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## SHARK SAMPLING PROGRAM FOR CENTRAL AMERICA

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**SUMMARY**

Since 2014, the IATTC staff has carried out three phases of collaborative research with OSPESCA and IATTC's Central American CPCs to develop a robust sampling methodology to improve data collection for shark fisheries[1] in Central American eastern Pacific Ocean (EPO) states. This work, funded by the FAO-GEF ABNJ project, IATTC capacity building fund, and the European Union, was completed in December 2021. The first phase of this work involved using satellite imagery to identify potential landing sites for small coastal vessels that primarily target sharks. The second phase was completed in 2019 and involved visiting the sites identified in phase 1 to verify the presence of fishing activity and to conduct an on-site fisher recall survey where respondents were asked to complete a questionairre pertaining to their fishing activities undertaken in the previous 12 months (2018) (see SAC-11-13 and references therein; Lennert-Cody et al. 2022). The third phase was undertaken in 2020–2021 and involved an on-site intercept survey whereby IATTC sampling technicians visited each verified shark fishing site and intercepted fishers as they completed their fishing trips to collect data pertaining to vessel and gear characteristics, and species and length composition of landed shark and non-shark species. The results from preliminary analyses of data collected in phase 3 were presented in IATTC-98b-02c. One of the core objectives of this project was to design a sampling program that could be used in the long-term to enable estimation of the total catch of sharks by species in the EPO by small coastal based vessels from the surveyed Central American countries (i.e., Costa Rica, El Salvador, Guatemala, Nicaragua and Panama). This document builds on the anecdotal and empirical information from the three phases of the project to present a general sampling protocol for estimating total catches of sharks by landing site, and discusses options for improving estimation of total shark catches by country. While the protocol focused on silky and hammerhead sharks, which were identified to be taxa of priority for IATTC management (SAC-11-13), it can be adapted to sample other shark and non-shark species.

The large number of landing sites and the dynamic nature of vessel and fishing activities and access to

[1] In the context of this proposal, a "shark fishery" is defined as any fishery in which sharks are caught, whether as target species or bycatch. It is recognized that these fisheries are multispecies and interact with various species/groups of large pelagic fishes (*e.g.,* tuna, billfish, dorado, sharks). Although with a target focus on sharks, it is envisaged that the proposed program will be expanded to include other species to fulfill various mandates under the Antigua Convention.

these sites makes surveying shark catches in this region extremely challenging. Any survey method used must make tradeoffs between precision of the estimates of total catch and costs and practicality of the program. For example, given finite survey resources, sampling could be conducted intensively at a few landing sites, or sampling could be spread lightly over many landing sites. Prior work by the IATTC in this region identified and characterized sites and fishing practices to develop an understanding of the regions' fisheries. This work indicated that catches of silky sharks appear to be concentrated at a relatively small number of sites. As such, the specific protocol presented here focused on more intensive sampling of these key silky shark sites, while dispersing survey effort to other sites that, based on prior studies, were believed to be have lower catches of silky sharks.

The protocol presented here is designed to provide reliable estimates of catch at sampled sites given the observed variability in day-to-day shark landings througout the region. However, designing a protocol for estimating total catch throughout a region requires both a design for accurately sampling catch at individual sites (presented here), as well as a strategy for allocating sampling effort across sites given logistical and budgetary constraints (for which further research is needed). The most accurate strategy would be to apply the protocol presented here at every landing site. However, this is unlikely to be possible in many regions given the costs and barriers to consistently accessing large numbers of dispersed landing sites. The optimal number and location of sites to be sampled with the protocol presented here will depend then on the objectives of the program (e.g., the desired coefficient of variation on the estimates of total catch) and the rate at which the value added of sampling additional sites decreases relative to the accuracy of alternative methods for filling in the catches at un-sampled sites, such as design- or model-based estimators. A combination program designed to sample catches at some sites and covariates related to fishing operations, offloading practices, and site traits across all landing locations could facilitate the use of model-based approaches to fill in catches at unsampled sites in a cost-effective manner. Further research is needed to answer these questions in specific regions.

The specific recommendations for the sampling protocol to estimate total catches of silky and hammerhead sharks at primary sites are as follows:

i) Within each country, several regions should be defined, that taken together, are considered to represent a reasonable percent of the estimated total silky shark catch for the country, and/or encompass a collection of sites that are otherwise of interest. Each region should be sufficiently small such that sampling technicians can travel between a "home base" (e.g., a rented house) and sites to be sampled, using public transportation, in less than a day, thus ensuring that daily sampling trips are possible.

ii) The specific regions, and the number of sites per region, that are to be sampled will depend on the goals of the program and level of funding. The regions and sites identified to be of importance based on analysis of the 2020–2021 intercept survey data could serve as a starting point.

iii) Once regions have been defined, and the sites to be sampled determined, a multistage sampling protocol should be implemented at each site and stratified by week of the year. The stages would be: 1) day of the week; and, 2) trips (pangas) on a given day.

iv) For the first stage of the protocol, days of the week would be selected using simple random sampling, on a weekly basis. It is recommended that sampling take place four days per week at each site.

v) For the second stage of the protocol, pangas landing on each sampling day would be selected using simple random sampling. If this proves to be impractical, then systematic sampling from a random starting trip can be used to collect one systematic sample of trips for each day at each site. It is recommended that 10 trips per day be sampled on each day, per site.

This protocol is intended to allow for sampling to begin at specific sites, with the possibility of modifying and/or expanding the sampling program as funding permits. The protocol will generate data for estimation of total catch, and its variance, by week, at each sampled site. This specific protocol is not explicitly designed to support extrapolation from sampled sites to all unsampled sites of a country, but rather to produce reliable catch estimates for important sites, with possible extrapolation to nearby sites known to have similar fleet dynamics, using model-based estimation methods, if ancillary data for neighboring sites are available.

To sample a single site (also commonly called an "access point", a location where catch is landed that can be sampled in a day) under this protocol will require a team of two sampling technicians, at a cost of US$40K per site per year. This cost includes sampling techncians' salaries, per diem, lodging and equipment. Once more field experience is obtained sampling 10 trips per site per day, it may be determined that more than one site can be sampled by a team of two sampling techncians per day, taking into consideration factors such as the duration of landing periods, tides, and sampling technicians' travel times. The number of sites that would need to be sampled to achieve a desired level of accuracy in total catch estimates will vary depending on the spatio-temporal dynamics in the relative abundance of the species in question in a given region. For example, in Central America silky shark catches appear to be concentrated at a relatively small number of sites, whereas catches of hammerheads are more widespread.

The above recommendations for a general sampling protocol should be reevaluated after the first year of sampling to determine whether the level of stratification and the sampling frequencies should be modified to improve statistical efficiency of the protocol. This is particularly important because the COVID-19 pandemic affected both data collection and fishing activity during the 2020–2021 study, thereby affecting recommendations for sampling. Furthermore, the proposed sampling protocol has been designed primarily around silky sharks, despite the intercept survey suggesting that catches of hammerhead sharks may be more widespread than catches of silky sharks (SAC-14 INF-L). As such, the protocol would need to be modified for application to hammerheads, or other species of interest to the IATTC.

The number of sites required for sampling will also depend on the goals of the project. Obtaining an estimate of the total catch for use in a stock assessment may require that many sites be sampled to achieve an acceptable level of precision. However, with the level of funding assumed in this paper, a sampling program for collection of catch and effort data, and potentially biological data (SAC-14 INF-J) and/or tissue samples for Close Kin Mark Recapture (SAC-12-14), could be facilitated by sampling at a few sites per country, and expanded as additional funding becomes available and/or the goals of the program change. For example, the program could start by including sites that contributed around 30% of the catch per country, which would involve sampling between one to two regions within a country and between one to three sampling sites per region. To apply this approach in Central America would cost approximately US$400K. but would not be adequate for estimation of total catch by country. A program for estimation of total catch by country would require considerably more funding to sample more sites and regions, and would need to be complemented by an extensive survey of sites across all countries for collection of ancillary data to support catch estimation with model-based methods such as those presented in SAC-14 INF-L.

There is a great need to maintain continuity of data collection to generate key fisheries data required by the IATTC staff and IATTC CPCs to assess and manage shark species in the EPO. As such, the IATTC scientific staff recommends that the Commission supports the establishment of a long-term sampling program for shark fisheries in Central America. The implementation of such a program in Central America in 2023 would coincide with the initiation of a shark fishery data collection improvement in Mexico, Ecuador and Peru under a second phase of the ABNJ program, which began in early 2023. Establishing a Central American program would mean that there would be a shark monitoring program that would be spatially continuous along most of the EPO coastline, an outstanding initiative that exists nowhere else in the world.

## BACKGROUND

The IATTC has been involved in several projects since 2014 to develop a sampling methodology necessary to obtain reliable data from artisanal and commercial ("medium scale" and "advanced scale") fisheries that land sharks and rays throughout Central America. Such data are critical for assessing stock status of shark species in the EPO. 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 research aimed to improve data collection for shark catches in the EPO, specifically in Central America, where it is believed much of the EPO shark catch is landed. Phase 1 of this collaborative project between the IATTC and OSPESCA[2] spanned September 2014 to December 2018[3], during which time a long-term regional data collection program for sharks was developed. During Phase 1, the existing data available for these fisheries were identified and compiled, and recommendations formulated for improving data collection. Also, three workshops were held, on data collection, assessment methods for shark species, and designing a pilot sampling program. Based on the success of Phase 1, Phase 2 of the project was funded for the period January 2018 to December 2019 to further develop and test sampling designs in a pilot study that would serve as a framework for a regional program in Central America for the IATTC Members to consider. Phase 2 led to improvements in sampling designs for estimation of shark catches species composition for artisanal fisheries, as well as for size composition of catches in the medium and advanced scale longline fleets in Costa Rica (Lennert-Cody et al. 2022).

Owing to the success of this previous work, additional funding was provided by the European Union (EU) in 2020 to conduct on-site sampling of sharks by the coastal fleets to further evaluate logistical challenges, and modify sampling designs to collect representative catch and effort, of prioritized shark species. The survey also aimed to better identify temporal scales of variability that will affect sampling frequency and evaluate the stability of shark landings at individual sites, both for the purpose of improving previous recommendations on establishing a long-term shark sampling program for fisheries in Central America (Document IATTC-98-02c). This document presents results of the analysis of the 2020–2021 survey data and recommendations for a proposed general sampling protocol for sharks in Central American states, with a view to extend this protocol to South American countries.

## DATA

This study is based on data collected for the shark fisheries of five countries in Central America: Costa Rica (CRI), El Salvador (SLV), Guatemala (GTM), Nicaragua (NIC) and Panama (PAN). Data from two different surveys were used in this study, 1) an on-site retrospective, or 'recall', survey, and 2) an on-site intercept survey. Data from a fisher recall survey—where fishers recalled their fishing activities for the preceding 12-months—were used to prioritize sites for the subsequent on-site survey where sample data were collected from fishers intercepted at access points (or sites) at the conclusion of their individual fishing trips (SAC-11-13). On each visit to a selected sampling site, data on catch and effort were collected, and later used to refine sampling protocols for a proposed long-term sampling program, as well as to verify order-of-magnitude (OOM; SAC-14 INF-L) estimates of the catches of silky and hammerhead sharks obtained from the fisher recall survey.

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[2] Organización del Sector Pesquero y Acuícola del Istmo Centroamericano

[3] Initially, the contract was to expire on 23 September 2017; it was later extended through 2018.

*On-site fisher recall survey*

Fisher interview data were collected from 513 shark landing sites (Table 1) visited in the 2019 on-site recall survey (SAC-11-13). One of the purposes of this survey was to select sites at which to collect detailed operational, effort and catch data for sharks during 2020–2021 in a subsequent on-site intercept survey that would provide the basis for OOM estimates of shark catch, by species, for each country. The data collection procedure in the recall survey involved intercepting panga fishers at a selected sampling site and first seeking their participation and consent as respondents in an interview pertaining to their shark fishing activities. For each panga crew consenting to an interview, a questionnaire was completed with a single crew member—usually the captain—to recall aspects pertaining to their fishing activities in 2018. Data from 3,590 interviews (Table 2) were explored to better understand how catch, effort and operational characteristics varied among vessels, seasons, and sites (SAC-11-13, Appendix B). In particular, information on catch composition per trip, number of trips per panga per week, and number of pangas operating at each site were summarized in terms of typical values and ranges. For sharks, annual catch by species was estimated by fishers in weight (kg). The landings sites covered in the on-site intercept survey did not include sites for which there were accessibility issues identified by sampling technicians during the recall survey nor sites for which there were accessibility concerns previously identified by the relevant national fisheries authorities.

*On-site intercept survey (Sample data)*

To refine catch and effort sampling protocols for an on-site intercept survey to address logistical challenges that can only be identified through practical implementation, data were collected at a subset of shark landing sites in Central America, from August 2020 to December 2021. The study focused on sampling landing sites that the recall survey indicated were of importance for silky shark landings, but data were also collected for all other species landed at those sites. The information collected from individual pangas included the species composition of the catch for the completed trip, the number of trips made in the previous week, and the characteristics of the panga and the fishing gear used during the completed trip. Information was also collected from fishers as to the fishing area and environmental conditions, as well as biometric information for individual sharks, such as sex, length(s), and type of processing (e.g., dressed, headed, gutted). In addition, sampling technicians periodically visited as many of the main silky shark landing sites as possible to obtain counts of pangas, although due to time constraints this was generally not performed on the same days as catch and effort sampling. Sampling was almost always conducted during Monday through Saturday because landings were considered unlikely to occur on Sundays when fishermen typically repair their fishing gear and spend time with their families. The work presented in this document focuses on analysis of the catch and effort data from the on-site intercept survey only. A description of fishery characteristics by country can be found in the Appendix of this document.

Catch composition of all shark and non-shark species landed was recorded in either number and/or weight (kg) of individuals. In these fisheries, depending on the life stage, sharks may be processed before being landed, and thus, length and weight data can correspond to processed trunks. For each panga intercepted by technicians, the catch composition recorded pertained to the entire fishing trip; regardless of whether multiple fishing gears were used.

To standardize catch-per-trip (CPT), catch was represented as weight only. The estimated coefficients from the relationship between numbers and weight (Table 3) were used to convert catches reported only in numbers to weight[4]. For silky shark, the relationship between numbers and weight was approximately linear, but for hammerhead sharks, the relationship generally showed two distinct patterns (Figure 1): one indicating an overall linear relationship between number and weight; and, the other, primarily at small numbers of individuals (e.g. 1–2 sharks), indicating no linear relationship. The first pattern may correspond to neonates and the latter to juvenile or adult hammerheads. Therefore, for the latter pattern, the average weight was estimated from data corresponding to individual sharks. In all subsequent analyses of CPT, these estimated weights were treated as though they were reported weights. In future, developing conversion models by life stage, that take into consideration levels of processing, could be beneficial.

In the analyses presented herein it was assumed that the landings of neonates were all hammerhead sharks, based on a general understanding of fishing practices in artisanal fisheries. This was necessary because it was not possible to obtain neonate catch amounts by species when catches of neonates were unloaded in baskets (‘*cestas*’) and, in the case of Panama, sometimes already processed as trunks (e.g., without skin, fins, head, or internal organs). As a result of this assumption, catches of hammerheads may be overestimated.

Obtaining data with which to evaluate catch and effort variability on a range of temporal scales was of particular interest for refining the sampling protocols previously presented in IATTC-98-02c. However, public safety measures put in place as a result of the COVID-19 pandemic prevented implementation of a fully hierarchical data collection protocol, with days nested within weeks nested within months. Sampling during 2020–2021 was managed in two phases, according to the bio-sanitary measures authorized by each country: 1) during the pandemic, with considerable restrictions on mobility and handling of samples and tissue collection; and, 2) after the pandemic, with only limited mobility restrictions and the possibility of sample collection. The timing and duration of these two phases differed by country (Table 4). In addition, to reduce travel costs between landing sites, and work within the various biosecurity controls created during the pandemic, it was necessary to plan and conduct sampling of landing sites by region within each country (Figure 2). Houses or apartments in these regions near the fishing localities were rented, where the sampling team lived during their work week.

## METHODS

### *Site selection for the on-site intercept survey*

Given the large number of shark landing sites identified from image analysis and the fisher recall survey (SAC-11-13), it was not possible to collect sample data at all sites, and thus sites had to be prioritized for sampling. To prioritize sites, the fisher recall survey data were used to obtain a rough estimate of total site-specific seasonal catch of two “principal” shark species groups; silky shark (*Carcharhinus falciformis*; FAL) and a hammerhead shark species complex (*Sphyrna spp*.; SPN). The indicative catch estimates were then used to rank sites, within each country, according to their catch contribution to each of the two taxa. The total catch for the three fishing gears combined (longline, gillnet and handline) was estimated using the following equation:

$$\hat{C}_i = W_i \cdot (cpt_i \cdot tpw_i \cdot P_i) \quad (1)$$

where, for site *i*, $\hat{C}_i$ is the estimated total catch of a species for the fishing season, $W_i$ is the estimated duration of the fishing season (in weeks; equal to number of months in fishing season x 4), $cpt_i$ is the

[4] This conversion was done using the sample data of trips for which catch was recorded in both numbers and weight. A generalized linear model (GLM) was fitted to the data with a gamma distribution and identity link, with weight as the response variable and numbers as the independent variable. Preliminary analyses indicated that this GLM performed better than a linear model with a square root or natural logarithm transformation of the response variable.

estimated catch-per-trip for the species (in weight), $tpw_i$ is the estimated number of trips per week, and $P_i$ is the estimated number of pangas. The component-specific estimates were computed as the average of the minimum and maximum 'typical' values reported to the technicians by fishers. To be precautionary, "fishing season" is defined as including any month where the catch of any shark species was recorded. However, this may lead to overestimation at sites where shark species other than the principal shark species are prominent in the catch at different times of the year. Site-specific catch estimates were then ranked within each country to determine which sites contributed most to the total seasonal catch estimate. To be precautionary, catch estimates were not extrapolated to sites that were not visited in the on-site intercept survey.

Once sites were ranked, they were grouped into three categories, for each of the species groups, to help prioritize sampling: 1) primary sites, which contribute to ~80% of the estimated total seasonal catch; 2) secondary sites, contributing to the subsequent 10%, so that the sum of the estimated catch from the primary and secondary sites is 90% of the estimated seasonal total; and, 3) tertiary sites, contributing the remaining 10%, so that the sum of estimated catch from primary, secondary and tertiary sites was 100% of the estimated seasonal total. To adapt the sampling methodology using the three categories to realities in the field, and to optimize use of financial resources where necessary, several regions were defined within each country (Figure 2), to achieve the following characteristics: each region contained at least one but, sometimes several, primary sites; round-trip travel between the sampling technician accommodations and primary sites was possible with public transportation in less than a day, so that sampling on the same day was still possible and transportation costs reasonable; and, several secondary and tertiary sites were also present within the region. Primary sites were intended to be visited several times per week, secondary sites once every two weeks, and tertiary sites once every 2–3 months. The aim purpose of visiting secondary and tertiary sites was to verify that the levels of fishing activity at those sites was as low as observed in the 2019 fisher recall survey.

By the time data collection began in the field, there were several factors that required a modification to the plan described in the previous paragraph. Specifically, the COVID-19 pandemic led to public safety measures that prohibited field work for a number of months, and then subsequently limited field work to only a few days per week in some countries. In addition, some sites visited in 2019 were determined to no longer be accessible (restrictions on access occurred at both landing sites and fishing localities) or unsafe for sampling due to a high number of COVID-19 cases reported in the area of the landing site. These factors required a modification to both sampling frequency and site selection. Thus, sampling was slightly less structured than originally planned, but was still limited to sampling only certain sites, and of those, some were visited more frequently than others.

*Refining sampling protocols*

The fisher recall survey contributed greatly to our knowledge about spatial aspects of these shark fisheries, but for refinements to the sampling protocol described in IATTC-98b-02c, it was necessary to further evaluate the frequency of sampling required at individual sites on a range of time scales. Therefore, analysis of the sample data in this study focused on evaluation of temporal variability in fishing activity. There were three analyses conducted: 1) an analysis of the level of variability occurring on daily, weekly and monthly scales; 2) following the results of (1), an evaluation of the precision obtained for the dominant temporal scale and how that changed with increased sampling on shorter time scales; and, 3) an assessment of the stability of the level of fishing activity across years at landing sites. All statistical analyses were done in the statistical freeware R (R Core Team 2021).

