INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

13TH MEETING

(*by videoconference*)
16-20 May 2022

DOCUMENT SAC-13-11

VULNERABILITY ASSESSMENT OF SHARKS CAUGHT IN EASTERN PACIFIC OCEAN PELAGIC FISHERIES USING THE EASI-FISH APPROACH

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SUMMARY

Sharks are a common catch, either as a target or incidental bycatch, in industrial and small-scale coastal (*i.e.*, 'artisanal') pelagic fisheries in the eastern Pacific Ocean (EPO). In general, sharks are long-lived, slow growing, and have low reproductive output, resulting in conservation concerns for many species impacted by fishing. In recognition of these concerns for sharks, the IATTC has implemented a range of conservation and management measures (CMMs) since at least 2005 to limit or prohibit the capture of sharks, or to promote handling practices to maximize their post-release survival. Due to the common paucity of catch and biological data available for the majority of shark bycatch species caught in EPO pelagic fisheries an ecological risk assessment (ERA) approach, Ecological Assessment for the Sustainable Impacts of Fisheries (EASI-Fish), was used to quantify the vulnerability of bycatch species to the cumulative impacts of multiple fisheries in the EPO. This approach can be used to guide fishery managers in prioritizing species that may require immediate management action to reduce the fishing mortality, or to highlight deficiencies in key information that are required to be addressed before re-assessment. A total of 49 shark species have been recorded to interact with industrial (purse-seine and longline) and artisanal (longline and gillnet) pelagic fisheries in the EPO, of which 32 species were formally assessed using EASI-Fish for the reference year 2019. Estimates of a proxy for fishing mortality ($\tilde{F}_{2019}$) and the spawning stock biomass per recruit (SBR_{2019}) in 2019 exceeded biological reference points ($F_{40\%}$ and $SBR_{40\%}$) for 20 species, classifying them as "most vulnerable", including hammerhead sharks (4 species), requiem sharks (10 species), threshers (*Alopias superciliosus and A. pelagicus*), mesopelagic sharks (3 species) and the commercially important blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*). The remaining 12 species were classified as "least vulnerable" (9 species) or 'increasingly vulnerable" (3 species), data reliability scores for 7 of these species were low, indicating high uncertainty in the model parameter values used. Key knowledge gaps identified were the location of fishing effort and the shark catch in artisanal fisheries and basic biological information for several species. The EASI-Fish assessment provided a first comprehensive assessment for prioritizing research and management on shark bycatch species. The flexibility and spatially-explicit framework of EASI-Fish can be used in future to rapidly and cost-effectively explore a range of potential hypothetical CMMs that may be implemented—in isolation or in combination—within the EPO to reduce fishery impacts on particularly vulnerable shark species identified, including silky, thresher and hammerhead sharks.

1. INTRODUCTION

Ecosystem-based Fisheries Management (EBFM) has been a concept of growing importance in fisheries globally since the late 1990s. It has gained worldwide momentum as an increasing body of evidence reveals the ecological impacts of fishing on non-target species, habitats, and the structure and function of ecosystems more broadly. Tuna fisheries in particular have great potential to disrupt the ecological processes of marine ecosystems as they remove large biomasses of predators that occupy high trophic levels including target tuna species and species incidentally caught as bycatch, such as sharks, that exert top-down predation pressure on lower trophic levels.

The Inter-American Tropical Tuna Commission (IATTC) has formally recognized the potential negative ecological consequences that may arise as a result of the activities of the tuna fisheries for which it has the responsibility to manage throughout the eastern Pacific Ocean (EPO). As a result, the IATTC has formally adopted an ecosystem-based approach to the management of its tuna fisheries through the Antigua Convention (IATTC, 2003), entering into force in 2010, in particular Article VII 1(f) "*adopt, as necessary, conservation and management measures and recommendations for species belonging to the same ecosystem and that are affected by fishing for, or dependent on or associated with, the fish stocks covered by this Convention…*".

Although many tuna and non-tuna fisheries have adopted the principals of ecological sustainability in their fisheries management framework, few have been able to operationalize processes that can demonstrate that the principals are being met. This, of course, is often not the fault of fisheries managers or policy makers, but an inherent problem with understanding the high taxonomic diversity and their biomasses within marine ecosystems and the sheer complexity of their inter-relationships. Further, more fundamental problems also persist pertaining to the availability of sufficiently reliable data to model and understand ecological systems and ultimately manage fisheries within this ecological context. Unfortunately, there is often insufficient reliable biological and catch information available for the majority of species with which fisheries interact, either directly or indirectly, especially those of little or no economic value. Therefore, assessing all impacted species using traditional stock assessment approaches is often both cost-prohibitive and impractical.

In 2018, the IATTC sought to explicitly address this problem with its formal inclusion as a goal of their Strategic Science Plan (SSP), to "*develop analytical tools to identify and prioritize species at risk*". The staff was successful in achieving this goal through the development of a flexible spatially-explicit quantitative ecological risk assessment approach—Ecological Assessment of Sustainable Impacts of Fisheries (EASI-Fish)—specifically designed to quantify the cumulative impacts of multiple fisheries for data-limited bycatch species (Griffiths et al., 2019a). The utility of this approach was first demonstrated for the purpose of prioritizing vulnerability of 24 bycatch species of epipelagic and mesopelagic teleosts, elasmobranchs, sea turtles and cetaceans caught in EPO tuna fisheries (Griffiths et al., 2019a). EASI-Fish was subsequently applied to individual bycatch species in the EPO to explore the efficacy of potential conservation and management measures (CMMs) for spinetail devil ray (*Mobula mobular*) (Griffiths and Lezama-Ochoa, 2021) and the critically endangered east Pacific stock of leatherback turtle (*Dermochelys coriacea*) (Griffiths et al., 2020; BYC-11-02). EASI-Fish has since been adopted outside of the IATTC to assess the ecological impacts of longline fisheries in the central Pacific Ocean (Gilman et al., 2021) and to assess the vulnerability of elasmobranchs caught as bycatch in the tuna fisheries of the western and central Pacific Ocean (Phillips et al., 2021).

