**339**	**198**	**795**	**579**

TABLE 2. Total number of PNG vessels by country and data source. (*: data in process of analysis, see text).
TABLA 2. Número total de embarcaciones PNG por país y fuente de datos. (*: datos en proceso de análisis, ver texto).

	Data source – Fuente de datos			
	Registry - Registros	Satellite - Satélite	Sampling technicians - Muestreadores	Fishers - Pescadores
Costa Rica	1,653	1,064	312	1,545
El Salvador	2,926	2,213	2,770	2,448
Guatemala	1,395	1,193	662	974
Nicaragua	1,913	804	1,239	1,128
Panama	*	419	930	3071
Total	**7,887**	**5,693**	**5,913**	**9,166**

TABLE 3. Landing site characteristics collected in the fisher interviews.
TABLA 3. Características del sitio de desembarque colectados en las entrevistas a los pescadores.

Information type	Variables recorded
Vessels	Total number observed while conducting the interview; number reported by fishers.
Effort	Type of motor and horse power, range (m), number of active vessels, average number of fishing days per vessel, number of rest days between fishing trips, number of fishers per vessel.
Fishing gear	Longline: number of sets, length of the mainline, hooks (number, type, size), effective fishing days, bait type, vertical position of longline in the water column, use of steel leaders. Gillnet: number of sets, length and depth of the net, vertical position of the net in the water column, mesh size.
Catch	Main species landed and type of catch processing, and differences in these by season (dry *versus* rainy).

TABLE 4. Percent use of gears in the PNG fleet, by season.
TABLA 4. Porcentaje de uso de artes de pesca en la flota PNG, por temporada.

%	Season - Temporada		Overall - Total
	Dry –Seca	Rainy –Lluviosa	
Gillnet – Red agallera	66	63	65
Longline – Palangre	17	19	18
Handline – Línea de mano	17	18	17
Purse seine - Cerco	≈ 0.1	≈ 0.1	≈ 0.1

TABLE 5. Variables collected during the second set of interviews on catch and effort.
TABLA 5. Variables colectadas durante el segundo grupo de entrevistas sobre captura y esfuerzo.

Information type	Variables recorded
Fleet and crew	Number of vessels (present and past), number of crew and other operators at the landing site, number of buyers with whom the vessel worked during the past year.
Effort	Number of trips per week by environmental conditions (good; bad) and season (dry; rainy).
Catch	Volume of landings per trip (minimum, maximum and typical) by season, and for sharks, also by life stage (neonate, juvenile and adult); seasonality of the landings (beginning, end and peak month); fishing area (distance to the coast and depth), type of processing of the catch and common name of the species in the unloading site.

TABLE 6. Examples of rules to be tested for sampling the PNG fleet.
TABLA 6. Ejemplos de reglas a ser evaluadas para el muestreo de la flota PNG.

Rule	Parameterization
The observer remains in the same fishing locality for *n* weeks	*n*, the number of weeks before potentially moving to another fishing locality.
The observer travels to another fishing locality	A distribution based on distance separating fishing localities (e.g. more likely to travel to a closer place) and importance (e.g. more likely to travel to a locality with bigger average shark landings).
The observer travels to different landing sites within the same fishing locality	Random selection of landing sites, considering the number of vessels at each site.

TABLE 7. NPG vessels and landing sites surveyed.

TABLA 7. Barcos NPG y sitios de desembarque entrevistados.

	Vessels surveyed – Barcos entrevistados	Fishing locality – Localidad pesquera	Landing sites – Sitios de desembarque
Costa Rica (119)	112	Puntarenas	10
	3	Chacarita	1
	4	Boca Vieja	1
Panama (62)	36	Puerto Pedregal	5
	1	Puerto Remedios	1
	1	Puerto Mutis	1
	8	Puerto Panamá	1
	1	Puerto Juan Díaz	1
	11	Puerto Vacamonte	1
	3	Puerto Mensabé	1
	1	Puerto Coquira	2
Total	**181**	**11**	**25**

TABLE 8. Preservation methods used by NPG vessels for shark catches in Costa Rica and Panama.
TABLA 8. Métodos de conservación usados por la flota NPG para la captura de tiburones en Costa Rica y Panamá.