*Temporal scales of variability*

To identify the dominant scales of temporal variability, analysis of variance (ANOVA) was performed, by site, on the number of pangas, and for both the silky shark and hammerhead sharks, on CPT, which are the two components of the catch estimation formula (eq. 1) that are not weekly values. ANOVAs were only performed for sites with sufficient data, defined here as at least 20 data points. In addition, the data had to contain multiple days sampled per week and multiple weeks per month, for a sufficient number of weeks and months during the study period. The factors included in the ANOVAs were: day of the week, week of the year (to capture non-seasonal pattern), and month (to capture seasonality). For both numbers of pangas and CPT, a square root transformation was applied before fitting the ANOVAs to remove heteroscedasticity of variances, as this performed better than a natural logarithm transformation or fitting a generalized linear model (GLM) with a Poisson distribution, or, in the case of number of pangas, a gamma distribution (with an added constant to address the issue of zero-valued observations).

Five different ANOVA models were fitted to the data: day of the week; week of the year; month; day of the week and week of the year; and, day of the week and month. Because of the sparsity of the data in time, and the possibility of differences in fishery characteristics among sites and countries (Appendix), ANOVA models were fitted by site, and interaction terms were not included in the models.

*Precision of weekly catch-per-trip estimates*

Evaluation of the coefficients of variation (CVs) of estimates can provide information useful for determining resource allocation in the sampling protocol. Following the results of the ANOVAs (described below), it was decided that the CV of weekly estimates of CPT would provide a useful measure with which to determine the number of days per week that a site should be sampled. CPT was selected because, as described in the Results section below, it was found to be the most variable of the three components considered for catch estimation (eq. 1). To compute the CV of weekly CPT it was assumed that the sample data were the result of simple random sampling of trips per day and days per week. The weekly CV of CPT at a site was estimated as the standard error of the mean weekly CPT divided by the mean weekly CPT, where the mean weekly CPT was estimated as the average of mean daily CPT values for all sampled days of the week. Weekly CVs could only be estimated for weeks with samples from more than one day. For the weekly CVs, the mean daily CPT values were assumed to be known without error. A finite population correction ("fpc"; e.g., Cochran 1977), which would scale the variance by one minus the proportion of the days of the week sampled, was not applied here, but the implications of using the fpc are considered below in the section on recommendations for the sampling protocol.

*Annual stability of site rankings*

For each country, site-specific OOM estimates of total annual catch from the intercept survey data (SAC-14 INF-L) were used to rank the sampled sites according to their contribution to the country-specific catch. Those catch-based rankings were compared to the catch-based rankings from the 2019 fisher recall survey. Differences in the site rankings between the two surveys were evaluated to determine the longer-term feasibility of a spatially stratified sampling protocol that focuses on sampling a limited number of sites within a few regions.

**RESULTS**

*Site selection*

The number of sites contributing the most to the estimated total fishing season catch, as estimated from the 2019 fisher survey data, differed for the two shark species groups (Table 5, Figure 2). For the silky shark, in most of the countries, only a few sites were estimated to have contributed most of the catch. To cover about 80% of the estimated silky shark catch, only 2–6 sites were required for PAN, CRI, SLV and NIC, and 15 sites for GTM. By contrast, for hammerhead sharks, more sites were generally required to cover about 80% of the catch. Specifically, 5 sites were required for CRI, but 12–15 sites for GTM, PAN and NIC, and 36 sites for SLV. However, it is noted that only 7 sites are estimated to cover about 50% of the hammerhead catch in SLV.

Given these results, which indicated that some sites contributed more to the total catch of each species group than other sites, sampling effort during the 2020–2021 intercept survey was concentrated in specific regions within each country (Figure 2), with a focus on sampling sites visited in the 2019 fisher recall survey that had high landings of silky sharks. From a practical standpoint, the need for this focus was due mainly to hammerhead sharks were landed at substantially more landing sites silky sharks. Therefore, with the resources available, it is acknowledged that it is not possible to estimate the total catch of both species groups with the same level of precision. Thus, within a country, each region contained at least one site from among those estimated to contribute to 80% of the total fishing season catch of silky shark. In addition to these primary sites, several sites of contributing less to the total estimated catches within each region were selected for sampling. The main purpose of sampling secondary and tertiary sites was to verify that large catches was not being periodically missed by sampling only primary sites. Within each region, site selection took into consideration accessibility, COVID-19 bio-safety restrictions and travel costs. Many of the primary landing sites for the silky shark were secondary or tertiary landing sites for hammerhead sharks.

Across all countries, 64% of primary silky shark landing sites and 27% of secondary and tertiary silky shark landing sites were sampled, while for the hammerhead landing sites, the coverage was 42% for primary sites and 10% for secondary and tertiary sites (Table 6). Among those sites most frequently visited, it was typically only possible to sample a few trips per day (Table 7) with the available resources, due to a decision early in the project to emphasize covering more sites according to the site ranking, rather than sampling only a few sites intensively. Depending on the country, about 100 trips—but up to several hundred trips—were sampled at primary sites during the study (Table 7). This sampling was distributed as evenly as possible over the study period, considering that the COVID-19 pandemic impacted the ability of sampling technicians to collect data in the field, where restrictions ranged from no access to access only a few days per week.

*Temporal scales of variability*

The time series of CPT, trips per panga per week (TPW) and number of pangas showed variability on a range of temporal scales. For CPT, among those frequently-visited sites (primary sites), the variability on shorter time scales (e.g., within a day, across days of the same week) were sometimes as large as that seen across the study period, ranging from no catch of the species group to over 500 kg, depending on the species, site and country (Figure 4). This corresponded to a range in CPT of more than one to two orders of magnitude. For several of the frequently-visited sites in CRI, GTM and NIC, there appears to have been little to no catch of either species groups landed during the study period, particularly for the silky shark. Seasonality in CPT was evident for some sites and countries, but both species groups appear to have been caught during many months of the year. For example, in SLV, catch of both species groups was reported during most months of the year. In contrast, in GTM and NIC, at the few sampled sites where landings occurred, there appears to have been little to no catch of silky shark from around January/February to April/May, depending on the country.

For TPW, among those frequently-visited sites, 1–7 TPW were typically recorded, although at one site in PAN 8 TPW were recorded(Figure 4). There were clear differences in TPW between sites of the same country and among countries, which may be in part due to COVID restrictions. For example, in SLV, 4–6 TPW were recorded (e.g., site 264), while at other sites, 1–3 TPW were typical. In NIC, there appeared to have been a periodicity in TPW across most sites sampled, but the pattern is not consistent for the same months sampled in both years (2020 vs. 2021). In GTM, 1–3 TPW were common over the entire study period. In CRI, two of the primary sites sampled were only active for part of the study period (sites 10,048 and 1,143), whereas one of the sites (site 844) had activity over most of the study period.

With respect to the number of pangas, similarity in the number of pangas at a site on short time scales, compared to longer-term differences across the study period was apparent (Figure 5). However, at some sites in each country, large differences in the number of pangas also occurred on short times scales, for example, at sites 704 and 10037 in PAN, site 159 in GTM, and site 571 in NIC.

Overall, the smallest scale of temporal variability consistently identified for number of pangas and CPT by the ANOVA analyses was weekly (Tables 8–9). The ANOVA results suggest that variability on weekly and monthly scales for these two components of equation (1) largely dominated over variability among days of the week (Monday through Saturday). Significant day-to-day variability in CPT was only consistently identified for NIC (Table 9). Of the 18 sites analyzed for numbers of pangas across the 5 countries, only one site had a *p*-value for day of the week that was less than 0.01 (Table 8). Given that week was significant for individual sites as frequently as month is interpreted as indicating that values of CPT and number of pangas were not strongly consistent across all weeks of a month (or months).

*Precision of weekly catch-per-trip estimates*

The CVs of mean weekly CPT for the two species groups were evaluated for each site with sufficient sample data, as a function of the number of days per week sampled, to investigate the relationship between sampling coverage (i.e., number of days per week) and precision (Figure 6). Mean weekly CPT was selected because weekly variability was the smallest consistently significant dominant scale of variability for CPT, as well as for the number of pangas from the ANOVA analyses (Tables 8 – 9), and CPT was often the most variable component of equation (1) (Figures 4–5).

Overall, CV values at or above 0.4 were common (Figure 6). Values ranged from 0 to 1; a value of 1 occurs when only one day of the week had a non-zero value for CPT. At some sites, particularly those sampled in NIC, PAN, and SLV, the CVs decreased as the number of days sampled per week increased. Paradoxically, there were a number of sites for which the CVs increased as the number of days sampled per week increased. This outcome would be consistent with trip-to-trip variability in CPT on any given day being large enough such that sampling only 1–2 trips per day (Table 7), out of a larger number of trips (Figure 3), does not allow for much benefit to be realized when sampling multiple days per week. Also, changes over the study period in processes affecting fishing activity, and thus, possibly CPT, could also be factors contributing to this result. For example, trends in CPT across the study period, such as seen for silky shark CPT at NIC site 10,033 would contribute to variability in the weekly CVs because achieving the same precision through time would likely require more sampling when mean CPT is low; the silky shark CPT at site 10,033 during 2020 was greater than in 2021 (Figure 4).

*Comparison of site rankings between the fisher recall and on-site intercept surveys*

A comparison of the site rankings for 2019 and 2020–2021, based on their contribution to the estimated country catch for each period, suggests that the importance of landing sites has the potential to change through time (Table 10). In some cases, sampled sites in 2020–2021 with the highest percentage of silky shark catch were not among those sites estimated to be contributing to the top 80% of catches based on the 2019 fisher survey (e.g., SLV site 10029). In other cases, sites within the top 80% of catches in 2019 that were not of primary importance were important in 2020–2021 (e.g., NIC site 10033). In CRI, there were two sites of primary importance in each period, but the sites were not the same for the two periods. For PAN, because there was no estimated catch of the silky shark (SAC-14 INF-L), the sites were ranked based on their contribution to hammerhead catch. The two most important sites according to the 2019 ranking were less important according to the 2020–2021 ranking (sites 704 and 10037). By contrast, some sites were found to be of similar importance in the two time periods, such as SLV site 10,027 and GTM sites 10,018 and 10,016.

There are several possible factors that may contribute to differences in landing site importance between the two surveys, including the source of the catch data, the methodology used to estimate the total catches, and the COVID-19 pandemic. Nonetheless, these comparisons suggest landing site may be temporally dynamic. Despite this, although the apparent importance of sites may have changed over time, the importance of regions did not change markedly. That is, the sites that were estimated to have become important were often located in the same region(s) as sites previously perceived to be important.

Consistent with the general pattern found for site rankings based on catch estimates from the 2019 fisher recall survey (Figure 3), the site rankings in the intercept survey indicated that, for several countries, the number of sites that contributed to about 80% of the silky shark catch was relatively small such as CRI, SLV, and NIC having 2, 12, and 8 sites, respectively (Table 10). This suggests that developing a sampling protocol for key shark landing sites may be extended to other sites and/or regions. In contrast, the landings in GTM and PAN were dispersed across a larger number of sites. However, the number of sites estimated to generate about 50% of the landings was still fairly small, with 12 sites for the silky shark in GTM and 8 sites for hammerhead sharks in PAN (Table 10).

Furthermore, in GTM and NIC, sites of primary importance for silky shark landings were also of importance for hammerhead shark landings (Table 10). This suggests that a sampling protocol designed around sites of importance for silky shark landings will also benefit efforts to monitor landings of hammerhead sharks in several of the countries.

**SAMPLING PROTOCOL RECOMMENDATIONS**

Practical experience obtained from the on-site collection of landings data, and analysis of these data suggest the following considerations are important for developing a sampling protocol for sharks.

1) It is more cost effective to base sampling technicians near spatial clusters of sites, which can be reached using public transportation in less than a day, than to have sampling technicians travel long distances every week from their homes to landing sites. This is due to the large extent and remoteness of the coastline of these countries, which would make randomly sampling from all sites within a country very costly and logistically challenging. For sampling technicians stationed in a region, their lodging would be provided by the project. Depending on the number of persons, the project would rent an apartment or a house.
2) Reasonable coverage of fishing activity related to the silky shark may be possible by sampling relatively few sites. However, the number of sampling technicians needs to be sufficient to provide some flexibility to sample more than just the most active sites in a region, if required.
3) Given that most landing sites can be allocated to a small number of regional strata, incremental increases in the number of sites sampled through time may be achieved by either adding sites to previous established regions with a sampling presence and/or by adding to regions to the sampling program to better cover the spatial extent of the fishery, both of which could be done as funding becomes available, depending on program priorities.
4) Stratifying sampling by week of the year by site is desirable to be able to adequately capture anticipated short-term variations in fishing activity. After more extensive data collection and analysis, the fishery dynamics may be better understood, and the sampling protocol modified as a result.
5) As a starting point, the following sampling frequency at selected sites is recommended:
    a. Sample four days per week. Sampling two days per week would be the minimum needed to estimate variance on the weekly catch estimates using a design-based estimation approach. On balance, the CVs on mean weekly CPT for sites sampled in NIC, PAN and SLV

(Figure 6) suggest that sampling should take place at least 3 days per week, and preferably 4 days per week. The ANOVA results suggest that the actual days of the week that are sampled are not of primary importance (but see Discussion section). Given the range of CVs obtained for mean CPT in this study (Figure 6), if 4 days per week were to be sampled, the fpc would decrease the variance on the mean CPT by roughly 67%, assuming a 6-day fishing week (i.e. 1-(4/6)) (assuming within-day variance is negligible). This would translate into a reduction in the CVs shown in Figure 6 of roughly 40% (i.e., the CVs would be multiplied by the square root of 1/3, which is equal to 0.58). Given that the CVs at 4 days sampling were largely greater than 0.2 and often greater than 0.4 and considering that the variance of mean CPT would only be one component of the variance on estimated weekly catch (eq. 1), sampling at 4 days per week to start seems a reasonable precautionary approach, until it is ascertained how much reduction in variance will be achieved by sampling more trips per day than was typically possible during this study. Sampling 4 days per week, with more trips per day, could also allow for a re-evaluation of the importance of variability among days of the week relative to that longer time scales. It is noted that although ANOVA results did not consistently identify day-of-the-week as an important consideration for sampling, for practical reasons, structuring the sampling in terms of selecting days of the week and then trips per day is considered of value.

b. Sample 10 trips per day. Based on the number of vessels recorded by sampling technicians at the various sites (Figure 5), this rule would be expected to lead to at least 10% coverage of trips at the landing sites sampled. This rule may lead to a change in sampling coverage over time, if the number of pangas at a site fluctuates. However, absent adequate information on which to establish an optimal level of sampling coverage of trips per day, 10 trips per day is about the largest number of trips sampled at any site during the study (Table 7). In combination with the recommendation of the number of days per week to sample, this should result in lower CVs for mean CPT than encountered during this study, where the CVs estimated from the study are considered unacceptably high (Figure 6). The decision on sampling frequency should be reevaluated, following future data collection and analysis, to determine what combination of sampling more/fewer trips per day and/or days per week (or other time period, such as month) would be necessary to achieve a desired level of precision.

Given the above, a general multistage sampling protocol is proposed, which focuses on catch estimation for the silky shark. This protocol is intended to allow for sampling to occur at specific sites, with the possibility of modifying and/or expanding the sampling program as funding permits. The protocol is intended to generate data for estimation of total catch and its variance, by week, at each sampled site. The protocol is not meant to allow extrapolation from sampled sites to all unsampled sites, but rather to produce reliable catch estimates for important sites, with possible extrapolation to nearby sites known to have similar fleet dynamics, if ancillary data for neighboring sites are available (see Discussion section). The performance of the protocol should be evaluated once adequate data have been collected. Customizing this general protocol, by country, may prove beneficial, if future data analysis identifies important differences in fleet dynamics among countries. The general protocol is summarized as follows.

i) Within each country, several regions should be defined, that taken together, represent a reasonable percent of the estimated total silky shark catch for the country or collection of sites that are otherwise of interest. Each region should be sufficiently small such that sampling technicians can travel between a “home base” (e.g. a rented house) and sites to be sampled, using public transportation, in less than a day, thus ensuring that daily sampling trips are possible.

ii) The specific regions, and the number of sites per region, that are to be sampled will depend on the goals of the program and level of funding. The regions and selected sites in the on-site intercept survey could serve as a starting point.

iii) Once regions have been defined, and the sites to be sampled determined, a stratified, multistage sampling protocol should be implemented at each site. The stratification would be week of the year. The stages are: 1) days of the week; and, 2) trips (pangas) on a given day.

iv) For the first stage of the protocol, days of the week to be sampled would be selected by simple random sampling, on a weekly basis.

v) For the second stage of the protocol, trips completed on a given day would be sampled. If all trips cannot be sampled, then preferably, simple random sampling of trips would be used. If simple random sampling of trips proves to be impractical, then systematic sampling from a random starting trip can be used to collect one systematic sample of trips for each day. At least two systematic samples would need to be collected per day to be able to estimate the variance in CPT among trips on a given day. Technically, from a single systematic sample of trips on each day, it is not possible to compare variance among trips of the same day to variance across days of the week. However, to estimate the variance of the mean CPT for the week using a design-based approach, in practice, only one systematic sample might be collected and the variance of weekly CPT estimated by the first stage variance (see for example Cochran 1977 pages 278 – 279).

For the general sampling protocol described above, estimation of the total weekly catch of a species group at a site, and its variance, can be obtained using, for example, design-based methods (Cochran, 1977; Lohr, 2022) for each of the components of equation (1), and the formula for the variance of the product of random variables. With this protocol, the estimate of the annual catch for each species group at a site would then be the sum of the weekly catch estimates. Depending on the number of sites sampled per region, model-based estimators of total catch might also be considered.

**SAMPLING COSTS**

One of the main challenges for any sampling program is the cost to obtain a given level of sampling coverage of sites. Establishing a sampling program that can deliver high-quality data in a cost-effective manner is paramount. The grouping of primary landing sites into regions for each country not only proved beneficial for sampling design development, but also for cost estimation. This is because subdividing extensive coastlines in important geographic regions, with their associated costs of sampling, compartmentalizes the costs, which facilitates the decision-making necessary to initiate a sampling program at a lower level of sampling coverage, and to expand that program as goal and funding evolve.

A table of sampling costs for the most important sites and regions of each country (Table 11) was developed using the site rankings from the estimates catches (Table 10) of the silky shark for CRI, SLV, GTM and NIC, and from those of hammerheads for PAN, presented in Table 10 to identify primary sites for sampling. The sampling costs include sampling technician salaries, per diem, travel and equipment. Operating costs (transportation, house rental, per diem) and human resources costs were standardized for the entire region, resulting in a cost of US$6,500 per year per sampling site for operational costs and US$16,800 per year per sampling technician (US$1,400 per month). The sampling protocol described above requires two sampling technicians per site, for a total annual sampling cost per site of US$40,100[5].

[5] The calculation was estimated for a technical team of two people per sampling site, with an annual salary of $16,800 per technician plus yearly operating costs ($6,500).

The cost of sampling to cover a certain percentage of the estimated annual catch of both species groups depends on how the estimated catch of each of the two species groups is distributed across landings sites and regions within a country (Figure 7). For example, in CRI and SLV, the regions estimated to be of primary importance for silky shark landings were not always the regions estimated to be of primary importance for hammerhead shark landings. In addition, the distribution of each species group's catch among landing sites of each region also varies. For example, in the silky shark regions in CRI (Figure 7), to cover an estimated 82% of the catch, it is necessary to sample only one landing site in each of two regions (Region 2 and Region 4; Table 10). This would cost, according to estimates presented in Table 11, about US$79,000 annually. Meanwhile, for hammerhead sharks, these same regions represent an estimated 21% of CRI catches and to sample sites representing about 80% of the hammerhead catch, it would be necessary to sample 71 landing sites, which would represent a considerable increase in cost. By contrast, some regions in GTM and NIC had high catches of both silky and hammerhead sharks, which would in principle lead to lower sampling costs. However, the estimated catches were widely distributed across more landing sites, implying a higher cost to sample sites representing an estimated 50% of the catches of both species groups.

Depending upon the purpose of sampling, scaling up the sampling protocol requires careful consideration. If the ultimate goal of a sampling program is to estimate total species catch by country, then it will be important to implement cost-effective means of monitoring fishing activity more broadly throughout each country and collecting the necessary ancillary data to be able to obtain a model-based estimate of total catch, such as that presented in SAC-14 INF-L. Previously, collection of ancillary data was done through a combination of analysis of satellite imagery for landing sites and numbers of pangas, and the fisher recall survey (SAC-11-13). More generally, remote monitoring of panga activity on a frequent basis, is a means of ensuring that any changes to fishing activity, both inside and outside of the regions designated for sampling, is detected in a timely manner so that the sampling can be adapted, if necessary.