As part of the SSP's subsequent ecological goal to "*evaluate the ecological impacts of tuna fisheries",* the staff has planned to incrementally assess key species groups (e.g., sharks, rays, sea turtles) in the near future using the validated EASI-Fish approach to identify vulnerable species and prioritize them for data collection, research and management. The first species group chosen for assessment was sharks, given the high taxonomic diversity and biomass caught in EPO tuna fisheries (Duffy et al., 2016) and because many species are unavoidable bycatch and present significant conservation issues to be addressed by the IATTC, its Members, and CPCs. For example, several shark species caught in the industrial and artisanal fisheries throughout the EPO are now listed in Appendix II of the Convention on International Trade in Endangered Species (CITES) (CITES, 2016) to curb international illegal trade of fin products.

Furthermore, sharks are a particularly vulnerable group of bycatch species in the EPO as the majority of species are long-lived, exhibit slow growth rates and low reproductive potential, which resulted in several shark species being ranked as among the most vulnerable of all bycatch species in a preliminary ecological risk assessment of EPO tuna bycatch (Griffiths et al., 2017; Duffy et al., 2019). Although some shark species are released alive—either mandated through IATTC Resolutions (e.g., C-11-10 for oceanic white tip sharks) using best handling and release practices, or due to their low economic value—post-release mortality (PRM) rates are unknown for most species to determine the full extent of fishing-induced mortality.

The aims of this paper were to undertake the first quantitative vulnerability assessment for sharks caught by pelagic fisheries in the EPO using the EASI-Fish approach to identify vulnerable species in 2019 and prioritize them for data collection, research and management. The year 2019 was chosen as the assessment year as it was considered the last complete fishing year to be representative of contemporary fishing effort regimes in the EPO before fishing effort, data collection and provision were significantly impacted by the COVID-19 pandemic that began around March 2020.

2. METHODS

2.1 Definition of the assessment region and included fisheries

The present assessment of sharks is limited to the IATTC Convention Area in the EPO (defined as the region from the coast of the Americas to 150°W between 50°S and 50°N) and characterizes the shark populations and EPO fisheries for 2019. It is possible that some shark species comprise more than one stock across the Pacific Ocean, but given there is insufficient information to clearly delineate stock boundaries for any species included in the assessment, for the purposes of the present study, each species was assumed to represent a single homogenous stock within the IATTC Convention Area. The converse may also be true for some pelagic species whereby species caught in the EPO are part of a larger continuous stock across the Pacific Ocean. Although work is being planned to undertake Pacific-wide assessments for some species in collaboration with the Secretariat of the Pacific Community (SPC), the inclusion of Western and Central Pacific Fisheries Commission (WCPFC) fisheries at this point was considered premature.

The industrial fisheries included the fishery by large-scale tuna longline fishing vessels (LSTLFVs) (herein called the "industrial longline fishery") and two purse-seine fisheries (Class 6 with a carrying capacity >363 mt and Classes 1–5 ≤363 mt). The data for these fisheries were obtained from vessel logbooks or collected by on-board scientific observers, or submitted to the IATTC by its Members under Resolutions C-03-05 and C-19-08 and described in Document SAC-08-07b. Specifically, the industrial longline fishery data were derived from vessels >24 m length overall (LOA) included in the IATTC Regional Vessel Register that are authorized to fish for tuna and tuna-like species, which primarily provide monthly reports of catch and fishing effort at a resolution of at least 5° x 5°—although a few CPCs submit data at 1° x 1°—and from national scientific observer programs that monitor at least 5% of the fishing effort by LSTLFVs over 20 m LOA required under Resolution C-19-08.

Effort data characterizing the fishery by Class 6 purse-seine vessels were collected by the onboard observer program of the Agreement on the International Dolphin Conservation Program (AIDCP) and National Programs in 2019, which covered 100% of the fishing effort. This fishery comprises three distinct sub-fisheries based on set type: i) sets associated with natural or artificial floating objects (OBJ), ii) sets associated with dolphins (DEL), and iii) sets on schools of tuna that are neither associated with dolphins or floating objects (NOA).

There are a range of smaller purse-seine vessels that operate in the EPO from small vessels (Classes 1–2) that are generally confined to coastal areas, to larger commercial vessels (Classes 3–5) that frequently fish on the high seas. The AIDCP does not require these smaller vessels to carry an observer, except in specific situations. Of the 75 Class 1–5 vessels that fished in the EPO in 2019, only 10 (13.7%) carried an observer. However, the Tuna Conservation Group (TUNACONS)—a consortium of Ecuadorian tuna fishing companies—has deployed observers on voluntary Ecuadorian vessels since 2018, with coverage being 12% of the total number of trips reported for all Class 1–5 vessels in the EPO in 2019 (IATTC, unpublished data). It has yet to be determined by IATTC scientists whether the data collected to date by TUNACONS is representative of the fleet in terms of gear characteristics, catch composition, and spatio-temporal distribution of effort. However, given the paucity of information on this fishery in the past, we included these data that were considered to represent the minimum spatial coverage of the fishery. Copies of logbook entries summarizing the fishing activities of vessels of Classes 1–5 were available via opportunistic collection by IATTC field staff at various landing ports. The fishery comprising Classes 1–5 vessels can also be separated on the same set type as the Class 6 fleet, except Class 1–5 vessels (i.e., <363 mt) are not permitted to make DEL sets (AIDCP, 2017). Each set position for Class 1–6 vessels was allocated to the nearest 0.5° x 0.5° grid cell to define each sub-fishery.

In contrast to the industrial purse seine and longline fisheries in the EPO, effort by the numerous small-scale artisanal fleets that operate within the EEZs of countries in the EPO is generally poorly documented by national fisheries agencies. Lack of reliable effort data has been the primary reason why artisanal fleets have not been included in previous EASI-Fish assessments of bycatch species in the EPO (Griffiths et al., 2019a; Griffiths et al., 2019b). However, sharks have been shown to be heavily impacted by coastal gillnet and longline fisheries (Alfaro-Shigueto et al., 2010; Cartamil et al., 2011; Martínez-Ortiz et al., 2015; Sosa-Nishizaki et al., 2020), so it was considered necessary to collate any available data sources on fishing effort for artisanal fisheries for their inclusion in the assessment.