	Preservation method – Método de conservación	Vessels - Barcos	
		Number – Número	%
Costa Rica (88)	Frozen	13	17
	Fresh/chilled	75	83
Panama (62)	Frozen	31	50
	Fresh/chilled	31	50

TABLE 9. Weighing methods used for shark catches by NPG vessels in Costa Rica and Panama.
TABLA 9. Métodos de pesaje usados para las capturas de tiburones por la flota NPG en Costa Rica y Panamá.

	Weighing method – Método de pesaje	Vessels - Barcos	
		Number – Número	%
Costa Rica (82)	One-by-one	13	16
	In groups	63	77
	Both	6	7
Panama (34)	One-by-one	0	0
	In groups	31	91
	Both	3	9

TABLE 10. Time (minutes) available for measuring fish in Costa Rica and Panama, by unloading method (N.A.: data not available).

TABLA 10. Tiempo (minutos) disponible para medir peces en Costa Rica y Panamá, según método de descarga (N.A.: datos no disponibles).

	Preservation method		Unloading method	
			One-by-one	Group
Costa Rica	Fresh/chilled	Before weighing	4	10
		After weighing	0	0
	Frozen	Before weighing	1	10
		After weighing	N.A.	0
Panama	Fresh/chilled	Before weighing	2	4
		After weighing	1	4
	Frozen	Before weighing	4	N.A.
		After weighing	2	N.A.

TABLE 11. Weight categories used in the super-sampling.
TABLA 11. Categorías de peso usadas en el supermuestreo.

Taxon	Small (kg) - Pequeños (kg)	Medium (kg) - Medianos (kg)	Large (kg) - Grandes (kg)
Sharks – Tiburones	<25	25-32	>32
Dorado	<3	3-6	>6
Billfishes – Picudos	<25	25-45	>45
Tunas – Atunes	<20	20-30	>30

TABLE 12. Description of the identified unloading blocks. Main species (based on proportion in number) are indicated. Any other species present is considered a secondary species for that block. See the text for details.
TABLA 12. Descripción de los bloques de descarga identificados. La especie principal (basada en proporción en número) son indicadas. Cualquier otra especie presente es considerada una espceie secundaria para ese bloque. Ver el texto para los detalles.

Unloading block – Bloque de descarga	Main species – Especie principal	Secondary species – Especies secundarias
DORADO	96.1% *Coryphaena hippurus* (DOL)	*Mustelus spp., Carcharhinus falciformis, Tetrapturus audax, Alopias pelagicus, Istiophorus platypterus, Xiphias gladius, Alopias spp., Thunnus albacares*
SHARKS – TIBURONES	86.7% *Carcharhinus falciformis* (FAL)	*Makaira nigricans, Coryphaena hippurus, Tetrapturus audax, Istiompax spp., Kajikia spp., Makaira spp., Istiophorus platypterus, Sphyrna spp., Xiphias gladius, Alopias spp., Thunnus albacares*
TUNAS – ATUNES	63.4% *Thunnus albacares* (YFT)	*Makaira nigricans, Coryphaena hippurus, Xiphias gladius*
BILLFISHES - PICUDOS	51.9% *Xiphias gladius* (SWO)	*Makaira nigricans, Coryphaena hippurus, Tetrapturus audax, Thunnus albacares*

TABLE 13. Parameters estimated for the taxon block transition matrix. Results are based on the six

super-samples shown in Figure 15.

TABLA 13. Parametros estimados para la matriz de transición de bloques por taxón. Los resultados están basados en las seis supermuestras mostradas en la Figura 15.

Taxon block – Bloque por taxón	Proportion - Proporción	Probability of jump – Probabilidad de salto
DORADO	36.20%	SHARKS (33.33%), TUNA (33.33%), BILLFISH (33.33%) TIBURONES(33.33%), ATUNES (33.33%), PICUDOS (33.33%)
SHARKS – TIBURONES	54.39%	DORADO (100%)
TUNAS – ATUNES	4.07%	SHARKS (100%) – TIBURONES (100%)
BILLFISHES - PICUDOS	5.34%	Terminal group (no transitions observed to other groups) Grupo terminal (no se observaron transiciones a otros grupos).

APPENDIX. PROTOTYPE OF SAMPLING FORM FOR THE CATCH COMPOSITION AND EFFORT OF THE PNG FLEET.