**DISCUSSION**

These results present a sampling framework for sampling sharks in coastal small scale fisheries in the EPO such as those encountered in Central America. However, several factors may influence the interpretation and these results as they relate to future data collection and catch estimation tasks. First, the COVID-19 pandemic impacted data collection in 2020–2021 on-site intercept survey in two important ways. Due to restrictions on access to fishing localities and landing sites, the coverage of days of the week within weeks and months was more opportunistic than would have been preferred. As a result, the apparent lack of variability in CPT among days of the week may be a result of insufficient data. For this reason, it is important to adequately sample within a week so that analyses of new data can revisit the question of important scales of temporal variability. Second, effects of the COVID-19 pandemic on tourism likely translated into reduced demand for some seafood products, which may have in turn affected what is considered the typical seasonality of some fisheries. Under typical conditions seasonality of fisheries is more pronounced, and so analysis of new data should aim to evaluate whether stratification by week or month might be more statistically robust.

A sampling program will need to include technician training for species identification of processed catch (e.g., trunks), which was undertaken in 2020. However, given the difficulty of identifying highly processed carcasses, especially neonates unloaded in baskets, additional data should be collected to validate species identification, such as tissue samples for DNA analysis.

Finally, future studies of fleet dynamics are important to support model-based estimation of fleet-level catches. The data collected in 2020–2021 on-site intercept survey identified possible differences in fisheries operational characteristics among countries, although impacts of the COVID-19 pandemic may have contributed to apparent differences since the vessels that continued to fish through the pandemic may have been biased towards the use of different gears or landing sites Nonetheless, better understanding fleet dynamics may allow for stratification of sampling by factors such as gear types and/or vessel characteristics, and would lead to improved performance of model-based estimators of total catch by improving a model's ability to identify site characteristics related to landings amounts of the different shark species groups.

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**APPENDIX**. Description of fisheries, by country.

## CRI

The shark landings by the medium and large-scale fishing fleet in this country are regulated, the only unloading option being to unload the catch individually. On the other hand, the small-scale or "artisanal" (panga) fleet has a shark unloading regulation that requires fishermen to unload their product at collection centers, if they unload sharks. Unloading is done individually, and the catch is weighed as a group.

When pangas land sharks at collection centers, the centers issue an invoice for the purchase of the product, which the fisherman uses to apply for a fuel subsidy (as long as the fisherman has a fishing license).

The panga fleet is divided into longlines and gillnets; pangas using longlines fish between 1 nm – 50 nm from the coast, while those using gillnets fish out to 10 nm from the beach. Both neonates and juveniles are caught by both types of fishing gears.

## SLV

The main fishing fleet that catches sharks in this country is the artisanal or "panga" fleet, and both types of fishing gear, longline and gillnet, are used. The longline fleet is subdivided into: 1) offshore longline, which refers to the distance that the pangas must travel to the fishing grounds, and targets mainly dorado and sharks (adults); and, 2) bottom longline or "calineras," which are more coastal and target mainly small coastal species such as snapper, grouper, croaker and sharks (neonates and juveniles). For both components of the longline fleet, catches of rays have been reported, mainly from the Dasyatidae family (adults). They are unloaded individually, usually whole, and sometimes eviscerated.

While sharks caught with gillnets can be landed in groups (>100lb) and individually (<100lb), and are landed whole. The sharks are caught mainly in the neonate to juvenile life stages. Once unloaded, they are processed (finning, gutting, and head cutting) and weighed as a group.

## GTM

This country has two fleets: 1) medium-scale and 2) small-scale artisanal or "panga." Catch unloading by the panga fleet is carried out individually (i.e., individual fish unloaded one at a time) and then classified by size[6], mainly for the silky shark species, and then weighed in groups by size. The other species in the catch are marketed individually and are generally not classified by size. The panga fleet it is divided into two components by type of fishing gear, longline and gillnets.

As in SLV, the longline fleet is further subdivided into two groups according to the target species: 1) surface and mid-water longline, targeting, depending on the time of year, species such as dorado, tuna, and sharks (primarily juveniles and adults, but occasionally small amounts of neonates are caught); and, 2) bottom longline, targeting small coastal species (snapper, sea bass, grouper, catfish, etc.), with sharks (mainly juveniles, but occasionally neonates and adults) considered as bycatch. In both types of longline, the sharks is gutted prior to landing and are landed individually.

In contrast, pangas that use gillnets catch sharks as bycatch, and unlike in other countries in the region, are mainly used as bait to catch manta rays and common stingrays (Family Dasyatidae) at two times of the year: 1) January-March, and 2) July-November.

[6] Small: 1 to 10 lbs; Medium: 10 to 20 lbs; Large: 20 to 50 lbs; Extra: >50 lbs.

## NIC

The shark fishery in this country is carried out by the artisanal fleet or "panga," which is divided into longline or "line" and gillnets or "trammel nets." Unlike other countries in the region, the panga longline fleet is subdivided into four types of longlines: 1) Parguero, 2) Rayera, 3) Doradera, and 4) Tiburonera. Unloading takes place mainly on the beach, and the catch is unloaded using tubs and carts to move the catch to the collection centers, where it is classified and weighed according to species group.

The longline “parguera” is carried out close to the coast, and their target fishery is snappers, but they also catch grouper, corvina, neonate sharks, and small rays. While the “rayero” longline is carried out in the coastal zone and is dedicated to catching rays and manta rays, which are landed gutted and cut in half, although sometimes they can be landed whole or only gutted. The use of “doradero” longlines takes place between 15nm and 50 nm from the coast and mainly targets dorado, which are landed whole and gutted. The “tiburonero” longline is used from 40nm to 200 nm from the coast, and targets sharks and manta rays. The catch is landed individually and typically whole, although sometimes it can be landed gutted.

## PAN

The shark fishery is carried out by two groups of fleets: 1) international and industrial fleets; and, 2) artisanal or "panga" fleets. The international fleet is characterized by its use of longlines, the multi-species nature of its catch, and fishing beyond 200 mn from the coast. The catch is unloaded in groups using cranes that are used to transport the frozen fish from the vessel wells to the dock, where it is classified and deposited in containers for export. The industrial longline fleet mainly targets species such as tuna and dorado, but sometimes catches rays. Its area of operation is within 200 nm of the coast. The catch is unloaded in groups, by species, using cranes, which deposit the fish in bins where it is weighed and taken to the processing plants. The "panga" fleet uses longlines and gillnets. Its fishing area ranges from 1nm to 100 nm from the coast, and it targets snappers, sea bass, grouper, tuna and sharks (neonates). The catch is unloaded in groups of species using boxes (‘cestas’) that are then weighed; each box of fish weighs approximately 100lb.

The panga longline fleet is small and targets coastal species such as snapper, grouper, and rays, while the gillnetters are numerous, and target mainly sharks (neonates) and tuna.

**Table 1**. Number of accessible landing sites and fishing localities covered in the 2019 fisher survey, by country. Fishing localities are communities or geographical regions whose population is primarily dedicated to marine fisheries and contain one or more landing sites. Landings sites are locations of interest where fish are unloaded.

| Country | Fishing Localities | | Landing sites | |
|---|---|---|---|---|
| | No. | % of total | No. | % of total |
| CRI | 53 | 91 | 107 | 62 |
| SLV | 48 | 61 | 180 | 75 |
| GTM | 24 | 75 | 86 | 51 |
| NIC | 30 | 81 | 95 | 65 |
| PAN | 33 | 89 | 45 | 75 |
| **Total** | **188** | **77** | **513** | **65** |

**Table 2**. Number of surveys by country, Central America, 2019.

| Country | No. Of Survey |
|---|---|
| CRI | 899 |
| SLV | 1206 |
| GTM | 468 |
| NIC | 662 |
| PAN | 355 |

**Table 3**. Estimated coefficients from the generalized linear models (GLMs) used to estimate trunk weight from number of trunks, by species group, for CRI, SLV, GTM and NIC. *: the equation was fitted to a subset of the data; see text for details. The last column shows the percentage of trips with converted catch for the sites included in the ANOVA modelling. No estimation was required for PAN (hammerheads). The GLM used for the conversion was a linear regression model with dependent variable number of sharks and independent variable weight of sharks, with a gamma error structure and identify link.

| | Estimated coefficient | Standard error | *p*-value | Percent trips with converted catch |
|---|---|---|---|---|
| **CRI** | | | | |
| Silky | | | | 0% |
| (too few individuals) | | | | |
| Hammerheads | | | | 0% |
| Intercept | 1.2488 | 0.4125 | < 0.01 | |
| Slope | 1.1468 | 0.1721 | < 0.01 | |
| | | | | |
| **SLV** | | | | |
| Silky | | | | 13% |
| intercept | -1.225 | 1.608 | 0.45 | |
| slope | 13.805 | 0.669 | < 0.01 | |
| Hammerheads* | | | | 10% |
| intercept | 0.4120 | 0.2566 | 0.11 | |
| slope | 0.8656 | 0.1632 | < 0.01 | |
| | | | | |
| **GTM** | | | | |
| Silky | | | | 0% |
| intercept | -4.7583 | 1.2483 | < 0.01 | |
| slope | 8.4923 | 0.8937 | < 0.01 | |
| Hammerheads* | | | | 9% |
| Intercept | 1.0705 | 0.2701 | < 0.01 | |
| slope | 0.5855 | 0.1194 | < 0.01 | |
| | | | | |
| **NIC** | | | | |
| Silky | | | | 0.2% |
| intercept | -3.441 | 1.836 | 0.06 | |
| slope | 19.299 | 1.192 | < 0.01 | |
| Hammerheads* | | | | 0.6% |
| intercept | -2.0428 | 1.0960 | 0.06 | |
| slope | 3.7454 | 0.9807 | < 0.01 | |

**Table 4**. COVID-19 bio-safety restrictions, by country, for the two years covered by the study. Cells that are blank indicate that the restriction did not exist. The restrictions in place in 2021 were not as strict as those in place in 2020.

| COVID-19 Restrictions | CRI | | SLV | | GTM | | NIC | | PAN | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Sampling days | X | | | | X | | | | X | |
| Access to fishing localities | X | X | | | X | X | | | X | X |
| Collection of biological data | X | | X | | X | | X | | X | |
| Sampling hours | X | X | | | X | X | | | X | X |

**Table 5**. Number of shark landing sites, both accessible and non-accessible, by country. Primary landing sites are defined as those landing silky and/or hammerhead sharks. "Main landing sites" refers to sites of importance of silky shark and hammerhead shark landings.

| Country | Shark landing sites | Main shark landing sites | *Silky shark* | | *Hammerhead sharks* | |
|---|---|---|---|---|---|---|
| | | | Primary | Secondary + Tertiary | Primary | Secondary + Tertiary |
| **CRI** | 145 | 37 | 2 | 1 | 4 | 33 |
| **SLV** | 206 | 171 | 5 | 5 | 36 | 133 |
| **GTM** | 167 | 98 | 15 | 18 | 13 | 69 |
| **NIC** | 108 | 95 | 6 | 27 | 13 | 82 |
| **PAN** | 50 | 43 | 1 | ---- | 13 | 30 |
| **Total** | **676** | **445** | **28** | **51** | **79** | **347** |

**Table 6**. Sampling coverage of silky shark and hammerhead shark landing sites from the main landing sites in Central American countries, achieved in 2020-2021.

| Main landing sites | | | *Silky shark* | | | | *Hammerhead sharks* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sampling site | | Primary | | Secondary + Tertiary | | Primary | | Secondary + Tertiary | |
| **Total** | **No.** | **%** | **No.** | **%** | **No.** | **%** | **No.** | **%** | **No.** | **%** |
| 445 | 79 | 18 | 18 | 64 | 14 | 27 | 33 | 42 | 35 | 10 |

**Table 7**. Sites sampled, by country, and number of trips sampled over the study period at each site. The last column shows the quantiles (minimum; 25th percentile; median; 75th percentile; maximum) of the number of trips sampled per day at the sites considered in the ANOVA analyses.

| Landing site/country | Number trips | Quantiles of trips sampled per day | Landing site/country | Number trips | Quantiles of trips sampled per day |
|---|---|---|---|---|---|
| **CRI** | | | **GTM** | | |
| 844 | 96 | 1;1;1;2;5 | 159 | 194 | 1; 1; 1; 2; 5 |
| 10048 | 83 | 1;1;2;3;6 | 10003 | 184 | 1; 2; 3; 4; 8 |
| 10049 | 34 | 1;1;1;1;2 | 160 | 121 | 1; 1; 1; 2; 4 |
| 1143 | 32 | 1;1;1;1;3 | 10018 | 100 | 1; 1; 1; 2; 6 |
| 10055 | 12 | | 10025 | 54 | 1; 1; 2; 3; 4 |
| 799 | 12 | | 204 | 20 | 1; 1; 1; 1; 3 |
| 10043 | 4 | | 149 | 14 | |
| 10076 | 2 | | 10016 | 10 | |
| 842 | 2 | | 10006 | 3 | |
| 1432 | 1 | | 117 | 3 | |
| | | | 94 | 2 | |
| | | | 10020 | 1 | |
| | | | 158 | 1 | |
| | | | 153 | 1 | |
| | | | 150 | 1 | |
| **SLV** | | | **NIC** | | |
| 10027 | 129 | 1; 1; 2; 2; 7 | 10033 | 439 | 1; 1; 2; 3; 14 |
| 264 | 115 | 1; 2; 3; 4; 8 | 566 | 248 | 1; 1; 2; 3; 7 |
| 462 | 90 | 1; 1; 2; 2; 5 | 675 | 231 | 1; 1; 2; 3; 8 |
| 255 | 71 | 1; 1; 1; 2; 4 | 563 | 227 | 1; 1; 2; 3; 6 |
| 10029 | 58 | 1; 1; 1; 2; 8 | 571 | 221 | 1; 2; 3; 4; 11 |
| 357 | 48 | 1; 1; 1; 2; 4 | 555 | 217 | 1; 2; 3; 3; 11 |
| 10030 | 41 | 1; 1; 2; 2; 6 | 676 | 57 | 1; 1; 1; 2; 5 |
| 256 | 38 | 1; 1; 1; 2; 3 | 648 | 55 | 1; 1; 1; 2; 5 |
| 454 | 18 | | 561 | 40 | 1; 1; 1; 2; 4 |
| 1387 | 13 | | 673 | 37 | 1; 1; 1; 1; 2 |
| 1435 | 9 | | 649 | 27 | 1; 1; 2; 2; 3 |
| 1388 | 8 | | 671 | 23 | 1; 1; 1; 2; 9 |
| 272 | 7 | | 556 | 22 | 1; 1; 1; 3; 3 |
| 461 | 6 | | 669 | 14 | |
| 442 | 4 | | 653 | 14 | |
| 355 | 2 | | 567 | 8 | |
| 354 | 2 | | 10075 | 7 | |
| 476 | 1 | | 10032 | 6 | |
| 444 | 1 | | 674 | 4 | |
| 271 | 1 | | 565 | 2 | |
| | | | 1365 | 1 | |
| | | | 668 | 1 | |
| | | | 667 | 1 | |

| | | | | | |
|---|---|---|---|---|---|
| **PAN** | | | | | |
| 1295 | 334 | 1; 2; 4; 6; 12 | | | |
| 1354 | 267 | 1; 3; 5; 8; 16 | | | |
| 700 | 193 | 1; 1; 3; 6; 9 | | | |
| 1355 | 185 | 1; 2; 3; 6; 11 | | | |
| 711 | 181 | 1; 1; 2; 3; 7 | | | |
| 704 | 109 | 1; 1; 1; 2; 4 | | | |
| 10037 | 61 | | | | |
| 701 | 35 | | | | |
| 1328 | 33 | | | | |
| 1360 | 8 | | | | |
| 10036 | 6 | | | | |
| 706 | 1 | | | | |

**Table 8**. Results from one-way ANOVAs (*p*-values shown) testing for differences in the mean number of pangas at sites sampled on at least 20 occasions within each country (excluding SLV). Results in bold indicate a significant difference at the level of $p \leq 0.01$. Indicated with an "x" are models that could not be fitted because of only one week was sampled in a month. wday: day of the week; wk; week of the year; mon: month; wday after week: day of the week after week of the year taken into consideration; wday after mon: day of the week after week of the year taken into consideration.

| | Site | wday | wk | mon | wday after wk | wday after mon |
|---|---|---|---|---|---|---|
| CRI | 844 | 0.20 | x | 0.12 | x | 0.74 |
| | 10049 | 0.13 | x | 0.32 | x | 0.18 |
| | | | | | | |
| GTM | 10018 | 0.69 | **0.04** | 0.05 | 0.58 | 0.59 |
| | 159 | 0.64 | **0.01** | 0.11 | 0.94 | 0.99 |
| | 149 | 0.87 | **< 0.01** | **< 0.01** | 0.73 | 0.91 |
| | 160 | 0.69 | **< 0.01** | **< 0.01** | 0.14 | **0.07** |
| | 10006 | 0.64 | 0.43 | 0.45 | 0.71 | 0.78 |
| | | | | | | |
| NIC | 571 | 0.93 | x | 0.27 | x | 0.26 |
| | 555 | 0.68 | x | 0.35 | x | 0.35 |
| | 675 | 0.34 | x | **0.05** | x | x |
| | 648 | 0.46 | x | 0.57 | x | x |
| | | | | | | |
| PAN | 704 | 0.13 | 0.15 | 0.13 | 0.67 | 0.47 |
| | 700 | 0.29 | **0.02** | **0.10** | 0.67 | 0.48 |
| | 10037 | 0.72 | **< 0.01** | **< 0.01** | 0.99 | 0.89 |
| | 1295 | 0.83 | **< 0.01** | **0.02** | 0.13 | 0.95 |
| | 1355 | 0.79 | **0.02** | **0.01** | 0.4 | 0.23 |
| | 701 | 0.87 | **0.02** | **0.05** | 0.73 | 0.79 |
| | 711 | 0.86 | **< 0.01** | **< 0.01** | 0.11 | 0.25 |

**Table 9**. The *p*-values from the site-specific ANOVAs for catch-per-trip (CPT) of the silky shark and hammerhead sharks, by site within country. Shown in bold are *p*-values less than or equal to 0.01. wday: day of the week; wk; week of the year; mon: month; wday after week: day of the week after week of the year taken into consideration; wday after mon: day of the week after week of the year taken into consideration.

| | wday | wk | mon | wday after wk | wday after mon |
|---|---|---|---|---|---|
| **CRI** | | | | | |
| Hammerhead | | | | | |
| Site 844 | 0.22 | **0.02** | 0.29 | 0.31 | 0.12 |
| | | | | | |
| **SLV** | | | | | |
| Silky | | | | | |
| Site 462 | 0.37 | **< 0.01** | **< 0.01** | 0.20 | 0.39 |
| Site 256 | 0.88 | **< 0.01** | **< 0.01** | 0.79 | 0.87 |
| Site 10027 | 0.37 | **0.10** | 0.17 | 0.54 | 0.49 |
| Site 10029 | **0.09** | **< 0.01** | **< 0.01** | **0.05** | 0.34 |
| Site 255 | 0.14 | **<0.01** | **< 0.01** | **0.05** | 0.69 |
| | | | | | |
| Hammerhead | | | | | |
| Site 462 | 0.97 | 0.27 | 0.20 | 0.82 | 0.89 |
| Site 10027 | 0.31 | **0.05** | 0.16 | 0.23 | 0.18 |
| Site 264 | 0.64 | **< 0.01** | **< 0.01** | 0.74 | 0.74 |
| Site 10029 | 0.35 | **< 0.01** | 0.16 | 0.33 | 0.47 |
| Site 357 | 0.41 | **< 0.01** | **0.03** | 0.27 | 0.74 |
| Site 10030 | 0.54 | 0.19 | **0.10** | 0.38 | 0.38 |
| Site 255 | 0.97 | **0.05** | **0.01** | 0.93 | 0.99 |
| | | | | | |
| **GTM** | | | | | |
| Silky | | | | | |
| Site 10018 | 0.35 | **< 0.01** | **< 0.01** | **0.10** | 0.24 |
| | | | | | |
| Hammerhead | | | | | |
| Site 159 | 0.38 | 0.66 | 0.27 | 0.85 | 0.63 |
| Site 10003 | 0.16 | **< 0.01** | **0.02** | 0.50 | 0.27 |
| Site 10018 | 0.54 | 0.50 | 0.98 | 0.43 | 0.41 |
| | | | | | |
| **NIC** | | | | | |
| Silky | | | | | |
| Site 10033 | **0.08** | **< 0.01** | **< 0.01** | 0.40 | **0.02** |

| | | | | | |
|---|---|---|---|---|---|
| Site 563 | 0.84 | < 0.01 | < 0.01 | 0.74 | 0.66 |
| | | | | | |
| Hammerhead | | | | | |
| Site 10033 | **0.02** | **< 0.01** | **< 0.01** | **0.02** | **< 0.01** |
| Site 563 | **0.07** | **0.09** | **0.09** | 0.37 | **0.05** |
| | | | | | |
| **PAN** | | | | | |
| Hammerhead | | | | | |
| Site 1295 | 0.16 | **< 0.01** | **< 0.01** | 0.97 | 0.71 |
| Site 1354 | **< 0.01** | **< 0.01** | **< 0.01** | **< 0.01** | **0.01** |
| Site 700 | **< 0.01** | **< 0.01** | **< 0.01** | **0.01** | **0.01** |
| Site 1355 | 0.74 | **< 0.01** | **< 0.01** | 0.95 | 0.98 |
| Site 711 | 0.88 | **0.01** | 0.21 | 0.93 | 0.80 |
| Site 704 | 0.87 | 0.15 | 0.22 | 0.65 | 0.45 |