Reasonably detailed effort data for artisanal longline vessels throughout Central America was available from IATTC's long-term research program that examined the effects of different hook types on bycatch rates, in part reported by Andraka et al. (2013). Some information was available from fishing effort maps in published scientific papers (Martínez-Ortiz et al., 2015) and reports (*e.g*., Ayala et al., 2008; Martínez et al., 2017) or maps of unpublished observer data. These maps were digitized, geo-referenced and fishing effort allocated to grid cells of appropriate resolution—usually 0.5° x 0.5°—in QGIS software. Unfortunately, some large spatial gaps in catch and/or effort data existed in some areas where artisanal fisheries are known to operate. However, in many of these areas, detailed data were available pertaining to the locations of fishing ports for artisanal fleets. For example, Ortíz-Álvarez et al. (2020) mapped coastal artisanal fishing ports from the northern Gulf of California, Mexico to the southern border of Colombia, while Alfaro-Shigueto et al. (2018) mapped fishing ports from Ecuador to Chile. Because these two studies focused on port-based interviews with fishermen pertaining to the characteristics of their fishing operations and interactions with protected species such as sea turtles, spatially explicit effort data were not available to determine where vessels fished from these ports. However, several sources of evidence suggest that artisanal fishers frequently traverse over one degree of latitude (~111 km) to reach their preferred fishing grounds, although many travel significantly further offshore to target large pelagic fishes in offshore waters (see Martínez-Ortiz et al., 2015). Therefore, it was reasonable to assume that at least one unit of fishing effort was expended in 2019 within each 0.5° x 0.5° grid cell adjacent to each fishing port.

In some coastal States in the EPO there is often not a clear distinction between artisanal and industrial vessels, as the former are often multi-gear (longline and gillnets) and multi-species, shifting their target among tuna, billfish, sharks and dorado on a seasonal basis (Martínez-Ortiz et al., 2015; Siu and Aires-da-Silva, 2016). Although some of these vessels can reach offshore waters (*e.g*., medium and large-scale fleets), the majority are less than 15 m LOA (generally called "pangas") and are more coastal in their operation. Because effort data for these domestic fleets were not available by vessel size, these fleets were collectively classified as "artisanal". In contrast, the domestic Mexican longline fishery target sharks using vessels (often >27 m LOA) and surface-set gear configurations similar to those used by the far seas longline fleet (Sosa-Nishizaki et al., 2020). Therefore, for the purposes of the present study, this domestic Mexican longline fishery was included as part of the industrial longline fleet.

Most coastal States have some form of a landings fishing inspection program conducted mainly for compliance purposes (Siu and Aires-da-Silva, 2016). Unfortunately, observer coverage of these fleets is extremely low and data are very limited for scientific purposes. Although sampling programs are being developed for the coastal nation fleets (see Oliveros-Ramos et al., 2019), data are not yet available. Therefore, using high-resolution fishing effort distribution maps from publications was considered the only feasible alternative to represent the spatial 'footprint' of these fisheries in the current assessment. As was the case with the fishing port data, fishing effort maps were imported into QGIS software, georeferenced, and where the presence of a single set in any 0.5° x 0.5° grid cell—5° x 5° or 1° x 1° for the industrial longline fishery—was considered presence of effort.

A detailed description of the datasets included in the assessment is provided in Table 1.

2.2 Species included in the assessment

This assessment sought to include all shark species recorded to have interacted with the 8 fisheries being considered using all data held in the IATTC databases. These include many of the aforementioned data sources used to derive fishing effort, specifically where catches were either reported by CPCs to the IATTC (e.g., industrial longline), or recorded by observers onboard purse-seine and longline vessels, or at landing ports throughout EPO coastal nations (see Table 1).

EASI-Fish and other ERA methods are tools that facilitate the process of prioritizing taxa of potential concern based on their susceptibility to being captured by a specific gear type and the capacity of their populations to withstand, or recover from, fishing impacts, which is directly related to their biological productivity. Therefore, a requirement of these ERA models is to include only species—as opposed to taxonomic aggregations such as "Thresher shark, nei"—in assessments given the often high divergence in the ecology and life histories of even closely related species, such as hammerhead shark species of the *Sphyrna* genus. Although there are many records in the data sources used where catches were reported as taxonomic aggregations, these were required to be omitted from consideration in the current assessment. It is therefore important to note that the presence and spatial distribution of catches of species implicitly included in taxonomic aggregations such as "Requiem sharks, nei", "Hammerhead shark, nei", "Mako shark, nei", "Thresher shark, nei" are likely to be, especially in the case of naturally rarer species within the aggregation, underestimated. It is for this reason that a precautionary assumption was made that any species recorded in pelagic fisheries catches from any reliable data source was available for capture to any fishery that overlapped with the predicted species distribution, irrespective of whether the species was explicitly recorded as being caught in that fishery.

Although this assessment provides a full account of the species reported to have interacted with the 8 fisheries, some species were represented by too few records of spatial presence to facilitate construction of a species distribution model (SDM), which underpins the EASI-Fish model. Therefore, an arbitrary threshold was established to exclude any species that was represented by fewer than 20 unique fishing records as it was assumed that these species were likely to be represented at such low frequencies since they do not frequently interact with the fisheries, and thus, the fisheries do not pose a significant threat to the sustainability of the populations of these species. However, an exception was made to this rule for the white shark (*Carcharodon carcharias*) given its worldwide conservation concern and being listed by the IUCN Red List of Threatened Species as "Vulnerable". The full list of shark species and the number of fishing events from which they were recorded in each fishery is shown in Table 2.

2.3 Assessing susceptibility as a proxy for instantaneous fishing mortality (*F*)

The vulnerability of each shark species was quantified using the EASI-Fish ecological risk assessment approach (Griffiths et al., 2019a). EASI-Fish is comprised of separate susceptibility and productivity components. The susceptibility component is used to approximate the instantaneous fishing mortality rate (F) that is compared to biological reference points (BRPs) used in the productivity component, specifically length-structured yield and biomass per-recruit models.

EASI-Fish estimates the proportion of a length class (j) of a species that is susceptible to incurring mortality by fishery x (S_{xj}) in a given year, and is represented as:

$$S_{xj} = \frac{G_x}{G}\left(D_x A_{xj} N_{xj} C_{xj} P_{xj}\right) \quad \text{(Eq. 1)}$$

where G is the total number of grid cells occupied by the species and G_x is the number of occupied grid cells containing at least one unit of fishing effort by fishery x during 2019. In this study, G was estimated for each species using SDMs. Inputs for the SDMs were presence-only data and six environmental variables (mean annual sea surface temperature, mean depth, mean salinity, mean annual surface primary productivity, mean annual dissolved molecular oxygen at the surface, and distance to nearest coast).