Formulario de muestreo para la flota de "Pangas" de Centroamérica – N° _______

1. Información General

Nombre del observador: ______________________________ Código del observador: __________
Localidad pesquera ID: __________ Sitio de Descarga ID: ___________ Fecha: dd/mm/aaaa Hora: ________
Embarcación: __________________ Matrícula: ____________________ Tipo: Panga/Mediana/Avanzada
Fecha zarpe: dd/mm/aaaa – HH:MM Fecha arribo: dd/mm/aaaa – HH:MM N° viajes semana pasada: _________
Número de tripulantes: __________ Número de fileteros: __________ Comprador: __________________

2. Proceso de la descarga

	Total	Descarga	Fileteo	Pesaje
Hora inicio				
Hora fin				

3. Área de pesca y condiciones ambientales

¿Frente a qué playa pesco?	Artes usados	Distancia a la costa	Latitud	Longitud	Profundidad (todas las artes)	
					Mínima	Máxima
	LL | GN | LHP | PS	km | mn			m | bz	m | bz

Condiciones ambientales durante la faena de pesca (0: malas, 1: buenas): ☐
Si fueron malas, indique: Viento ☐ Marea ☐ Tormenta ☐ Otros: ______________________

4. Captura.

Especie objetivo: ______________ Calificación de la captura total: ☐ (1: muy mala – 2: mala – 3: normal – 4: buena – 5: muy buena)

Especie	Código FAO	CCE[1]	Manifiesto de descarga					Descarga		
			Número	Peso kg | lb	Estadios capturados			Número	Peso kg | lb	Tipo de corte
					Neonato	Juv.	Adulto			
	DOL									
	FAL							(Tabla 5)		
	SPL							(Tabla 5)		

5. Número de cuerpos en la descarga por estadios (tiburones y rayas)

	Especie (código FAO)							
	FAL	SPL						
0 – Neonatos								
1 – Juveniles								
2 - Adultos								
3- Hembras grávidas[2]								

[1] CCE: Calificación de la captura por especie. 1: muy mala – 2: mala – 3: normal – 4: buena – 5: muy buena.
[2] Realizar siempre la biometría para las hembras grávidas, indicar en la columna de observaciones ("Obs.") el número de crías si es posible o AB si abortó durante la captura y las crías fueron descartadas o no pueden ser contadas.

6. Esfuerzo

PALANGRE	Carnada: 1. ______________(%) 2. ______________(%) 3. ______________(%)						
Reinal de acero	N° de lances	N° de anzuelos	Tipo de anzuelo	Profundidad (m | bz)		Duración faena	
				MIN	MAX	Total	Efectiva
SÍ [ ] NO [ ]							
RED AGALLERA	N° de lances: ______ Longitud: _______ m Alto: ________ m Luz de malla: _____/_____/_____ pulgadas						
LÍNEA DE MANO	N° de lances: ______ N° anzuelos: ______ Carnada: 1. __________(%) 2. __________(%) 3. __________(%)						

7. Biometría

N°	Cód. FAO	Sexo	Estadio	Madurez	Longitud				Peso (kg)				Obs.
					LT/LD[3]	LP/AD[4]	LID[5]	LIC[5]	Total	Vísceras	Cabeza	Aletas	
01		[M] [H]											
02		[M] [H]											
03		[M] [H]											
04		[M] [H]											
05		[M] [H]											
06		[M] [H]											
07		[M] [H]											
08		[M] [H]											
09		[M] [H]											
10		[M] [H]											
11		[M] [H]											
12		[M] [H]											
13		[M] [H]											
14		[M] [H]											
15		[M] [H]											
16		[M] [H]											
17		[M] [H]											
18		[M] [H]											
19		[M] [H]											
20		[M] [H]											
21		[M] [H]											
22		[M] [H]											
23		[M] [H]											
24		[M] [H]											
25		[M] [H]											
26		[M] [H]											
27		[M] [H]											
28		[M] [H]											
29		[M] [H]											
30		[M] [H]											
31		[M] [H]											
32		[M] [H]											
33		[M] [H]											
34		[M] [H]											
35		[M] [H]											
36		[M] [H]											
37		[M] [H]											
38		[M] [H]											
39		[M] [H]											
40		[M] [H]											
41		[M] [H]											
42		[M] [H]											

[3] Longitud total (LT, cm) para tiburones, longitud de disco (LD, cm) para rayas.
[4] Longitud precaudal (LP, cm) para tiburones, ancho de disco (AD, cm) para rayas.
[5] Longitud interdorsal (LID, cm) y longitud interna del clasper (LIC, mm) para tiburones.