**Table 10**. Ranking of sites, within each country, based on: a) the percentage of total seasonal catch estimated from fisher interview data collected in 2019, for the silky shark (FAL) for CRI/SLV/GTM/NIC and for hammerhead sharks (SPN) for PAN, by site; and, b) the percentage of total catch of silky sharks, and separately, of hammerhead sharks estimated from sample data collected in 2020 – 2021 (SAC-14 INF-L). Only those sites representing a cumulative percent catch of about 80% are shown. "*": indicates a sampled site. Percentages may sum to more/less than 100% due to rounding error. Not shown for PAN from the 2019 estimates is the only site with estimated silky shark catch because there were no PAN sites estimated to have silky shark landings, based on the 2020 – 2021 sample data. The list of sites for GTM was truncated at 60% of the silky shark catch because 54 sites were required to reach 80%.

| Site | 2019 Fisher survey ranking % FAL catch (cumulative %) | 2019 Fisher survey ranking % SPN catch (cumulative %) (PAN only) | Region | Site FAL | 2020 – 2021 Sample ranking % FAL catch (cumulative %) | Region FAL | Site SPN | 2020 – 2021 Sample ranking % SPN catch (cumulative %) | Region SPN |
|---|---|---|---|---|---|---|---|---|---|
| **CRI** | | | | | | | | | |
| 10049 | 70% | | 4 | 1143* | 58% | 4 | 982 | 7.3 | 7 |
| 811 | 26% (96%) | | 7 | 1357 | 24% (80%) | 2 | 810 | 6.58 (13.88%) | 1 |
| | | | | | | | 1206 | 5.72 (19.6%) | 7 |
| | | | | | | | 10055 | 4.52 (24.12%) | 3 |
| | | | | | | | 1024 | 4.2 (28.32%) | 1 |
| | | | | | | | 1023 | 4.04 (32.36%) | 1 |
| | | | | | | | 755 | 3.42 (35.78%) | 2 |
| | | | | | | | 10060 | 3.17 (38.95%) | 7 |
| | | | | | | | 10069 | 2.85 (41.8%) | 7 |
| | | | | | | | 993 | 2.81 (44.61%) | 2 |
| | | | | | | | 10050 | 2.73 (47.34%) | 7 |
| | | | | | | | 1087 | 2.33 (49.67%) | 3 |
| | | | | | | | 922 | 2.17 (51.84%) | 2 |
| | | | | | | | 982 | 6.58 (13.88%) | 7 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **SLV** | | | | | | | | | |
| 256 | 36% | | 2 | 304 | 12% | 6 | 1388 | 16.95 | 4 |
| 255 | 30% (66%) | | 2 | 10029* | 11% (24%) | 3 | 264 | 9.03(25.98%) | 7 |

| Site | 2019 Fisher survey ranking % FAL catch (cumulative %) | 2019 Fisher survey ranking % SPN catch (cumulative %) (PAN only) | Region | Site FAL | 2020 – 2021 Sample ranking % FAL catch (cumulative %) | Region FAL | Site SPN | 2020 – 2021 Sample ranking % SPN catch (cumulative %) | Region SPN |
|---|---|---|---|---|---|---|---|---|---|
| 10027 | 17% (83%) | | 3 | 10027* | 11% (35%) | 3 | 249 | 4.37(30.35%) | 1 |
| | | | | 255* | 10% (45) | 2 | 333 | 4.19(34.54%) | 8 |
| | | | | 256* | 8% (53%) | 2 | 10027 | 3.44(37.98%) | 3 |
| | | | | 462* | 8% (61%) | 3 | 357 | 3.25(41.23%) | 1 |
| | | | | 503 | 5% (66%) | 4 | 255 | 2.65(43.88%) | 2 |
| | | | | 328 | 4% (70%) | 8 | 313 | 2.19(46.07%) | 4 |
| | | | | 302 | 3% (73%) | 3 | 272 | 1.91(47.98%) | 3 |
| | | | | 280 | 3% (76%) | 6 | 300 | 1.75(49.73%) | 6 |
| | | | | 504 | 2% (79%) | 4 | 330 | 1.46(51.19%) | 8 |
| | | | | 317 | 2% (81%) | 8 | | | |
| | | | | | | | | | |
| **GTM** | | | | | | | | | |
| 10021 | 12% | | 2 | 10018* | 11% | 2 | 10025 | 11.62 | 4 |
| 10018 | 12% (24%) | | 2 | 10016* | 11% (22%) | 2 | 10003 | 11.52(23.14%) | 1 |
| 10007 | 11% (35%) | | 5 | 149* | 11% (32%) | 5 | 159 | 8.71(31.85%) | 2 |
| 10016 | 10% (45%) | | 2 | 117* | 5% (37%) | 2 | 160 | 5.16(37.01%) | 2 |
| 10020 | 5% (50%) | | 2 | 10009 | 2% (40%) | 6 | 10016 | 4.54(41.55%) | 2 |
| 150 | 5% (55%) | | 2 | 101 | 2% (42%) | 2 | 204 | 4.43(45.98%) | 4 |
| 10022 | 4% (59%) | | 2 | 10005 | 2% (43%) | 2 | 10007 | 2.99(48.97%) | 5 |
| 10017 | 3% (62%) | | 2 | 71 | 2% (45%) | 2 | 10001 | 2.97(51.94%) | 5 |
| 10006 | 3% (65%) | | 2 | 10017 | 1% (47%) | 2 | | | |
| 103 | 3% (68%) | | 2 | 195 | 1% (48%) | 2 | | | |
| 149 | 2% (70%) | | 2 | 48 | 1% (49%) | 2 | | | |
| 10002 | 3% (73%) | | 6 | 123 | 1% (50%) | 2 | | | |
| 153 | 2% (75%) | | 2 | 124 | 1% (51%) | 2 | | | |
| 117 | 3% (78%) | | 2 | 90 | 1% (52%) | 2 | | | |
| 10005 | 2% (80%) | | 2 | 10012 | 1% (53%) | 2 | | | |
| | | | | 10015 | 1% (54%) | 4 | | | |

| Site | 2019 Fisher survey ranking % FAL catch (cumulative %) | 2019 Fisher survey ranking % SPN catch (cumulative %) (PAN only) | Region | Site FAL | 2020 – 2021 Sample ranking % FAL catch (cumulative %) | Region FAL | Site SPN | 2020 – 2021 Sample ranking % SPN catch (cumulative %) | Region SPN |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 45 | 1% (55%) | 5 | | | |
| | | | | 238 | 1% (56%) | 5 | | | |
| | | | | 102 | 1% (57%) | 5 | | | |
| | | | | 129 | 1% (58%) | 6 | | | |
| | | | | 44 | 1% (59%) | 6 | | | |
| | | | | 141 | 1% (60%) | 6 | | | |
| | | | | | | | | | |
| **NIC** | | | | | | | | | |
| 571 | 22% | | 5 | 10033* | 25% | 4 | 563 | 17.04 | 4 |
| 566 | 19% (41%) | | 4 | 563* | 19% (44%) | 4 | 675 | 11.77(28.81%) | 4 |
| 673 | 14% (55%) | | 4 | 639 | 11% (54%) | 2 | 549 | 11.75(40.56%) | 1 |
| 563 | 14% (69%) | | 4 | 640 | 6% (60%) | 2 | 555 | 11.63(52.19%) | 2 |
| 10033 | 8% (77%) | | 4 | 555* | 6% (66%) | 2 | 10033 | 10(62.19%) | 4 |
| 676 | 4% (81%) | | 4 | 671* | 5% (71%) | 4 | 637 | 7.04(69.23%) | 2 |
| | | | | 658 | 5% (76%) | 3 | 566 | 3.99(73.22%) | 4 |
| | | | | 1362 | 4% (80%) | 2 | 556 | 3.83(77.05%) | 2 |
| | | | | | | | 682 | 2.92(79.97%) | 4 |
| | | | | | | | 648 | 1.6(81.57%) | 2 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **PAN** | | | | | | | | | |
| 704 | 23% | | 5 | | | | 1304 | 11% | 6 |
| 10037 | 11% (34%) | | 5 | | | | 1340 | 10% (21%) | 6 |
| 721 | 11% (45%) | | 2 | | | | 711* | 8% (29%) | 6 |
| 1295 | 6% (51%) | | 4 | | | | 704* | 6% (35%) | 5 |

| Site | 2019 Fisher survey ranking % FAL catch (cumulative %) | 2019 Fisher survey ranking % SPN catch (cumulative %) (PAN only) | Region | Site FAL | 2020 – 2021 Sample ranking % FAL catch (cumulative %) | Region FAL | Site SPN | 2020 – 2021 Sample ranking % SPN catch (cumulative %) | Region SPN |
|---|---|---|---|---|---|---|---|---|---|
| 711 | 5% (56%) | | 6 | | | | 1341 | 5% (40%) | 6 |
| 1316 | 4% (60%) | | 2 | | | | 1354* | 4% (44%) | 4 |
| 701 | 4% (64%) | | 5 | | | | 703 | 4% (47%) | 5 |
| 724 | 4% (68%) | | 1 | | | | 10041 | 3% (50%) | 5 |
| 700 | 3% (71%) | | 3 | | | | 699 | 3% (53%) | 3 |
| 1354 | 3% (74%) | | 4 | | | | 724 | 2% (55%) | 1 |
| 720 | 2% (76%) | | 2 | | | | 707 | 2% (58%) | 1 |
| 1355 | 3% (79%) | | 4 | | | | 700* | 2% (60%) | 3 |
| 707 | 2% (81%) | | 1 | | | | 1324 | 2% (62%) | 3 |
| | | | | | | | 10036* | 2% (64%) | 5 |
| | | | | | | | 1335 | 2% (66%) | 5 |
| | | | | | | | 1352 | 2% (67%) | 4 |
| | | | | | | | 1295* | 2% (69%) | 4 |
| | | | | | | | 706* | 2% (71%) | 2 |
| | | | | | | | 1293 | 2% (72%) | 3 |
| | | | | | | | 697 | 2% (74%) | 3 |
| | | | | | | | 1291 | 2% (76%) | 2 |
| | | | | | | | 1305 | 1% (77%) | 2 |
| | | | | | | | 1316 | 1% (78%) | 2 |
| | | | | | | | 1322 | 1% (79%) | 3 |
| | | | | | | | 10037* | 1% (80%) | 5 |

**Table 11**. Estimation of sampling costs, by country, region and landing sites. To avoid overestimation or underestimation, the costs have been standardized for all of Central America. To achieve a higher level of coverage of the estimated catch by country, for the cost, sampling those sites estimated to represent more than 10% of the total catch by country would be recommended.

| Country | Region | Landing site | Catch (%) FAL | Catch (%) SPN | Sampling technician required | Total Cost by Landing site | Sampling Coverage (%) by all region | | | Sampling coverage (>10%) by landing site | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | FAL | SPN | Total Cost | FAL | SPN | Total Cost |
| **CRI** | 4 | 1143 | 58% | <1% | 2 | $40,100 | **82%** | **0%** | **$79,200** | **82%** | <1% | **$79,200** |
| | 2 | 1357 | 24% | 0% | 4 | $79,200 | | | | | | |
| **SLV** | 2 | 255 | 10% | 3% | 2 | $40,100 | **18%** | **7%** | $79,200 | **10%** | **3%** | **$40,100** |
| | | 256 | 8% | 4% | 4 | $79,200 | | | | | | |
| | 3 | 10029 | 11% | 3% | 2 | $40,100 | **33%** | **3%** | $171,800 | **22%** | **3%** | **$79,200** |
| | | 10027 | 11% | <1% | 4 | $79,200 | | | | | | |
| | | 462 | 8% | <1% | 6 | $118,300 | | | | | | |
| | | 280 | 3% | 0% | 8 | $171,800 | | | | | | |
| | 4 | 503 | 5% | 0% | 2 | $40,100 | **8%** | **0%** | $79,200 | | | |
| | | 504 | 2% | 0% | 4 | $79,200 | | | | | | |
| | 6 | 304 | 12% | 0% | 2 | $40,100 | **15%** | **0%** | $79,200 | **12%** | **0%** | **$40,100** |
| | | 302 | 3% | <1% | 4 | $79,200 | | | | | | |
| | 8 | 328 | 4% | 0% | 2 | $40,100 | **6%** | **0%** | $79,200 | | | |
| | | 317 | 2% | 0% | 4 | $79,200 | | | | | | |
| **GTM** | 2 | 149 | 11% | 0% | 2 | $40,100 | **49%** | **7%** | $552,500 | **33%** | **6%** | **$118,300** |
| | | 10016 | 11% | 5% | 4 | $79,200 | | | | | | |
| | | 10018 | 11% | 2% | 6 | $118,300 | | | | | | |
| | | 117 | 5% | 0% | 8 | $171,800 | | | | | | |
| | | 101 | 2% | 0% | 10 | $196,500 | | | | | | |
| | | 10005 | 2% | 0% | 12 | $235,600 | | | | | | |
| | | 102 | 1% | 0% | 14 | $ 274,700 | | | | | | |
| | | 123 | 1% | 0% | 16 | $ 328,200 | | | | | | |

| Country | Region | Landing site | Catch (%) FAL | Catch (%) SPN | Sampling technician required | Total Cost by Landing site | Sampling Coverage (%) by all region | | | Sampling coverage (>10%) by landing site | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | FAL | SPN | Total Cost | FAL | SPN | Total Cost |
| **GTM** | 2 | 124 | 1% | 0% | 18 | $ 352,900 | | | | | | |
| | | 129 | 1% | 0% | 20 | $ 392,000 | | | | | | |
| | | 141 | 1% | 0% | 22 | $ 431,100 | | | | | | |
| | | 10015 | 1% | 0% | 24 | $ 470,200 | | | | | | |
| | | 10017 | 1% | 0% | 26 | $ 552,500 | | | | | | |
| | 4 | 195 | 1% | 0% | 2 | $40,100 | **1%** | **0%** | **$40,100** | | | |
| | 5 | 10009 | 2% | 1% | 2 | $40,100 | **5%** | **1%** | **$171,800** | | | |
| | | 44 | 1% | 0% | 4 | $79,200 | | | | | | |
| | | 45 | 1% | 0% | 6 | $118,300 | | | | | | |
| | | 48 | 1% | 0% | 8 | $ 171,800 | | | | | | |
| | 6 | 71 | 2% | 0% | 2 | $40,100 | **5%** | **1%** | **$171,800** | | | |
| | | 90 | 1% | 0% | 4 | $79,200 | | | | | | |
| | | 238 | 1% | 0% | 6 | $118,300 | | | | | | |
| | | 10012 | 1% | 0% | 8 | $171,800 | | | | | | |
| **NIC** | 2 | 639 | 11% | 0% | 2 | $40,100 | **27%** | **12%** | **$171,800** | 11% | 0% | **$40,100** |
| | | 640 | 6% | 0% | 4 | $79,200 | | | | | | |
| | | 555 | 6% | 12% | 6 | $118,300 | | | | | | |
| | | 1362 | 4% | 0% | 8 | $171,800 | | | | | | |
| | 3 | 658 | 5% | 0% | 2 | $40,100 | **5%** | **0%** | **$40,100** | 5% | 0% | |
| | 4 | 10033 | 25% | 10% | 2 | $40,100 | **49%** | **27%** | **$118,300** | 44% | 27% | **$79,200** |
| | | 563 | 19% | 17% | 4 | $79,200 | | | | | | |
| | | 671 | 5% | <1% | 6 | $118,300 | | | | | | |
| **PAN** | 1 | 707 | | 2% | 2 | $40,100 | 0% | 4% | **$79,200** | | | |
| | | 724 | | 2% | 4 | $79,200 | | | | | | |
| | 2 | 706 | | 2% | 2 | $40,100 | 0% | 6% | **$171,800** | | | |

| Country | Region | Landing site | Catch (%) FAL | Catch (%) SPN | Sampling technician required | Total Cost by Landing site | Sampling Coverage (%) by all region | | | Sampling coverage (>10%) by landing site | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | FAL | SPN | Total Cost | FAL | SPN | Total Cost |
| **PAN** | 2 | 1291 | | 2% | 4 | $79,200 | | | | | | |
| | | 1305 | | 1% | 6 | $118,300 | | | | | | |
| | | 1316 | | 1% | 8 | $171,800 | | | | | | |
| | 3 | 699 | | 3% | 2 | $40,100 | 0% | 12% | **$250,000** | | | |
| | | 697 | | 2% | 4 | $79,200 | | | | | | |
| | | 700 | | 2% | 6 | $118,300 | | | | | | |
| | | 1293 | | 2% | 8 | $171,800 | | | | | | |
| | | 1324 | | 2% | 10 | $196,500 | | | | | | |
| | | 1322 | | 1% | 12 | $250,000 | | | | | | |
| | 4 | 1354 | | 4% | 2 | $40,100 | 0% | 8% | **$118,300** | | | |
| | | 1295 | | 2% | 4 | $79,200 | | | | | | |
| | | 1352 | | 2% | 6 | $118,300 | | | | | | |
| | 5 | 704 | | 6% | 2 | $40,100 | 0% | 18% | **$250,000** | | | |
| | | 703 | | 4% | 4 | $79,200 | | | | | | |
| | | 10041 | | 3% | 6 | $118,300 | | | | | | |
| | | 1335 | | 2% | 8 | $171,800 | | | | | | |
| | | 10036 | | 2% | 10 | $196,500 | | | | | | |
| | | 10037 | | 1% | 12 | $250,000 | | | | | | |
| | 6 | 1304 | | 11% | 2 | $40,100 | 0% | 34% | **$171,800** | **0%** | **21%** | **$ 79,200** |
| | | 1340 | | 10% | 4 | $79,200 | | | | | | |
| | | 711 | | 8% | 6 | $118,300 | | | | | | |
| | | 1341 | | 5% | 8 | $171,800 | | | | | | |

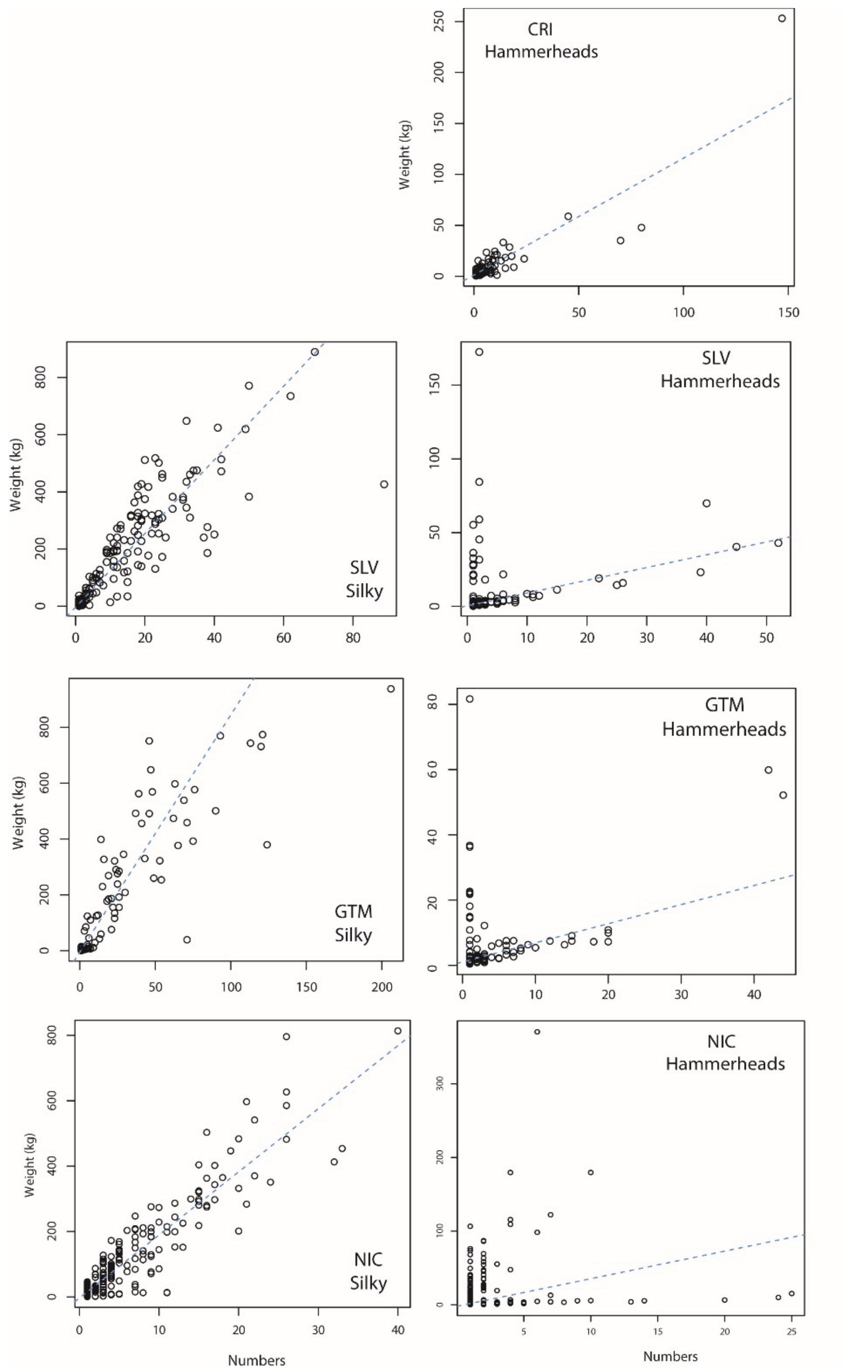



**Figure 1**. Relationship between catch in numbers and catch in weight for the silky shark (top) and for hammerhead sharks (bottom), by country, for trips for which catch of the species was recorded in numbers and weight. The dashed blue lines are the fitted relationships (Table 3) used to convert catch reported in number of trunks to weight. In the case of hammerheads, the fitted lines shown do not apply to small numbers of trunks above a certain weight (see text for details). There were too few silky sharks for CRI to estimate the estimate the relationship between number and weight.