To ensure the environmental range in which a species can occur is well-represented by the input data, Pacific-wide presence records were used. Obtaining Pacific-wide records was facilitated by a collaboration with SPC, and to also begin collaborative work with on Pacific-wide assessments for selected shark bycatch species (Project L.2.d, SAC-13-01). Presence records included reported catch and observer records for all fisheries in both the WCPFC and EPO Convention Areas as well as available records from AquaMaps (www.aquamaps.org), which are submitted by non-Regional Fishery Management Organizations (RFMO) sources such as academic institutions, where data may represent spatially-explicit catches, sightings, tagging locations, or estimated locations along movement paths derived from archival and/or satellite tags (Table 3).

SDMs were predicted to a resolution 0.5° x 0.5° and represented an ensemble of predictions from four modelling approaches: Bioclim, Boosted Regression Trees, Generalized Linear Models, and MaxEnt (Fig. 1). In cases where one or more models performed poorly, the single best performing model having an Area Under the Curve (AUC) score of >0.8 and a True Skill Statistic (TSS) score of >0.7 was used to define the species' distribution. The final appearance of the SDM prediction can change significantly depending on the threshold upon which the predicted probability of presence (ψ)is used to create binary values of species presence. For example, at a threshold of 0.4, predicted probabilities of presence above and below 0.4 are predicted to be absence and presence records, respectively. Consequently, the selected value of the threshold for the SDM outputs influences the proportion of the stock exposed to fishing. Therefore, we sought to incorporate uncertainty in the SDM by running EASI-Fish using a range of plausible ψ values. For each SDM, this range was determined by overlaying the distribution of predicted probability of presence with that of predicted probability of pseudo absences. The ψ value where these two distributions intersected was selected to define the most probable species distribution and upper and lower bounds were selected by visual inspection of the two distributions on either side of the intersection point (e.g., Fig. 2). Further details pertaining to the SDM methodology can be found in Phillips et al. (2021).

Fishing effort for each fishery in 2019 was overlaid on the SDM predictions to calculate G_x. The percentage overlap of each fishery was calculated by dividing G_x by G. Effort data for purse-seine vessels and artisanal effort from published maps were resolved at 0.5° x 0.5° as described above. However, data for the industrial longline fleet were available at 5° x 5° or 1° x 1° resolution, so it was conservatively assumed that there was at least one unit of effort in each 0.5° x 0.5° cell contained within each of these larger grid cells that contained effort.

The first four parameters in the parentheses of Equation 1 (D_x, A_{xj}, N_{xj}, and C_{xj}) comprise what is generically regarded as "selectivity" in stock assessments, which combines, often implicitly, "population availability" (the relative probability that a shark of length class j is located in the area and time where the fishery is operating) and "contact selectivity" (the relative probability that a shark of length class j will be retained once it comes in contact with the gear) (Millar and Fryer, 1999). Because selectivity curves were not available for the majority of shark bycatch species in each fishery, it was considered important to disaggregate selectivity components as far as practicable. These components are described hereafter.

Fishing season duration (D_x) is the proportion of the year that the population is available to fishery *x*, expressed as the number of fishing days divided by 365. Between 2018 and 2020 in the EPO, Resolution C-17-02 mandated an annual 72-day closure for purse-seine vessels of Class 4–6 (>182 mt carrying capacity), including a 30-day closure of the area known as the "corralito" (4°N–5°S, 96°–110°W).

Seasonal availability (A_{xj}) is the proportion of length class *j* that is available to capture by fishery *x*, given that some species undertake extensive intra-annual migrations outside the boundaries of the fishery, where they are unavailable for fishery interactions. Given the lack of tagging data for most shark species in the EPO to indicate seasonal movement outside of the fishery, a precautionary value of 1.0 was used for length class *j* in fishery *x*.

Encounterability (N_{xj}) is the proportion of length class *j* that may potentially encounter the gear used by fishery *x* based on the species' distribution in the water column relative to the normal fishing depth range of the gear. Minimum, maximum, and mean dive depths of each shark species were defined using the results from electronic tagging studies or longline experiments using time-depth recorders. The effective fishing depth range for each fishery in the EPO was defined as:

- 0–150 m, 0–150 m and 0–200 m for Class 6 purse-seine vessels deploying DEL, NOA and OBJ sets, respectively. These values are based on the upper quartile of net depths documented by Lopez et al. (2021) to be used in DEL, NOA and OBJ sets in the EPO in 2019, being about 210 m, 210 m, and 280 m, respectively, and assuming an effective fishing depth of 45–75% of the net depth (see Hall and Roman, 2013),
- 0–120 m for purse-seine vessels Classes 1–5 for both NOA and OBJ sets (Ernesto Altamirano, IATTC, pers. comm.),
- 0–300 m for industrial longlines, which covers the depth range of both 'shallow' and 'deep' sets since insufficient data are currently available from effort data submitted to the IATTC to separate the two set types as separate fisheries (see Griffiths et al., 2017),
- 0–100 m for surface-set gillnets set by the artisanal fishery that typically target sharks (Ayala et al., 2008).
- 0–100 m for surface-set longlines set by the artisanal fishery, which covers the depth range to the deepest hook of both shallow 'dorado' sets and deeper 'tuna/billfish/shark' sets (see Andraka et al., 2013),

Contact selectivity (C_{xj}) describes the proportion of length class *j* that is retained once it encounters the gear used by fishery *x*. In the absence of reliable gear selectivity curves for most shark species, a precautionary knife-edge selectivity ($C_{\mathrm{xj}} = 1.0$) was assumed from the smallest shark recorded by observers in each fishery to the largest length class in the model.

IATTC Resolution C-19-04 mandates the release of some shark species (*e.g.,* oceanic white tip) in all fisheries. Therefore, fishing mortality would be overestimated unless the component of the catch that survives mandatory release is accounted for. This is introduced in the model as post-capture mortality (PCM) (P_{xj}), the proportion of length class *j* that is caught by fishery *x* and dies during, or soon after release. Post-release mortality data was not available for the majority of shark bycatch species in the EPO, so a precautionary value of 1.0 was used for fishery *x* where data was not available.

Following the estimation of the overall susceptibility of length class *j* to incurring mortality from fishery *x* (S_{xj}), a proxy for the instantaneous fishing mortality rate in 2019 ($\widetilde{F}_{2019}$) for each shark species caught by all fisheries was estimated as:

$$\widetilde{F}_{2019} = -\,ln\left[1 - \sum_{x=1} q_x E_x \left(\frac{\sum_{j=1}^{n} S_{xj}}{n}\right)\right] \quad \text{(Eq. 2)}$$

Here, n is the number of length classes (in 2-cm increments) extending to the average length at which a shark may grow if it were to live indefinitely (L_∞). Fishing effort (E_x) is total effort, scaled from zero to 1, of fishery x applied in area G_x in 2019, while the catchability coefficient (q_x) is the fraction of the stock that is caught by one unit of effort (E_x) in fishery x. In many data-limited fisheries values for q and E are unknown. A precautionary approach is to assume both parameters are equal to 1, meaning all sharks in a grid cell are caught if all other susceptibility parameters are fully realized.

$\widetilde{F}_{2019}$ was then compared with values for F for the selected BRPs derived from the per-recruit models (described below). However, it needs to be reiterated that, because of the several conservative assumptions and likely uncertainty in the parameters used in deriving the $\widetilde{F}_{2019}$ estimate, it should only be considered a proxy for F—and potentially an overestimate. It is for this reason that the results from EASI-Fish should not be used to define the biological status of a species' population, *sensu* a stock assessment, but rather to quantify the vulnerability of species.

2.5 Characterizing species productivity using per-recruit models

A yield-per-recruit (YPR) model was used to characterize the biological dynamics of each shark species using the generic approach of Ricker (1975), which Chen and Gordon (1997) adapted for lengths as:

$$YPR = \sum_{j=1}^{n} \frac{W_j b_j F}{b_j F + M}\left[1 - e^{-(b_j F + M)\Delta T_j}\right] e^{-\sum_{k=1}^{j-1}(b_k F + M)\Delta T_k} \quad \text{(Eq. 3)}$$

Here, new recruits and fully recruited length classes are denoted by the subscripts j and k, respectively. W_j is the mean weight of a shark in length class j, while selectivity (b_j) is the proportion of the population in length class j that is caught across all fisheries, represented as:

$$b_j = \sum_{x=1}^{n} S_{xj} \quad \text{(Eq. 4)}$$

In the absence of age or length-specific estimates of the instantaneous natural mortality rate (M) for most shark species in the EPO, M was estimated by empirical equations (see Section 2.6) and assumed to be constant across all length classes. However, in cases where estimates of M were available from stock assessments (e.g., Clarke et al., 2018; ISC, 2018; Tremblay-Boyer et al., 2019), they were applied either to appropriate length classes or maintained across all length classes. F was disaggregated into increments of 0.01, from zero to L_∞ from the specialized von Bertalanffy growth function (VBGF) that can be represented as:

$$L_t = L_\infty(1 - exp[-K(t - t_0)]) \quad \text{(Eq. 5)}$$

where L_t = length at age t, L_∞ = the mean asymptotic length that an animal may attain if it lived indefinitely, K = the Brody growth parameter, and t_0 = the hypothetical age at length zero. Although this is a widely accepted model to characterize growth in broadcast-spawning teleosts, the VBGF can underestimate length-at-age for young ages for sharks. This is because many sharks are viviparous (i.e., give birth to live young) the VBGF does not consider the substantial embryonic growth that occurs before the time of birth, which would normally be characterized by t_0. Therefore, the VBGF was reparametrized where the length at birth (L_0) was substituted for t_0.

$$L_t = L_\infty - (L_\infty - L_0)\, exp[-Kt]) \qquad \text{(Eq. 6)}$$

The parameter ΔT in Eq. 3 represents the time taken for a fish to grow from one length class to the next, represented as:

$$\Delta T_j = \frac{1}{K} ln \frac{L_\infty - L_j}{L_\infty - L_j - d_j} \qquad \text{(Eq. 7)}$$

where K and L_∞ are parameters from the von Bertalanffy growth function (Table 4), and d is the width of the length class, calculated as L_{j+1} - L_j.

The spawning stock biomass-per-recruit (SBR) model of Quinn and Deriso (1999) is complementary to YPR, and can be modified to suit the analysis of length rather than age classes and be represented as:

$$SBR = \sum_{j=1}^{n} W_j m_j \prod_{x=r}^{j-1} e^{-(b_j F + M)} \qquad \text{(Eq. 8)}$$

where W_j is the mean weight of a shark in length class j (L_j) taken from a length-weight relationship (Table 4), m_j is the proportion of mature females at the mean length of length class j, and the product operator describes the number of sharks surviving from the length at recruitment (L_r) to L_j. Because the model calculates relative SBR, the initial number of breeding females was set to a value of one. The value for m_j for each species was taken from a female maturity ogive, represented in the logistic form:

$$m_j = \frac{1}{1 + e^{\left(-r\left(L_j - L_{50}\right)\right)}} \qquad \text{(Eq. 9)}$$

where L_j is the mean length of a shark in length class j, L_{50} is the length at which 50% of the population is mature, and r is the curvature parameter. Where this information was not available, published estimates of the length at first maturity was used, which is generally conservative since it occurs at a size smaller than L_{50}.

2.6 Natural mortality

The instantaneous natural mortality rate (M yr^{-1}) is one of the most influential parameters in stock assessment models, but is notoriously difficult to estimate directly (Kenchington, 2014; Then et al., 2015). Consequently, empirical equations based on life history traits, $t_{\max}$ and VBGF parameters (L_∞, K, t_0), are often used as an alternative. There are over 30 natural mortality estimators in existence, none of which have been proven to perform better than another for all species (Kenchington, 2014). Therefore, it is commonplace to run stock assessment models using a range of M values derived from multiple estimators. Therefore, M was calculated for each species using six estimators recommended by Kenchington (2014) and Then et al. (2015) (Table 5). Priority was given to M values that were estimated directly (*e.g.,* from tagging or stock assessment), followed by $t_{\max}$-based estimators (Hoenig$_{\text{nls}}$ and

$\text{Hoenig}_{\text{tmax}}$) for long-lived species such as elasmobranchs, and finally *K*-based estimators (Jensen, $\text{Pauly}_{\text{nls}}$, $\text{Pauly}_{\text{LKT}}$ and Pauly_{KT}). Where species lacked information on longevity and L_∞, L_∞ was estimated from maximum recorded length (L_{max}), using the method of Froese and Binohlan (Froese and Binohlan, 2000), and used in the Pauly_{LT} estimator with a mean annual water temperature of 25˚C for the EPO (Fiedler and Talley, 2006).