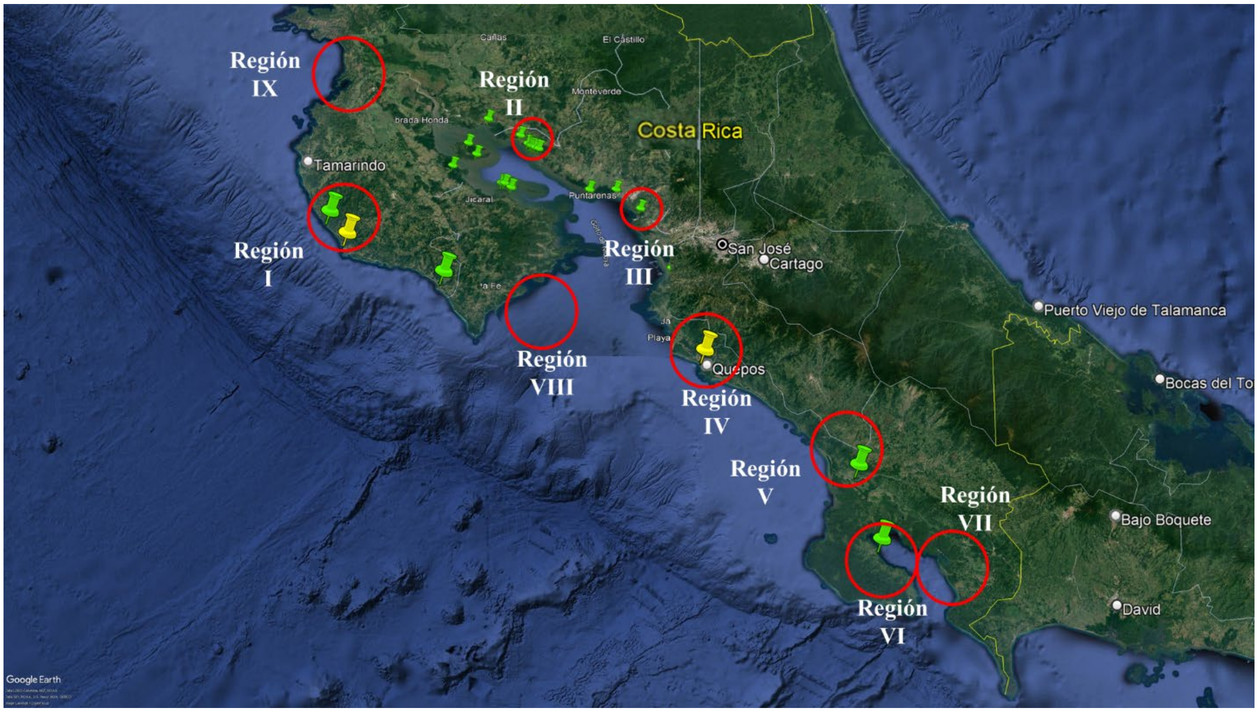



**Figure 2**. Distribution of the landing sites by regions of CRI, 2020-2021.


**Figure 2**. Distribution of the landing sites by regions of SLV, 2020-2021.

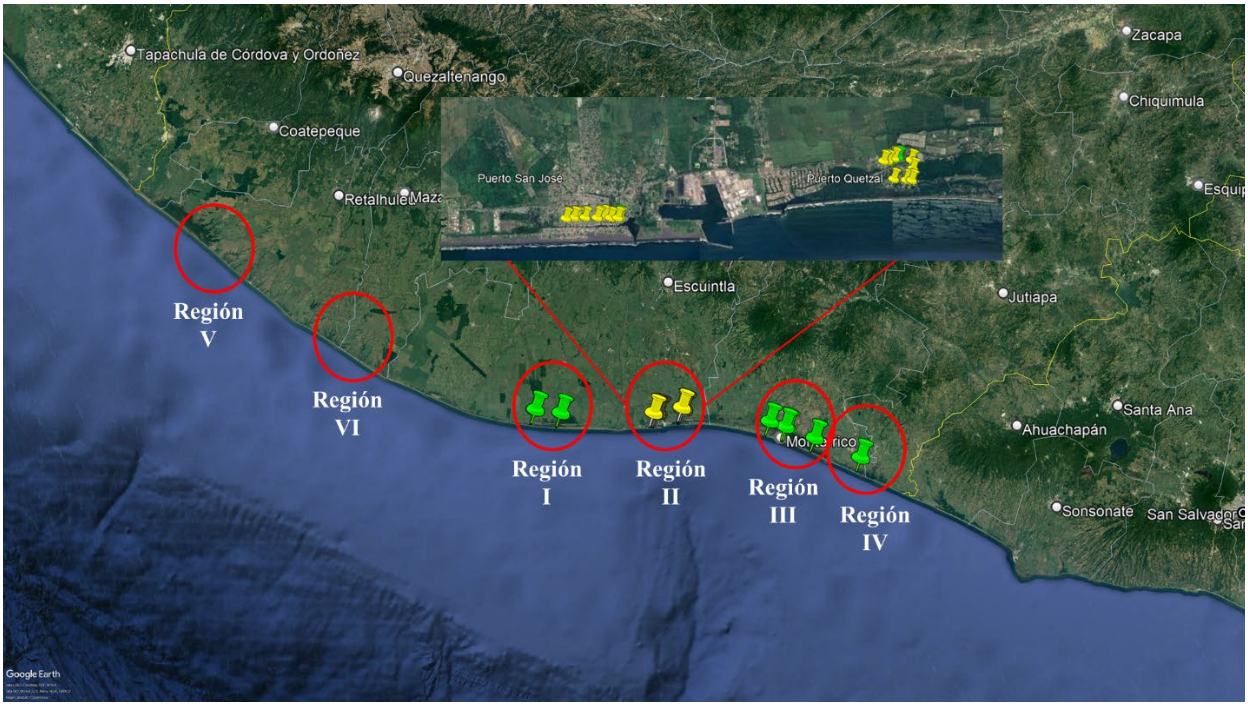



**Figure 2**. Distribution of the landing sites by regions of GTM, 2020-2021.


**Figure 2**. Distribution of the landing sites by regions of NIC, 2020-2021.

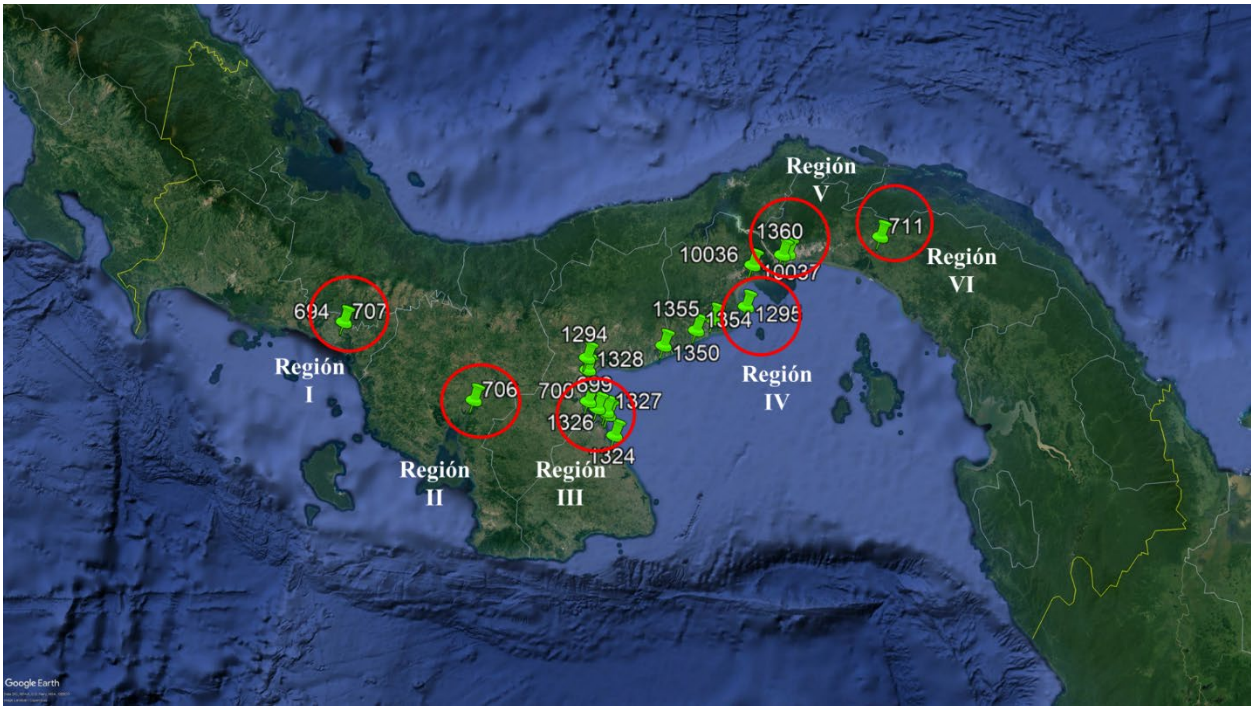



**Figure 2**. Distribution of the landing sites by regions of PAN, 2020-2021.

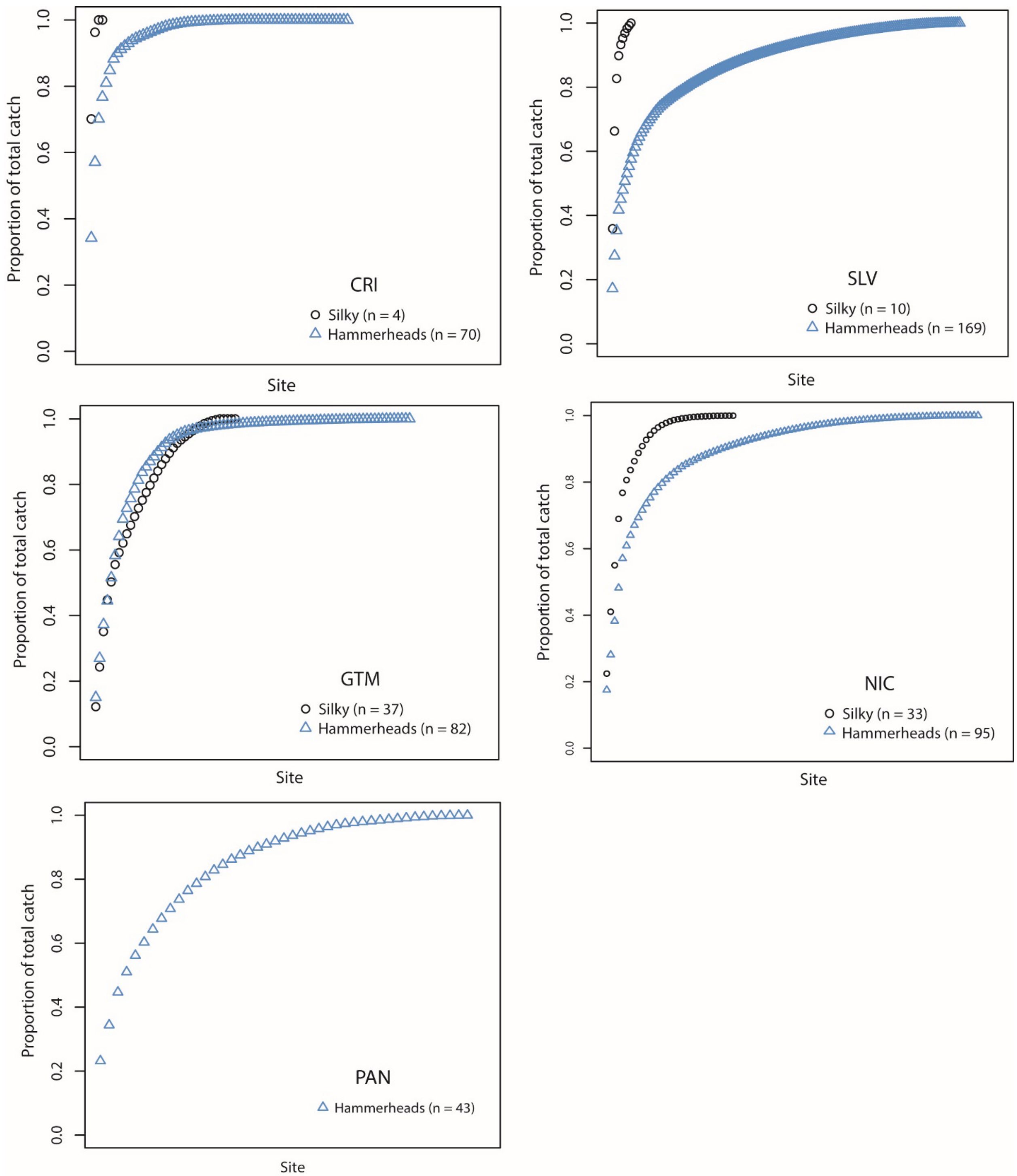
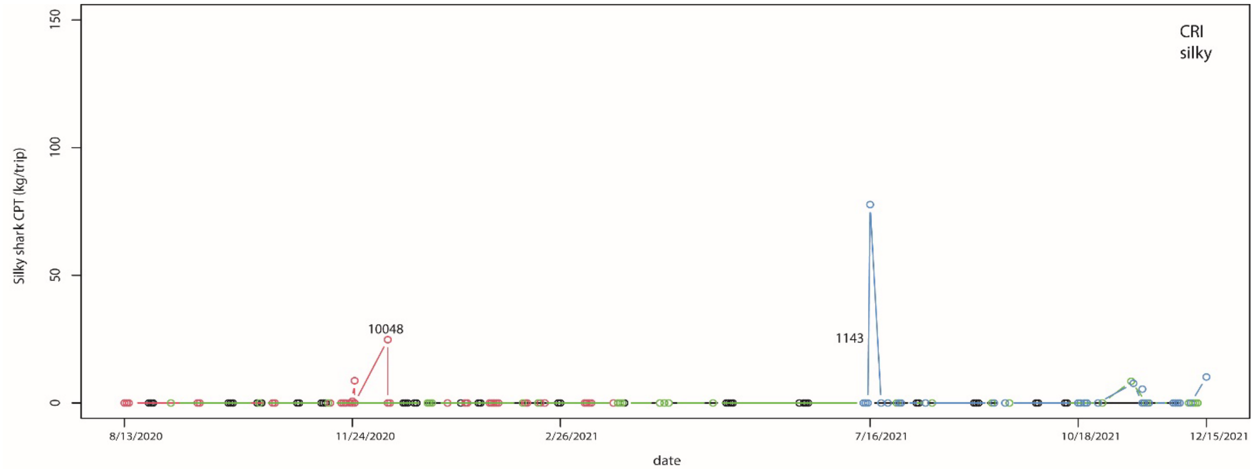
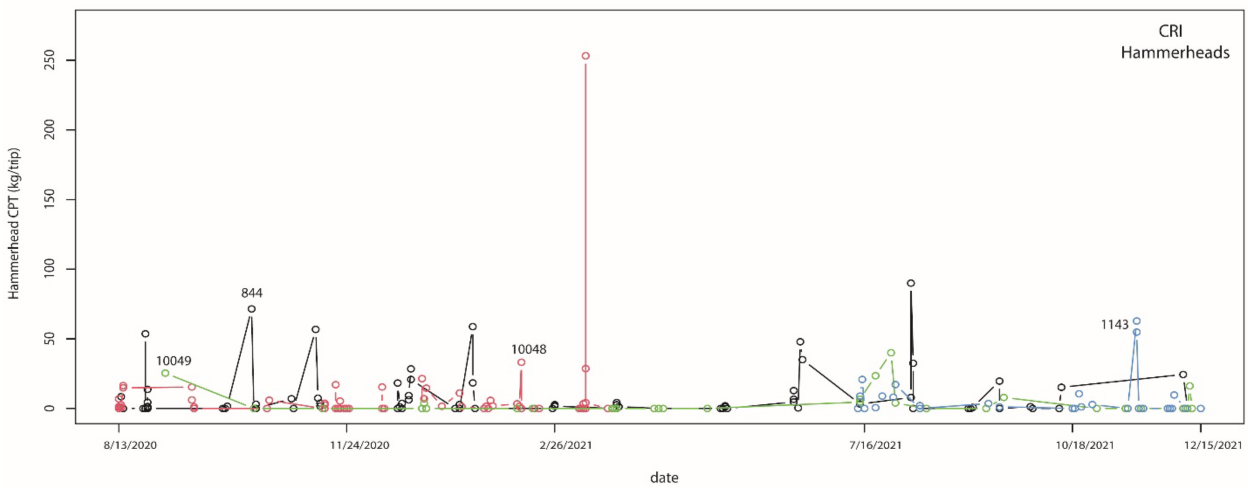



**Figure 3**. Proportion of the estimated fishing season catch, by site, for the silky shark (black circles) and hammerhead sharks (blue triangle), by country. The number of sites for which the species was present in the fisher interview data is indicated by *n*. For a species, sites are order for greatest to least contribution to the total season catch; the order of sites is not the same for the two species.



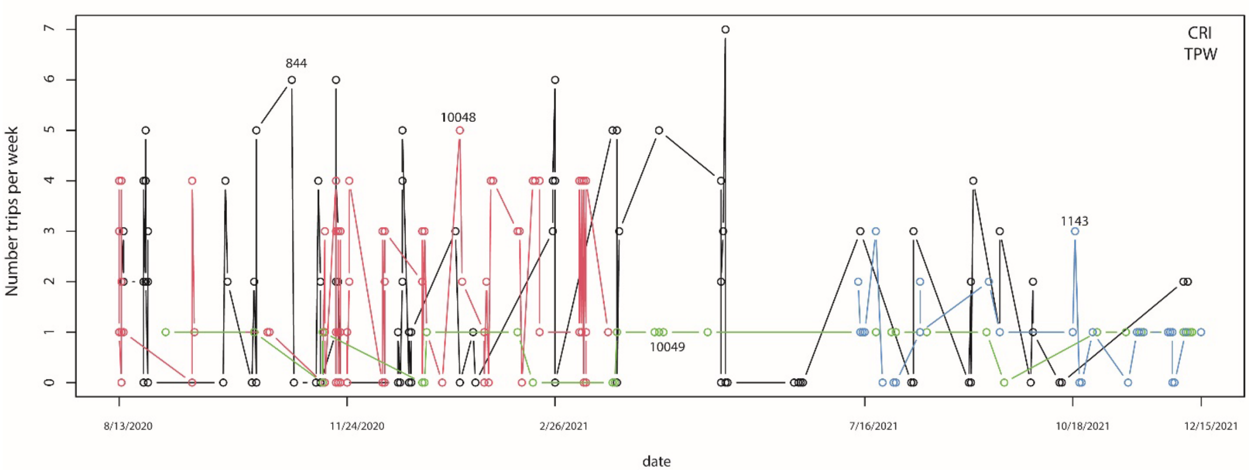




**Figure 4**. Silky catch-per-trip (CPT; top), hammerhead CPT (middle) and number of trips per week (TPW; bottom), by country (sites with zero catch of either the silky shark or hammerhead sharks for all or nearly all visits are not shown).