2.7 Biological Reference Points (BRP)

Depending on the life history of a species, various BRPs have been used in stock assessment models to assess the status of a population relative to an estimated *F* value for a particular time period or specific year. EASI-Fish uses a similar approach, but it is important to emphasize that its BRPs are used to quantify the relative vulnerability of a population that would be expected to hinder the lifetime yield of an animal—regardless of the present population size—rather than to determine stock status. YPR models assume that recruitment is constant and independent of stock size—equivalent to a steepness (*h*) value of 1 (Gabriel and Mace, 1999). Therefore, use of a *F* value at which yield is maximized (F_{MAX}) can be overly optimistic owing to sharks often having a strong stock-recruitment relationship (*i.e.*, $h<1$). Unfortunately, the stock-recruitment relationship is difficult to estimate (Lee et al., 2012), and hence taxonomic group-based proxies are often used in stock assessments as a result.

In a comparison of BRPs used in EASI-Fish to assess bycatch species with diverse life histories from teleosts to marine mammals, Griffiths et al. (2019a) suggested that $F_{40\%}$ is appropriate for elasmobranchs and is therefore adopted here to assess the 32 sharks species caught in the EPO. However, it is worth noting that Cortés and Brooks (2018) suggested that for slow-growing and long-lived species, such as elasmobranchs, a BRP of as high as $F_{80\%}$ should be used. Explicitly, $F_{40\%}$ is the *F* value corresponding to 40% of the spawning potential ratio (SPR), which is the SBR at the F_{2019} value divided by the SBR if $F=0$. The corresponding $\text{SBR}_{40\%}$ BRP is the SBR value at $F_{40\%}$.

The vulnerability of each of the 32 shark species in 2019 was determined using $\tilde{F}_{2019}$ and the corresponding SBR value (SBR_{2019}) relative to the $F_{40\%}$ and $\text{SBR}_{40\%}$ values and displayed on a 4-quadrant "vulnerability phase plot" (Fig. 4). The vulnerability definitions of these quadrants are: i) "Least vulnerable" (green; $\tilde{F}_{2019}/F_{40\%}<1$ and $\text{SBR}_{2019}/\text{SBR}_{40\%}>1$), ii) "Increasingly vulnerable" (orange; $\tilde{F}_{2019}/F_{40\%}>1$ and $\text{SBR}_{2019}/\text{SBR}_{40\%}>1$), iii) "Most vulnerable" (red; $\tilde{F}_{2019}/F_{40\%}>1$ and $\text{SBR}_{2019}/\text{SBR}_{40\%}<1$), and iv) "Decreasingly vulnerable" (yellow; $\tilde{F}_{2019}/F_{40\%}<1$ and $\text{SBR}_{2019}/\text{SBR}_{40\%}<1$).

2.8 Implementation of the model

The model was built in Microsoft Excel, with customized routines written in Visual Basic for Applications (VBA) to perform Monte Carlo simulations to generate uncertainty estimates for specific model parameters using a uniform distribution prior that ranged between a defined minimum and maximum value. The YPR and SBR models were then run 10,000 times using Monte Carlo simulations, each time drawing a random sample from the distribution prior defined for each parameter. The mean, standard error (SE), standard deviation (Std Dev), and 95% confidence intervals (95% CI) were derived for the BRPs $\tilde{F}_{2019}$, $F_{40\%}$, SBR_{2019}, and $\text{SBR}_{40\%}$.

3. RESULTS

3.1 Estimates of susceptibility and a proxy for fishing mortality (*F*)

All susceptibility parameter values contributing to the overall susceptibility (S_{xj}) estimate for each species assessed in EASI-Fish and detailed descriptions of the source or derivation of these values are provided in Appendices 1 and 2.

The industrial longline fishery overlapped with the distribution of all 32 species by at least 9%. This fishery had the highest mean areal overlap for 28 of the species assessed, ranging between 14% (*Lamna nasus*) and 98% (*Isurus paucus*). This high overlap was due to the fishing effort being distributed across most of the EPO between 40°N and 40°S, which is substantially larger than the other fisheries (Fig. 5).

The artisanal longline fishery had the highest mean areal overlap for 4 species—all having predominately coastal distributions where the fishing effort was primarily distributed—ranging between 40% (*Rhizoprionodon longurio*) and 68% (*Sphyrna media*), with an additional 14 species exceeding 20%. The artisanal gillnet fishery had low (<15%) areal overlap for the majority of species assessed, with the highest overlaps being for *R. longurio* (26%), *S. media* (19%), *S. corona* (17%), and *Nasolamia velox* (16%).

None of the purse-seine fisheries had the highest overlap with any assessed species, but the extent of overlap was high for many species. With respect to Class 6 purse-seine vessels, areal overlap was highest for DEL (0.05–41%) and OBJ (0.07–51%) sets but considerably lower for NOA sets (0.06–19%). The species with the highest overlap with DEL sets were *Carcharhinus limbatus* (41%), *C. obscurus* (37%), and *C. galapagensis* (36%). The species with the highest overlap with OBJ sets were *Dalatias licha* (51%), *C. porosus* (45%), *C. altimus* (43%), *C. brachyurus, S. lewini, and S. zygaena* (42%). With respect to NOA sets, only three species had overlaps of more than 15%, including *S. media* (19%), *C. porosus* (17%), and *Alopias vulpinus* (16%).

For purse-seine Class 1-5 vessels, the areal overlap was substantially lower than for Class 6 vessels due to effort being restricted to the region surrounding the Galapagos Islands (Fig. 6). OBJ sets had the highest overlap with *C. altimus* (21%), *C. porosus* (20%), *S. media* (20%), *S. mokarran* (17%), *S. corona* and *A. vulpinus* (15%). For NOA sets, areal overlap was low for all species, with the highest overlaps being for *S. media* (8%) and *N. velox* (7%).

It is important to note that the aforementioned species with the highest overlap in the purse-seine fishery are infrequently caught, if at all, and may reflect the very restricted distributions of these species in the EPO relative to the widespread distribution of effort.

When taking other susceptibility factors into account (*e.g.*, encounterability, contact selectivity, etc) to assess the cumulative impacts of the 8 fisheries included in the assessment, the 20 species having the highest fishing mortality rates ($\tilde{F}_{2019}$)—ranging from 0.49–1.83 yr^{-1}—were hammerheads (*Sphyrna* spp.; 5 species), requiem sharks (*Carcharhinus* spp.; 8 species), threshers (*A. superciliosus* and *A. vulpinus*), whale shark (*Rhincodon typus*), and the two commercially important species, the shortfin mako (*Isurus oxyrinchus*) and the blue shark (*Prionace glauca*) (Fig. 6a). The fisheries contributing most to the total fishing mortality of these species were generally the industrial and/or artisanal longline fisheries as well as OBJ or DEL sets of the Class 6 purse seine fishery (Fig. 6 b and c).

3.2 Vulnerability status of shark species in the EPO

The biological parameter values and their sources used in the YPR and SBR models for each species to derive their vulnerability status are shown in Table 4 and Appendix 3, respectively, while EASI-Fish estimates of the $F_{40\%}$ and $\text{SBR}_{40\%}$ BRPs are provided in Table 6.

Based on estimated mean values of BRPs, 20 species exceeded the $F_{40\%}$ and $\text{SBR}_{40\%}$ BRP threshold values (see Fig. 4), resulting in the classification of these species as "most vulnerable" (Fig. 7; Table 6). Of the remaining 12 species, 3 species (*Isurus paucus, Dalatias licha,* and *Zameus squamulosus*) exceeded the $\text{SBR}_{40\%}$ BRP threshold value and were categorized as "increasingly vulnerable", while 9 species did not exceed either of the BRP threshold values and were deemed "least vulnerable" (Fig. 7; Table 6).

Of the 20 species having the highest $\tilde{F}_{2019}$ values (Fig. 6a), 19 were classified as "most vulnerable". Figure

7 shows a distinct group of 8 species with the highest vulnerability ranks being hammerheads (*S. zygaena*, *S. lewini,* and *S. media*), requiem sharks (*C. falciformis*, *C. porosus* and *C. limbatus*), bigeye thresher (*A. superciliosus*), and shortfin mako (*Isurus oxyrinchus*). Notable species among the remaining "most vulnerable" species are blue shark (*P. glauca*), oceanic whitetip shark (*C. longimanus*), two additional species of hammerheads (*S. corona* and *S. mokarran*), pelagic thresher (*A. pelagicus*), the mesopelagic crocodile shark (*Pseudocarcharias kamoharai*), and a range of generally neritic carcharhinid sharks such as *N. velox*, *C. leucas* and *C. plumbeus* (Fig. 7).

Of the 9 species classified as "least vulnerable", some had neritic distributions (*Carcharodon carcharias*, *Galeocerdo cuvier*, *R. typus*, *C. galapagensis* and *C. obscurus*) or a high latitude distribution (*L. nasus* and *L. ditropis*) that avoided significant overlap with high seas longline and purse seine fisheries, or had mesopelagic vertical distributions (*I. brasiliensis* and *A. vulpinus*) that limited their interactions with the gear used in high seas fisheries with a depth range of 0–300 m.

When considering the reliability scores for key EASI-Fish parameters, 7 species were considered to have low reliability scores that had the potential to lead to an incorrect assignment to a vulnerability category. These species were *C. altimus, N. velox, Isistius brasiliensis, I. paucus, R. longurio, D. licha, S. media, S. corona* and *Z. squamulosus* (Fig. 8). Of these species, *D. licha, Z. squamulosus* and *I. paucus* had large error bars around the mean vulnerability value and were the only species to be classified as "increasingly vulnerable", indicating the high uncertainty in their vulnerability status. Only *I. brasiliensis* was classified as "least vulnerable" and represents the only potential false negative. The remaining species were classified as "most vulnerable", which although may indicate a false positive, this is a desirable precautionary classification that explicitly highlights the uncertainty in their model input parameter values and can help guide research managers in prioritizing resources to collect additional data on these species.

4. DISCUSSION

4.1 Vulnerable shark species in the EPO

Sharks have been a major focus of various conservation and management measures developed by the IATTC for its fisheries. However, these measures have primarily focused on a small number of species that are either a target or retained bycatch species (e.g., blue shark), caught frequently (e.g., silky shark) in one or more fisheries, or those that have significant conservation status declared by external organizations such as the IUCN (e.g., oceanic whitetip shark and whale shark). In other words, species with the highest economic or conservation profiles have been the focus of management efforts as the absence of reliable data and/or assessment methods has hindered the identification of other potentially vulnerable species and appropriate management responses. The present assessment identified 20 species that were considered "most vulnerable", some of which are already the focus of specific conservation measures under IATTC resolutions, but many are not. The most vulnerable species identified span a broad spectrum of biological and ecological traits that make some more vulnerable to particular fisheries for specific reasons (*e.g.,* high spatial overlap), while others are more vulnerable to other fisheries for different reasons (e.g., selectivity of a specific size range). As a result, it is unlikely that there will be a single "silver bullet" management strategy that will be successful in mitigating all fishery impacts for each species (see Dulvy et al., 2017). The EASI-Fish approach employed in the present study was successful in quantifying the cumulative impacts of EPO fisheries on shark species, allowing a triage approach for identifying species that may require additional research and monitoring before re-assessment, or species that require immediate management intervention.