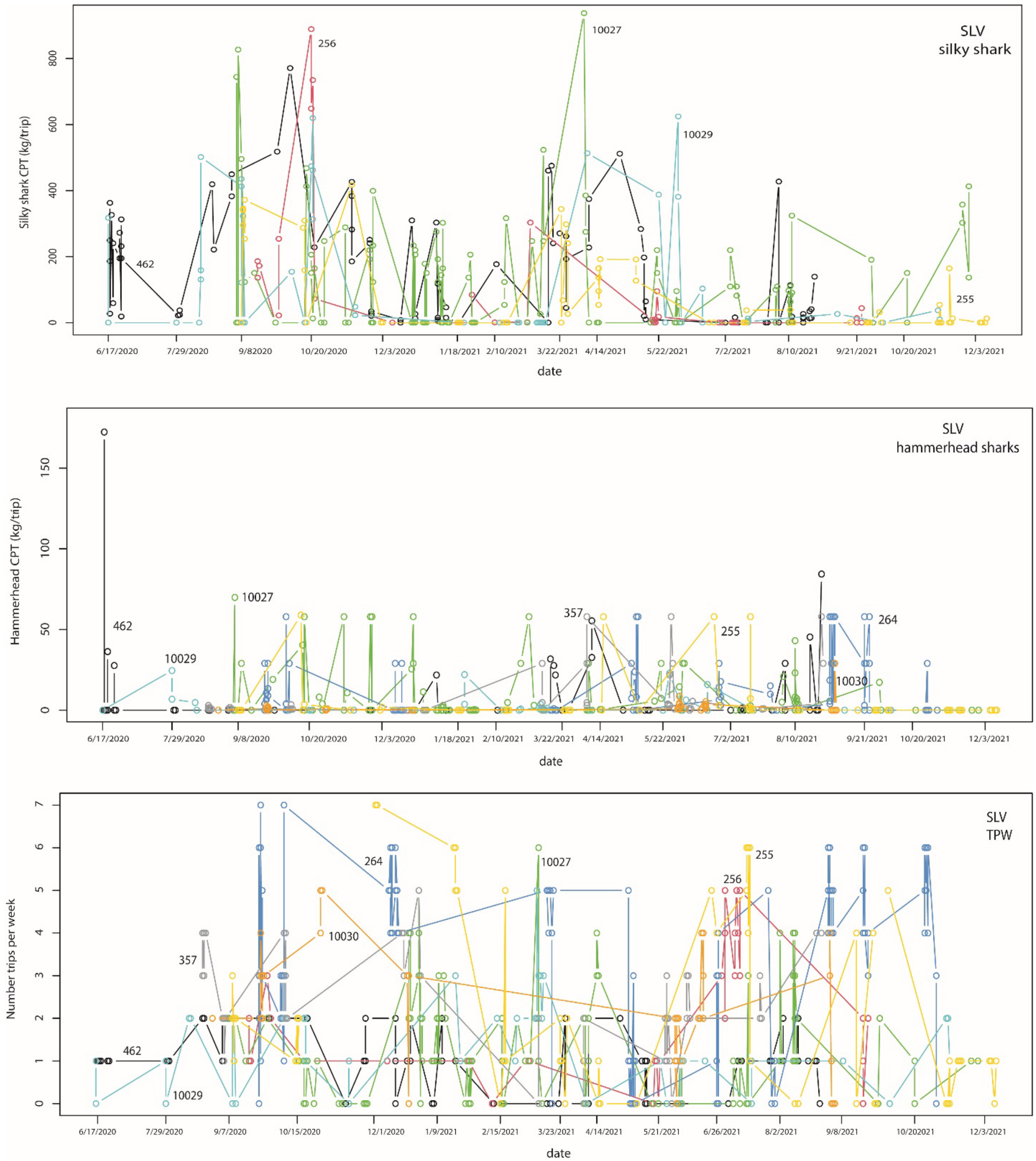



**Figure 4** continued.

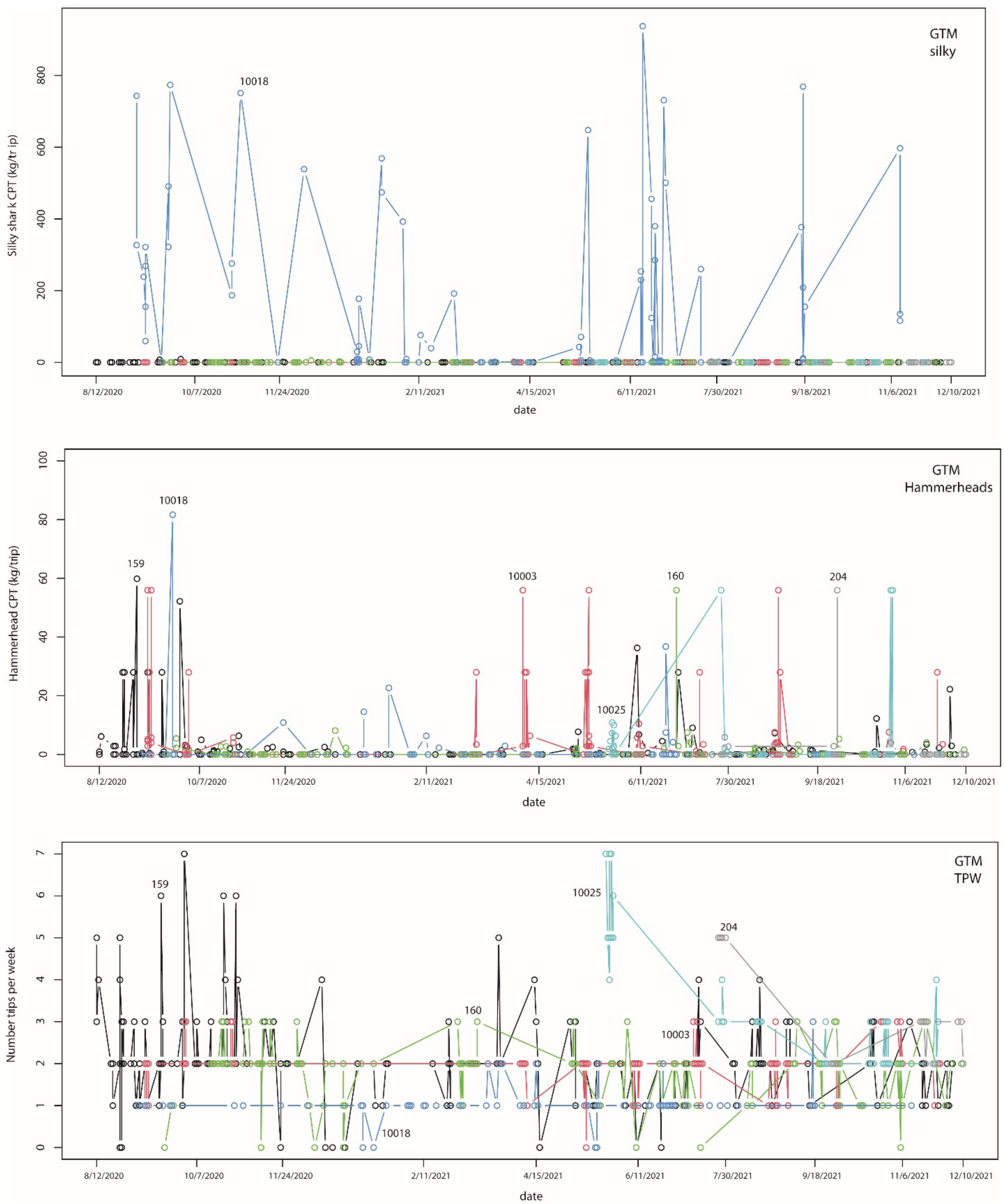



**Figure 4** continued.

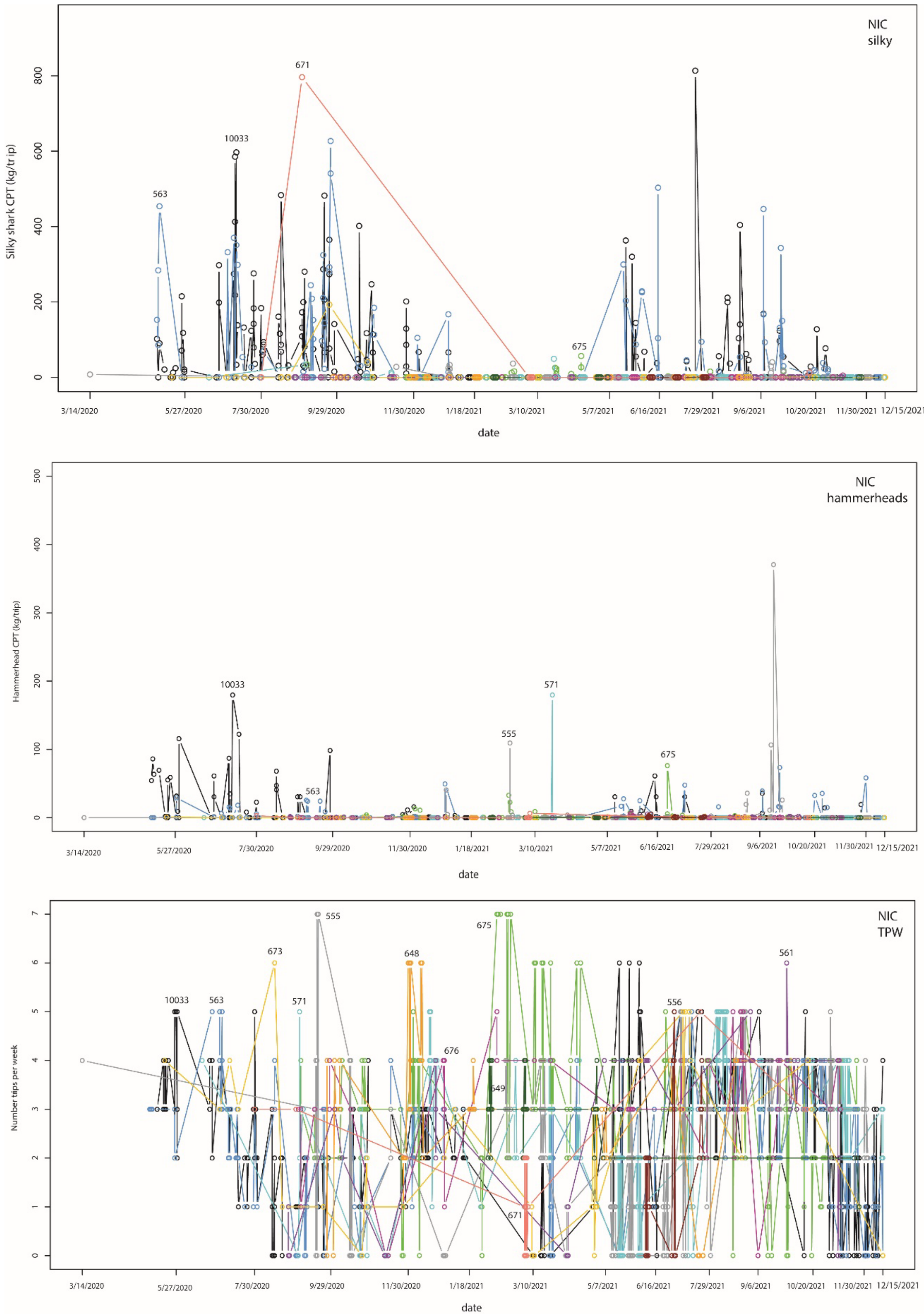
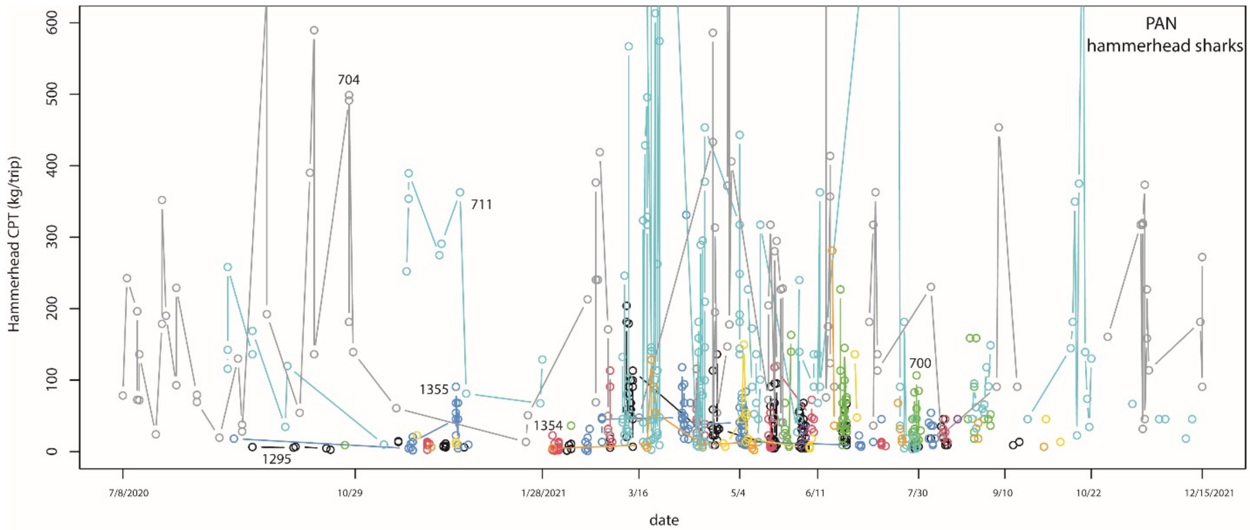



**Figure 4** continued.



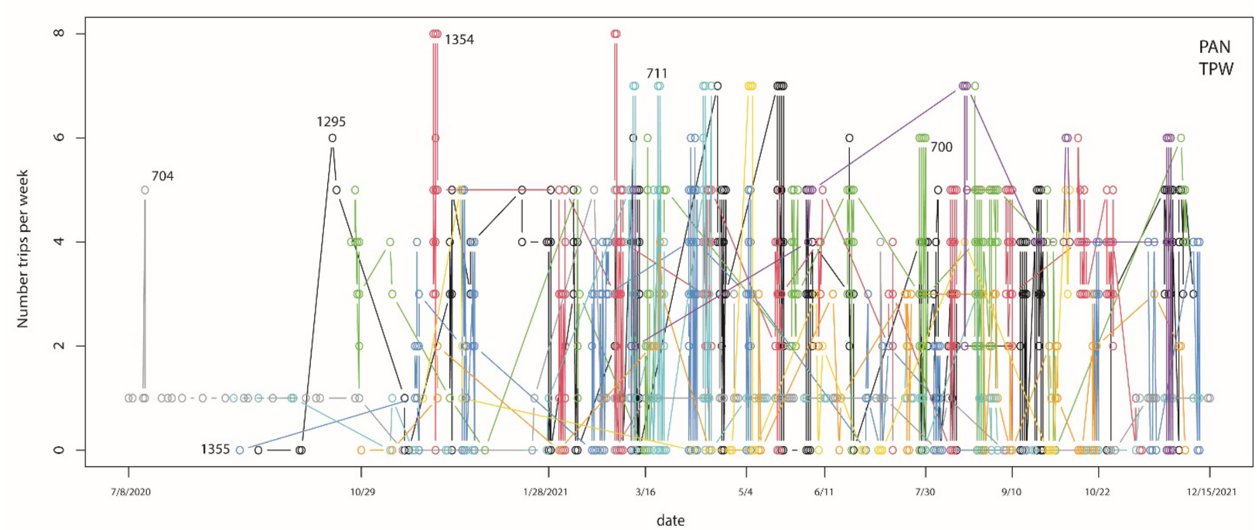




**Figure 4** continued. The y-axis of the CPT graph was trimmed to show detail.

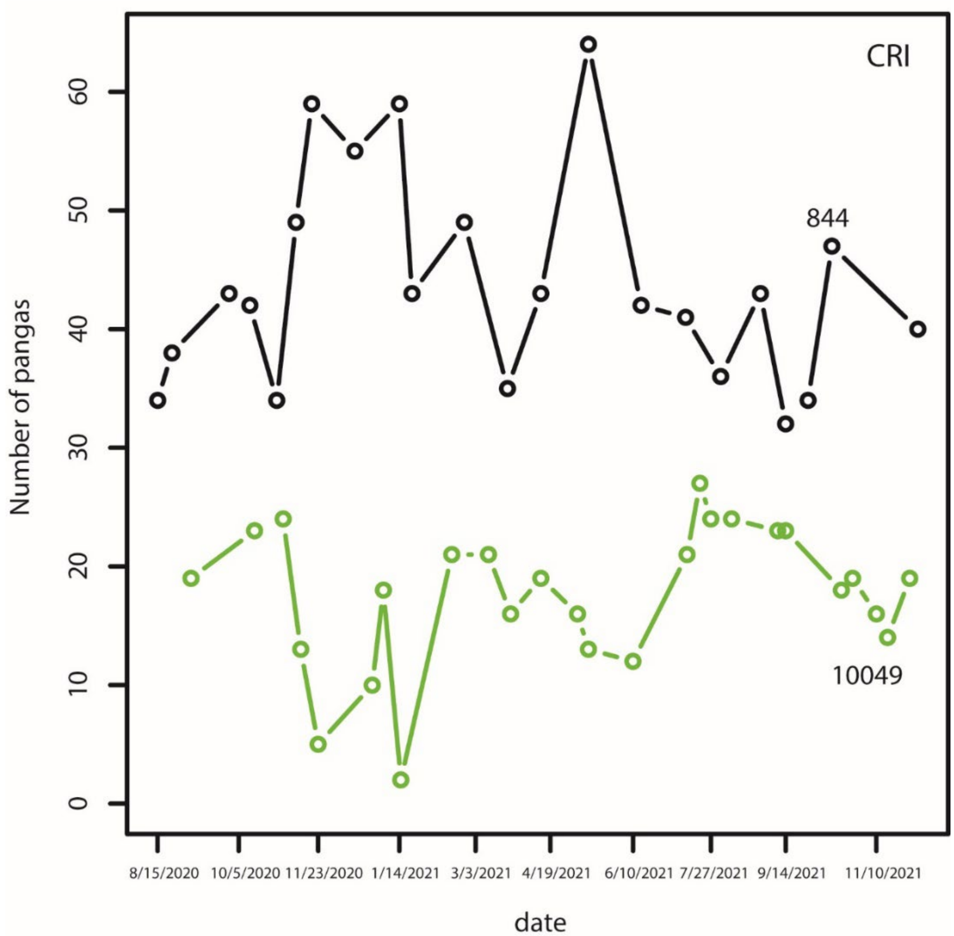


**Figure 5**. Times series of number of pangas, by site, in CRI, for sites with at least 20 data points.

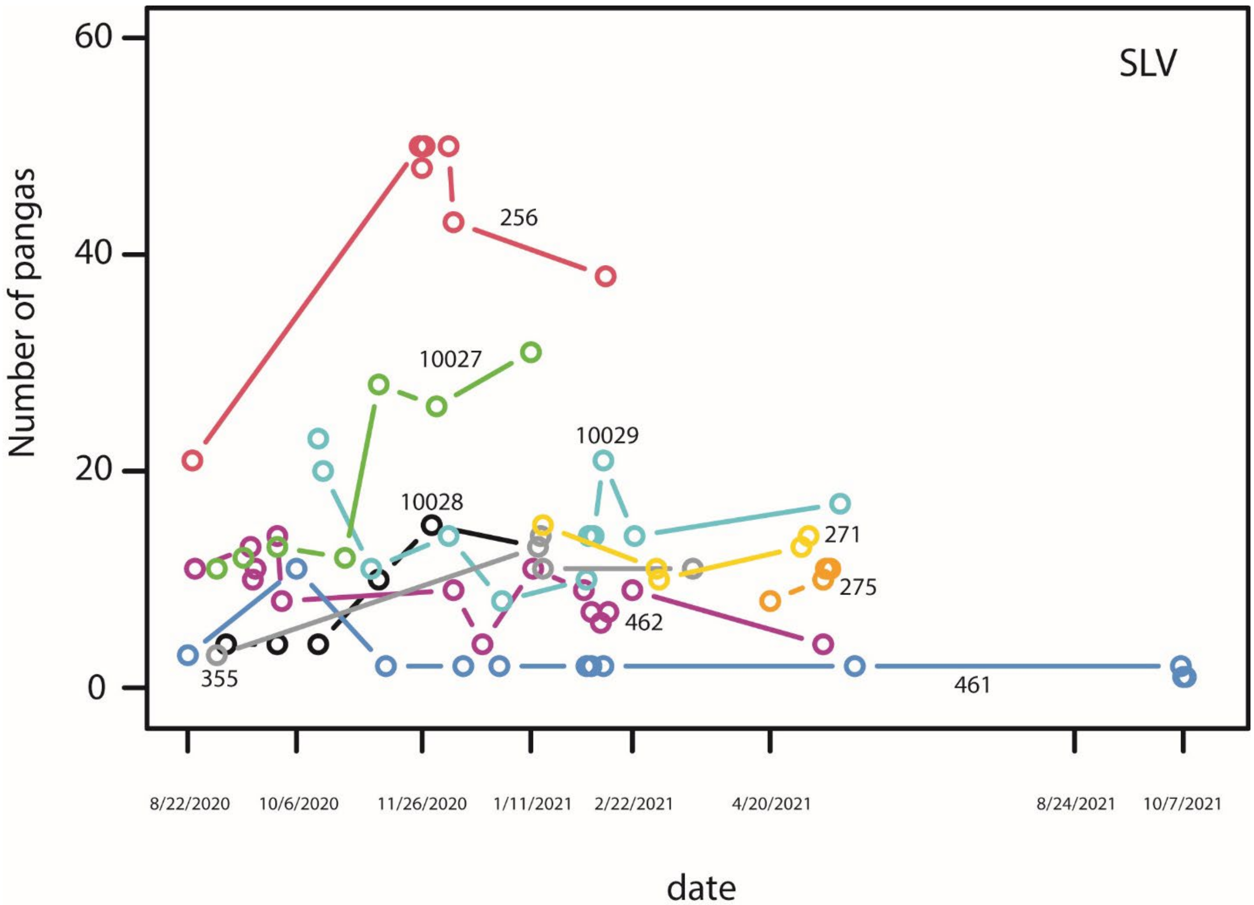


**Figure 5** continued. Times series of number of pangas, by site, in SLV, for sites with at least 5 data points.

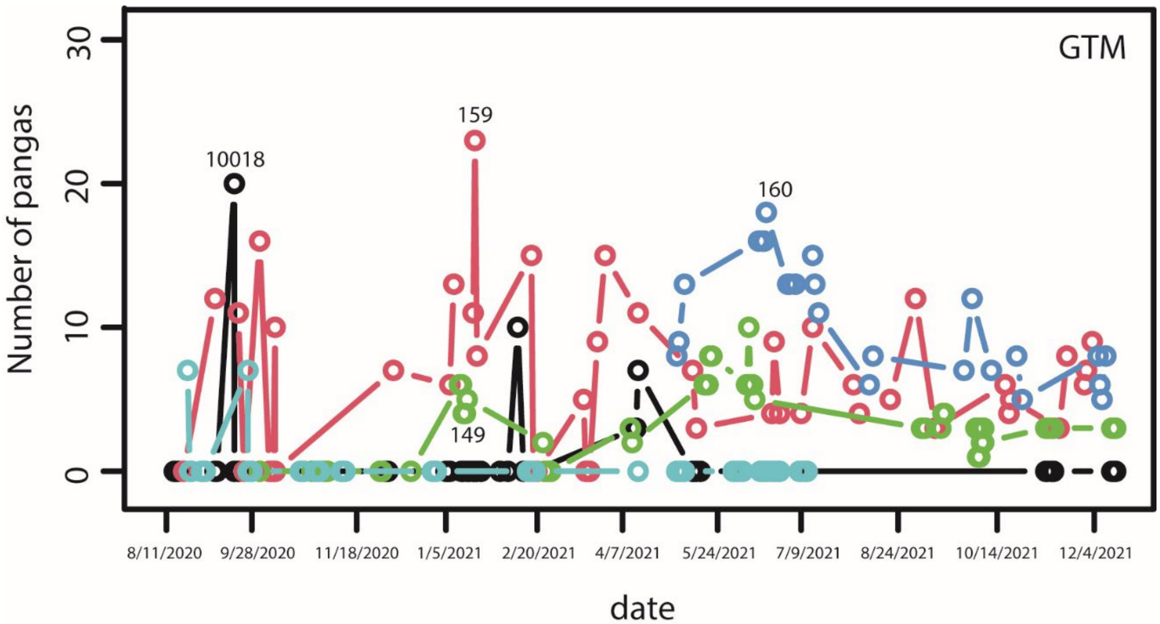



**Figure 5** continued. Times series of number of pangas, by site, in GTM, for sites with at least 20 data points.

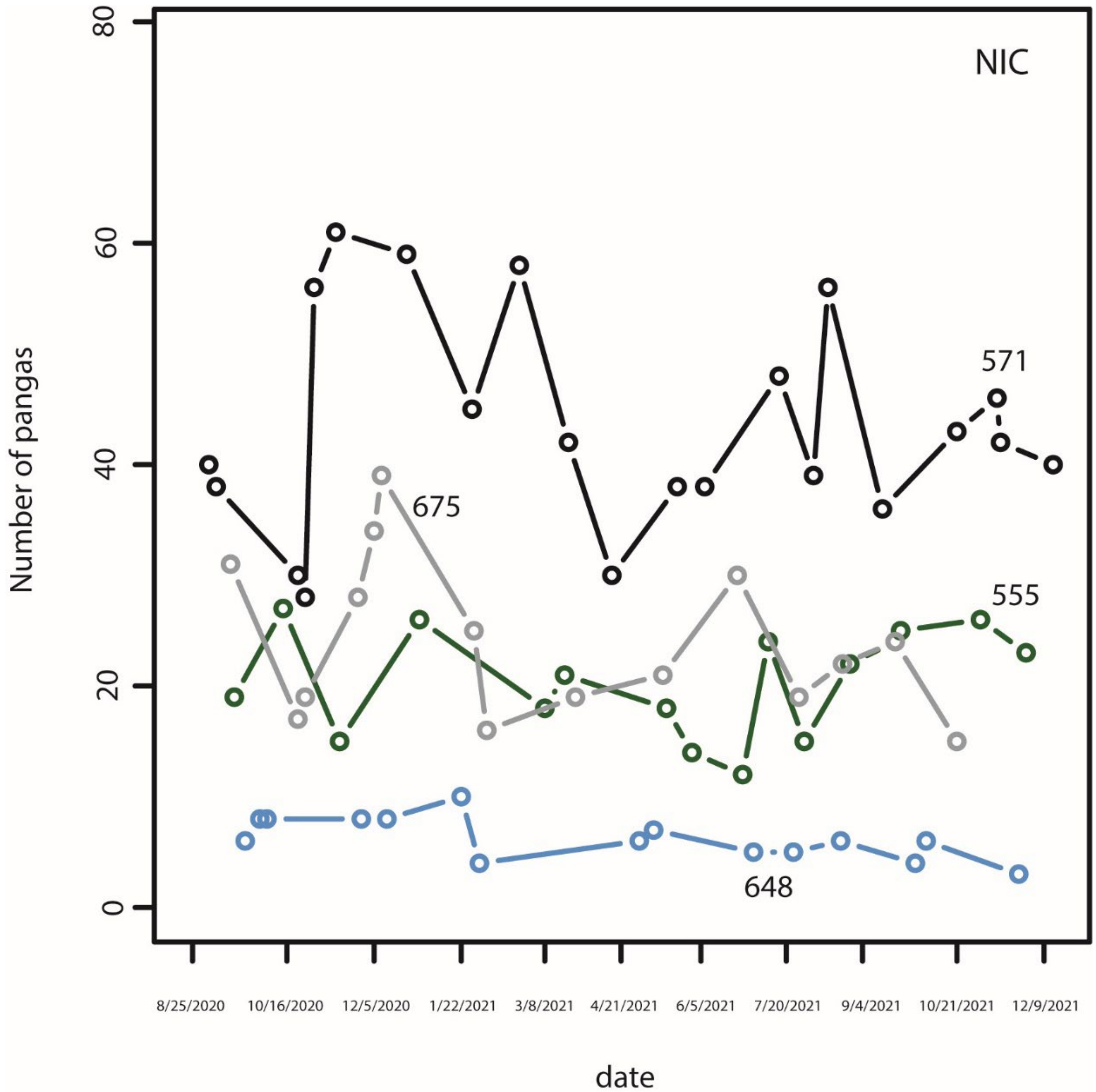



**Figure 5** continued. Times series of number of pangas, by site, in NIC, for sites with at 15 data points.

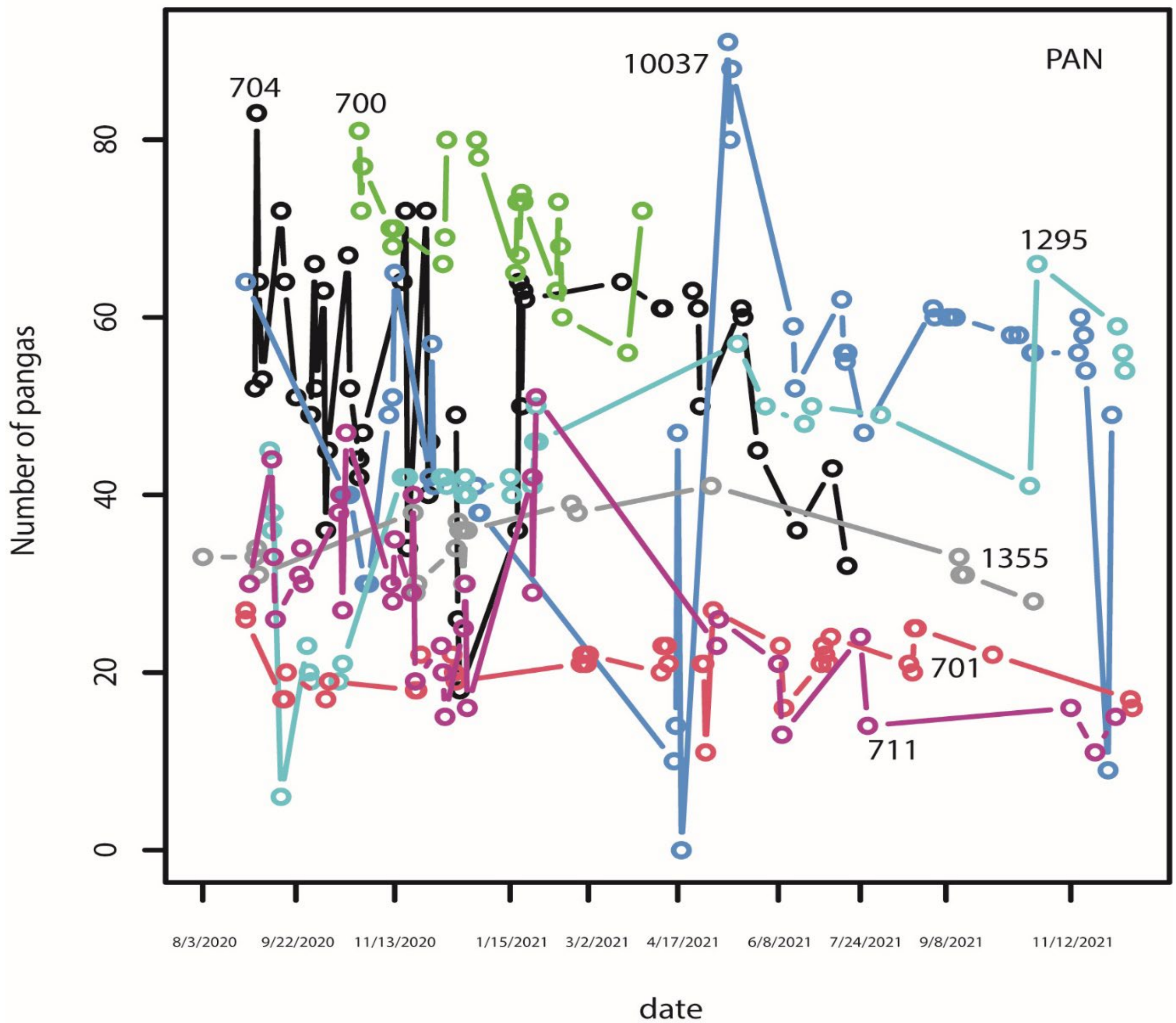



**Figure 5** continued. Times series of number of pangas, by site, in PAN, for sites with at least 20 data points.

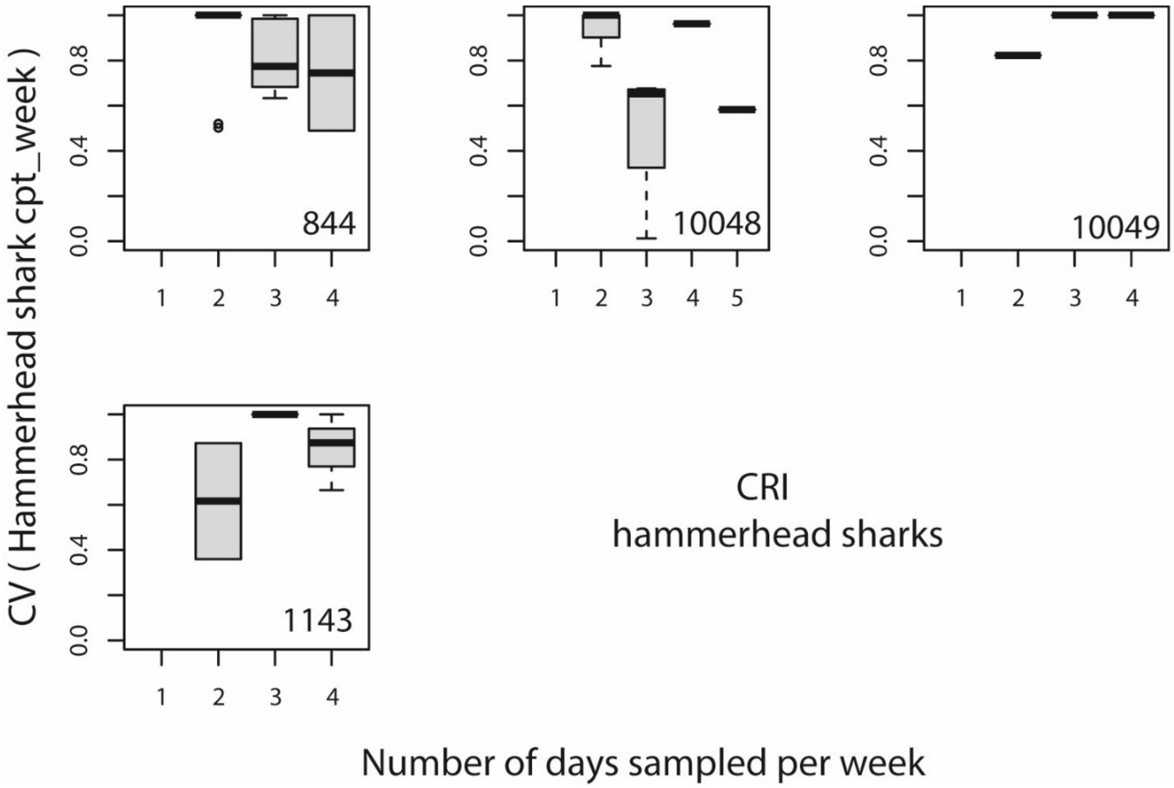



**Figure 6**. Box-and-whisker plots of the coefficient of variation for the weekly mean silky shark catch-per-trip (CPT) (top) and hammerhead CPT (bottom), at the sites in that are shown in Figure 4 (with sufficient data), *versus* the number of days sampled during the week, by country.

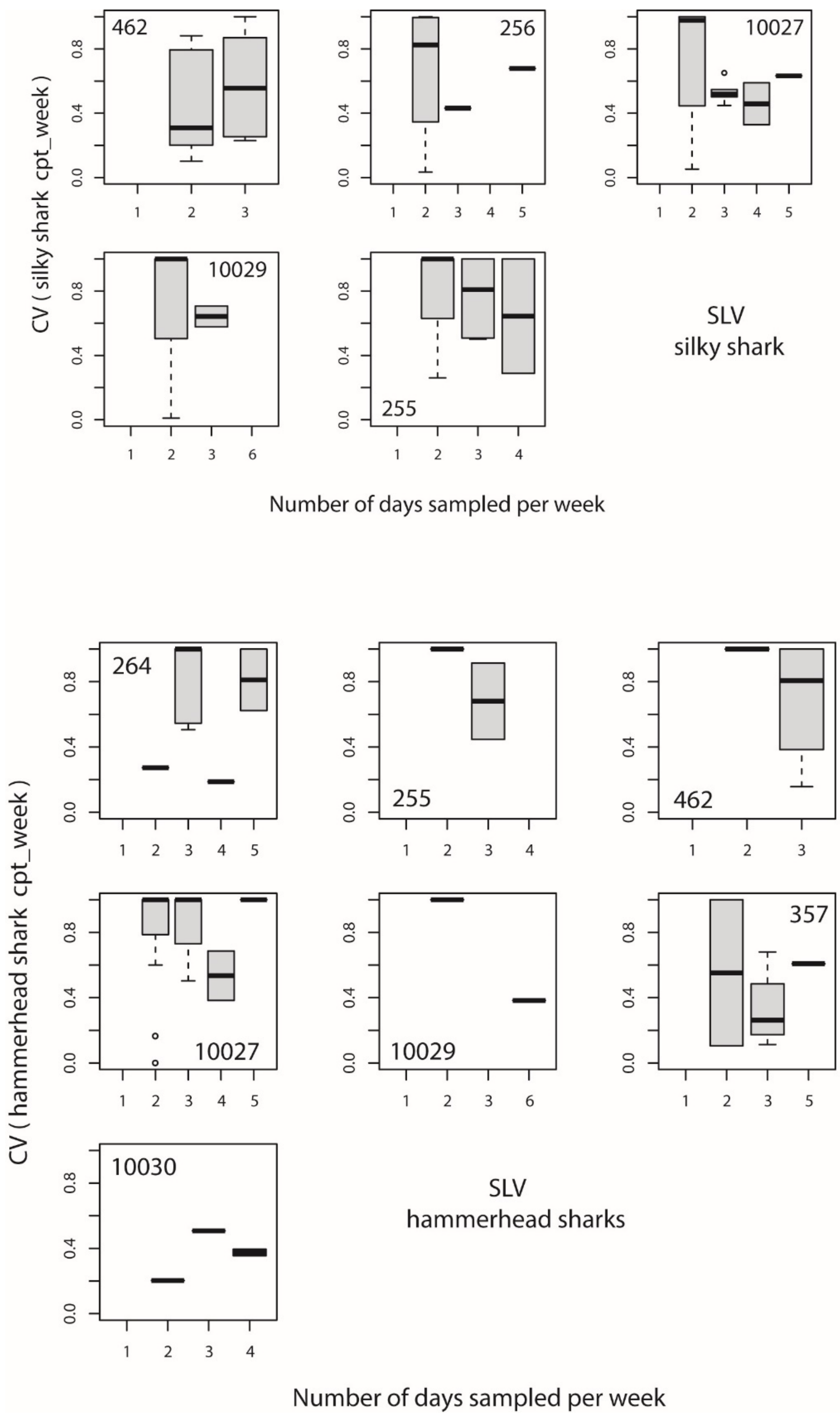



**Figure 6** continued.

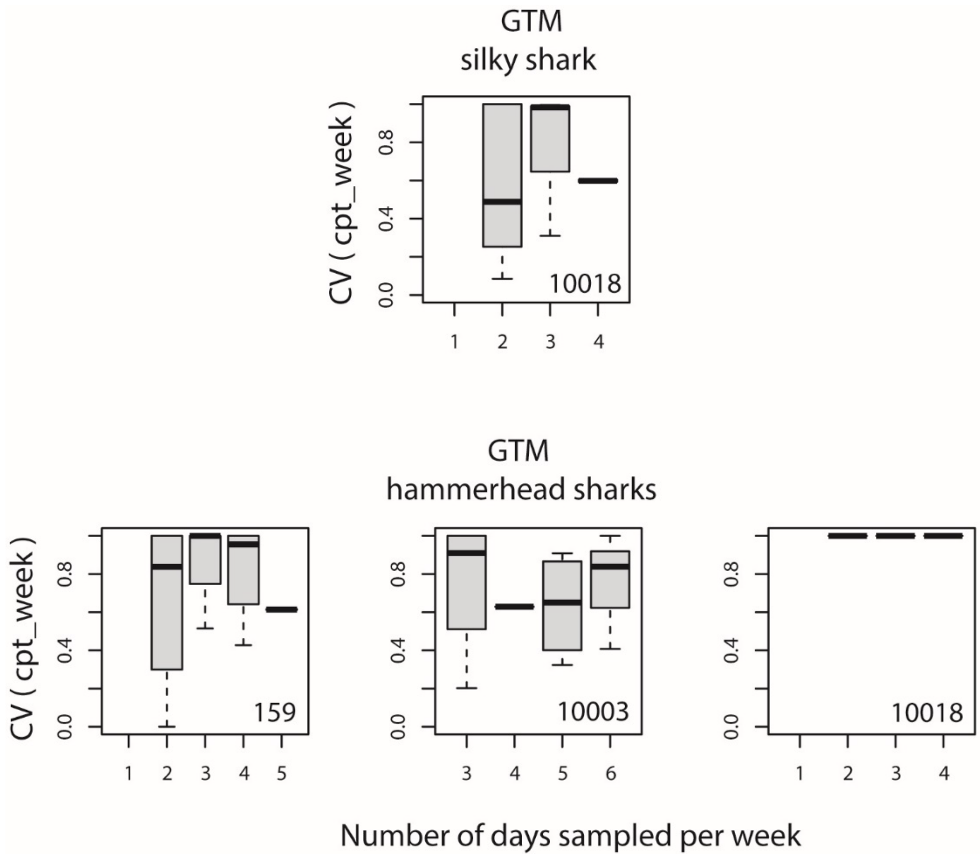



**Figure 6** continued.

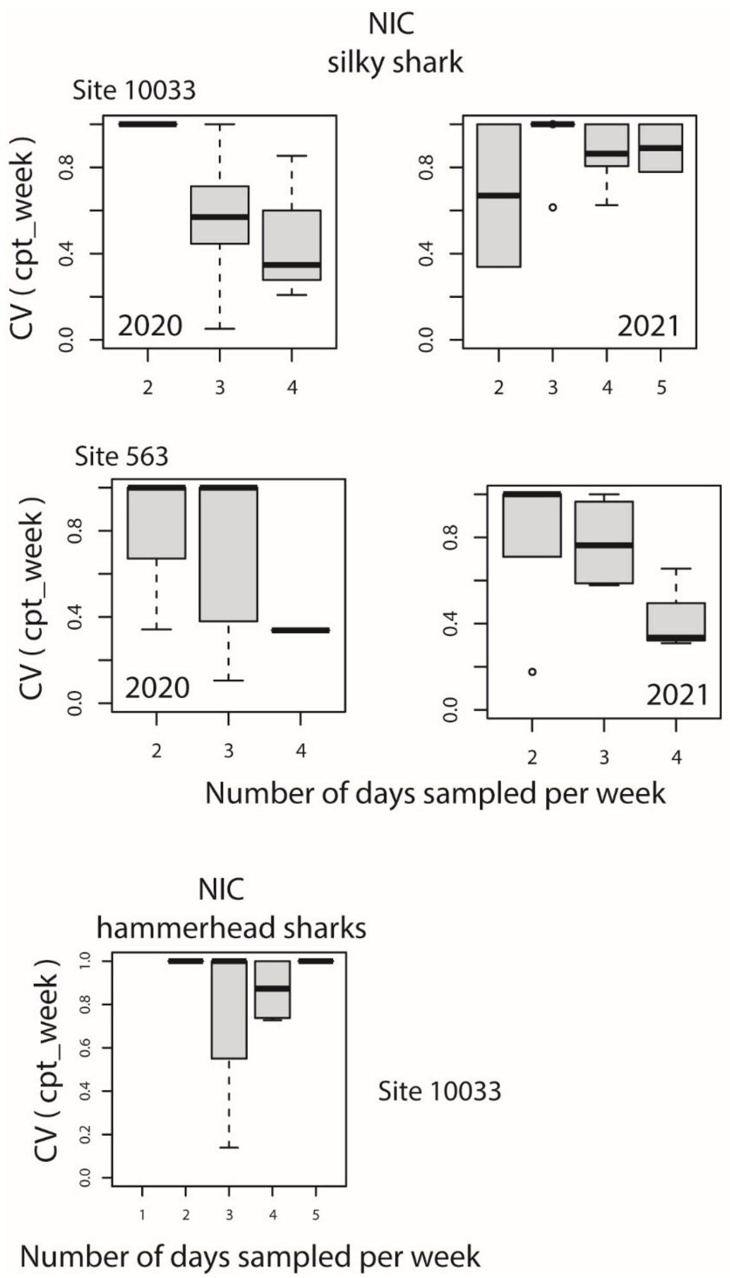



**Figure 6** continued.

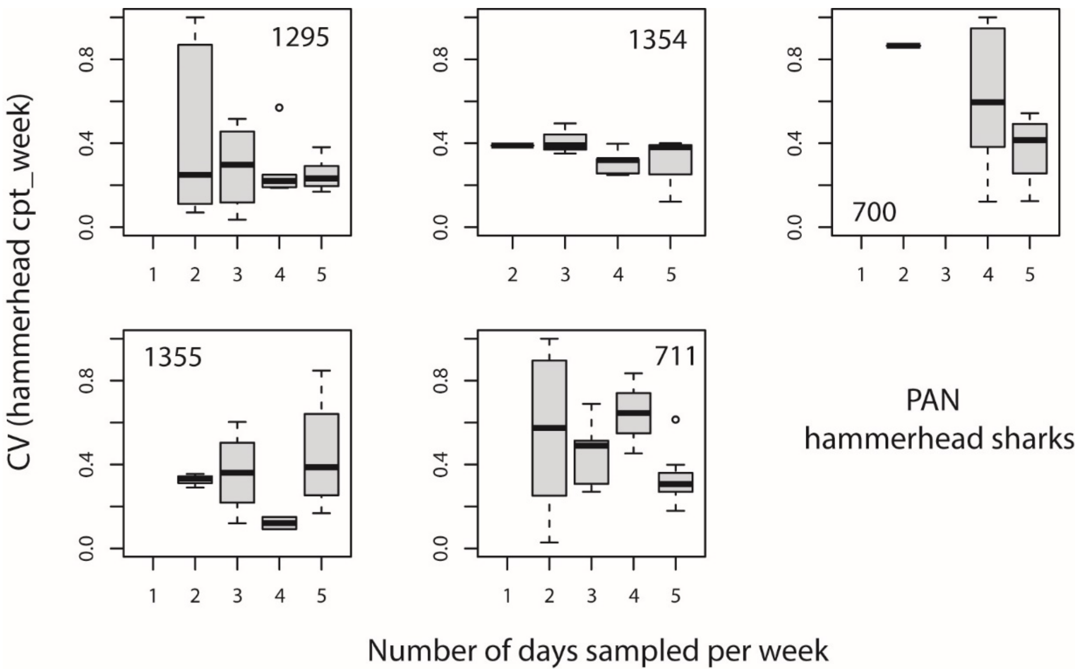



**Figure 6** continued.

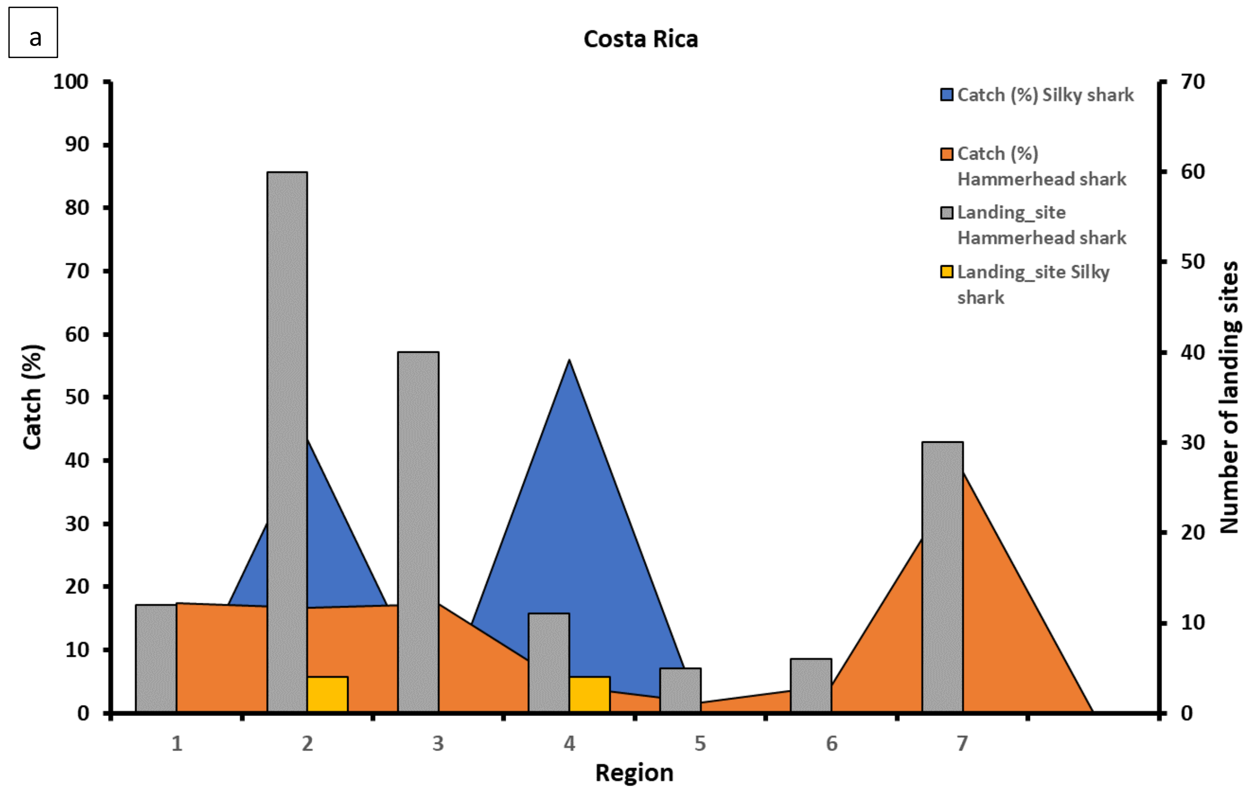
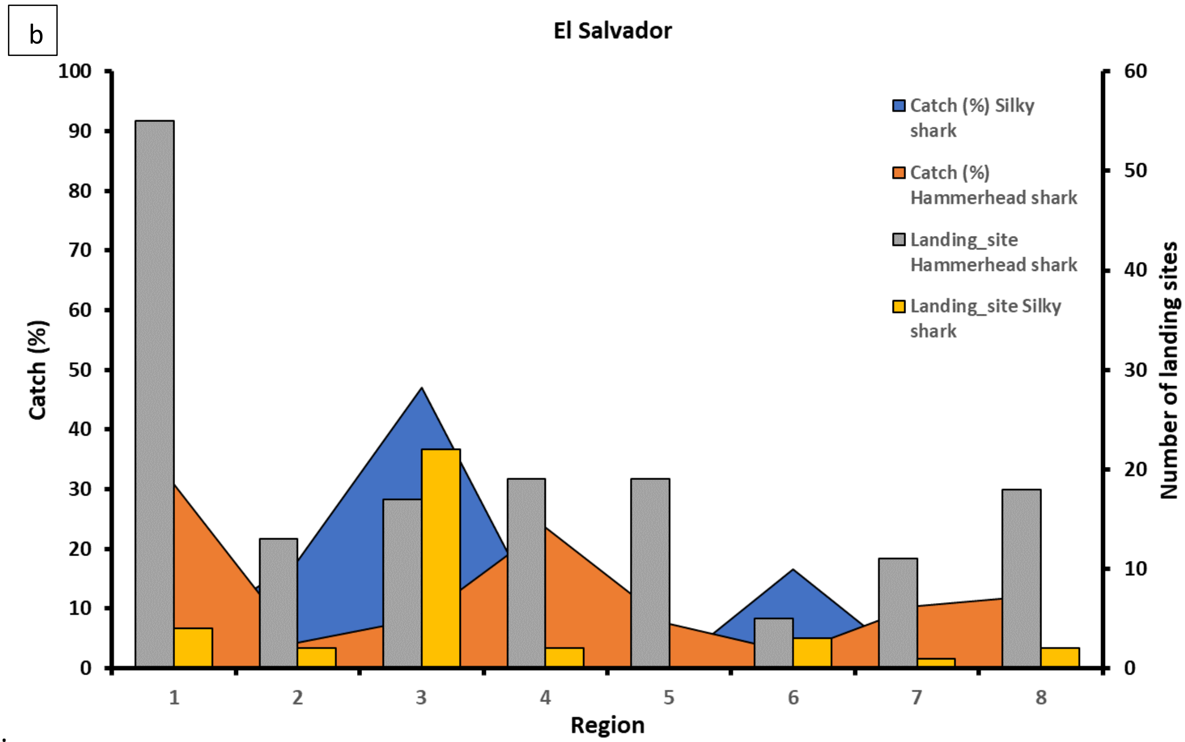



**Figure 7**. Percent of the estimate total country catch of each of the two species groups, by region, and number of landing sites, by region.

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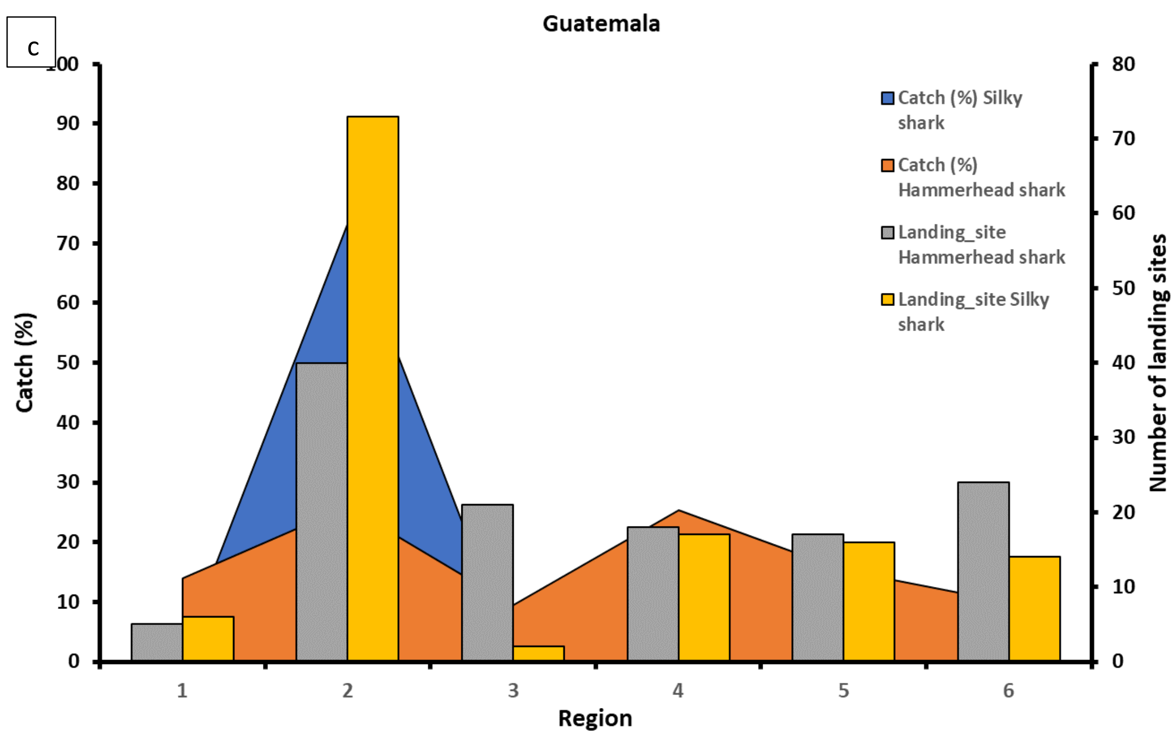
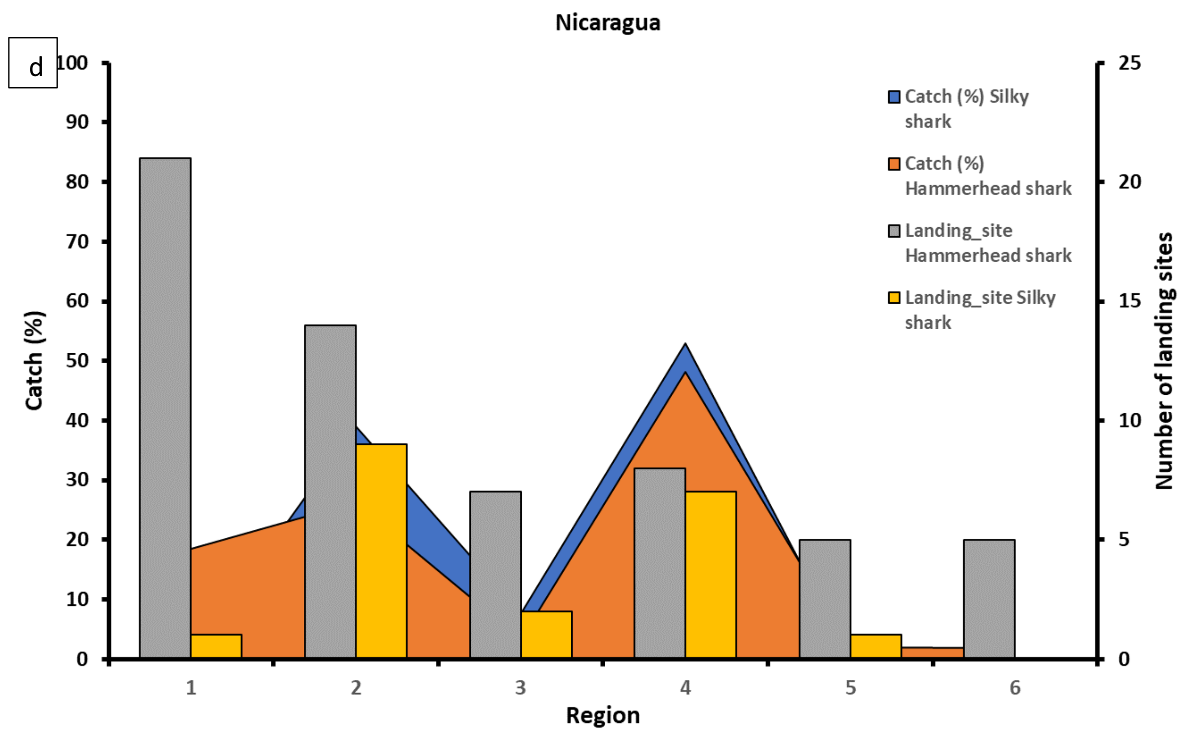



**Figure 7** continued



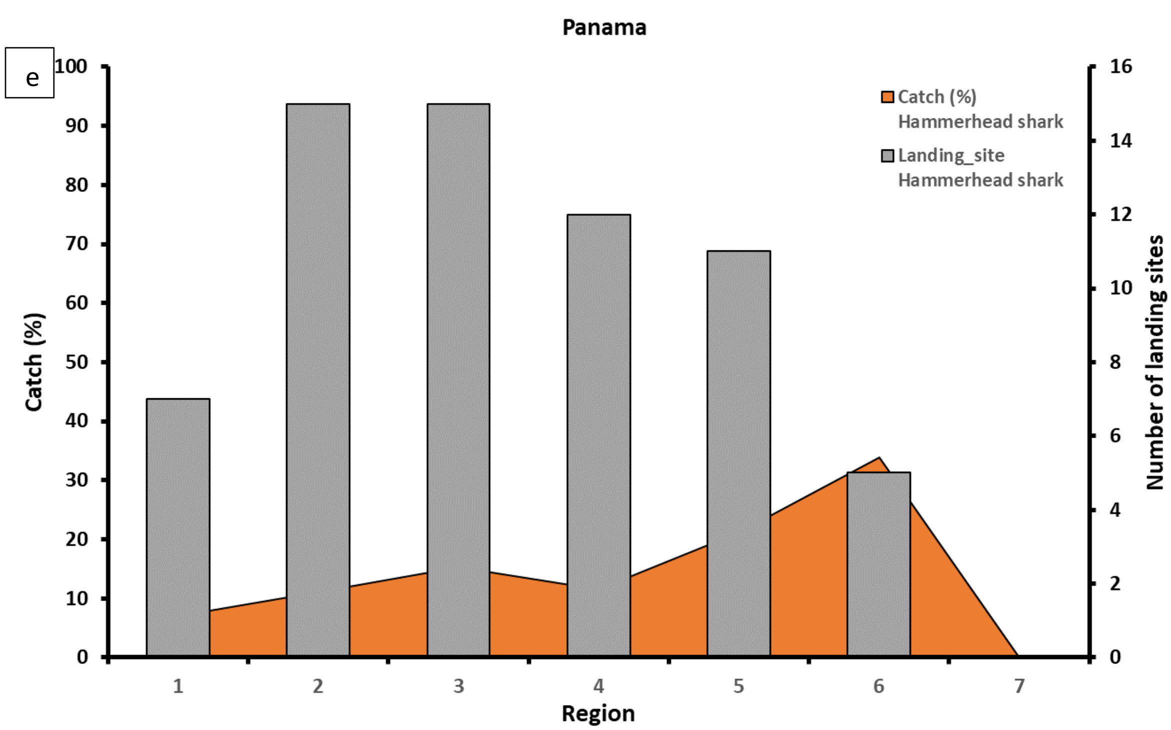




**Figure 7** continued