Blue and mako sharks

Among the group of "most vulnerable" species were those of known economic importance to both industrial and artisanal longline fisheries, namely blue and shortfin mako sharks. Not only do these longline fisheries have the largest effort footprint in the EPO, especially the industrial longline fishery, and thus, a greater likelihood of overlapping with the distribution of blue (*P. glauca*) and shortfin mako (*I. oxyrinchus*) sharks, but these species are either targeted directly, or occupy similar niches as target species (i.e., swordfish, bigeye, yellowfin and albacore tunas). In ERAs, it is commonplace to exclude target species since the primary objective of an ERA is to usually identify potentially vulnerable data-poor species. However, all shark species were included in the present assessment for the purposes of completeness and transparency. Such is the economic importance of blue and shortfin mako sharks in the longline fisheries in the EPO and throughout the Pacific that there is reliable biological data (see Fig. 8) and catch data from industrial fisheries that has enabled stock assessments to be undertaken in the north Pacific for both blue (ISC, 2017) and shortfin mako sharks (ISC, 2018) and in the south Pacific for blue shark (Neubauer et al., 2021). As such, no specific management recommendations will be made from the present assessment as the ISC and WCPFC plan to continue Pacific wide assessments of these species from which explicit management measures can be developed. However, a significant shortcoming of these stock assessments for these frequently caught and economically important species is a lack of catch and size data that is submitted to the IATTC for the artisanal fleets of Central America, which currently hinders the ability of scientists to recommend management advice. In an attempt to better assess shark stocks in the EPO, the IATTC staff is discussing the possibility of conducting a collaborative stock assessment for South Pacific blue shark with the Commission Permanente del Pacífico Sur (CPPS).

An important caveat of the assessment of mako sharks is the common misidentification of longfin mako (*I. paucus*) for the more common *I. oxyrinchus* throughout their overlapping global distributions (Levesque, 2007; Mucientes et al., 2013). This issue also appears to exist in the EPO purse-seine fishery where *I. oxyrinchus* was recorded in 1109 sets and *I. paucus* has never been recorded, but “Mako shark, nei” (*Isurus* spp.) was recorded in 329 sets. Given the *Isurus* genus contains only these two species, it is possible that these records pertain to *I. paucus*. However, because SDMs and EASI-Fish require species-specific information these generic records could not be used. Considering that the entire SDM for *I. paucus* was based entirely on the records from 671 sets made by the industrial longline fishery, the omission of a 329 potential presence records from regions outside of where the longline fishery operates where environmental variables may be different could have compromised the quality of the final prediction map and ultimately the precision of the fishing mortality estimate. This may explain the higher probability of occurrence in offshore waters west of about 110°W where longline effort is highest, despite suggestions that *I. paucus* may be more prevalent in shelf areas (Mucientes et al., 2013).

A major issue that has arisen from the misidentification or misreporting of *I. paucus* in most ocean basins is an almost complete paucity of biological data, except for a reproductive study from northern Cuba (Ruiz-Abierno et al., 2021). As a result, debates regarding the sustainability of *I. paucus* are often underpinned by a strong assumption that the growth and reproductive dynamics of the well-studied *I. oxyrinchus* are an acceptable proxy for *I. paucus* (see Gallagher et al., 2014b; Levesque, 2008). In the absence of reliable species-specific information, this assumption was also required to be made in the present study to characterize growth and longevity, but this uncertainly was reflected in low data reliability scores for *I. paucus* (see Fig. 8). Nonetheless, despite their apparent similarities in population dynamics, vulnerability of *I. paucus* was substantially less than for *I. oxyrinchus*. This was primarily attributed to *I. paucus* occupying deeper waters (0–760 m; Hueter et al., 2017) than *I. oxyrinchus* (0–400 m; Nasby-Lucas et al., 2019), and therefore having lower encounterability, and thus fishing mortality, by the longline fishery (0–300 m), which overlapped with 93–98% of the distribution of *I. paucus*. Although several authors believe *I. paucus* occupy deeper waters than *I. oxyrinchus*, (Compagno, 2001; Ebert, 2001; Mucientes et al., 2013), the only reliable information on vertical distribution is from two sharks tagged with archival tags in the Atlantic Ocean (Hueter et al., 2017) and so these depth estimates applied to the EPO should be viewed with caution, hence the low data reliability score. Nonetheless, the results from EASI-Fish clearly indicated that *I. paucus* should be considered a vulnerable species that requires, at a minimum, significant efforts to improve regionally-specific species-specific catch data through improved observer training on the identification of *Isurus* species to improve the reliability of SDMs and studies that can provide reliable parameter values for growth and reproductive biology.

Silky and oceanic whitetip sharks

Silky shark and oceanic whitetip shark were identified as "most vulnerable" reiterating their recognized conservation importance based on their high prevalence as bycatch in both longline and purse-seine fisheries and their trends of declining catch rates (Lennert-Cody et al., 2019), which led the IATTC to implement retention prohibition measures for oceanic whitetip shark in all EPO industrial tuna fisheries in 2011 (Resolution C-11-10) and in all purse-seine fisheries for silky shark in 2016 (Resolution C-16-06). These species are also listed under the Convention on International Trade in Endangered Species (CITES) Appendix II to curb international trade of their fins. Subsequently, the quality of their catch data has significantly improved, especially in the purse-seine fishery (Class 6), which has 100% observer coverage. Consequently, initial attempts have been made by the IATTC and WCPFC to develop stock assessments for these species in the Pacific Ocean (Rice and Harley, 2012;2013; Clarke et al., 2018; Tremblay-Boyer et al., 2019) with some promising results to further improve these assessments in future should species-specific catch data improve, particularly for artisanal fleets. One of the primary problems with previous stock assessments has been a lack of reliable time series of data of catch, CPUE, and sex/size composition, which may be overcome by implementing a close-kin mark-recapture study that would provide estimates of absolute adult abundance and adult natural mortality (SAC-12-14).

Interestingly, despite the well documented decline in the population of oceanic whitetip shark in most of the world's oceans (Baum and Myers, 2004; Clarke et al., 2013; Tolotti et al., 2015; Tremblay-Boyer et al., 2019) the vulnerability of oceanic whitetip was estimated to be lower than silky shark in the current assessment, despite both species having similar susceptibility values and biological traits. This result was due to the inclusion of post-release mortality (PRM) estimates of 15–19% for oceanic whitetip sharks derived from tagging experiments in Pacific longline fisheries (Musyl et al., 2011; Hutchinson et al., 2021) to reflect the retention prohibition mandate for longlines. In contrast, the default post-release mortality value of 100% was used for all species assumed to have economic importance to the longline fishery (see Appendices 1 and 2), including the silky shark. PRM estimates were, however, applied to silky shark in the purse-seine fishery, but high fishing mortality in the DEL and OBJ purse-seine fisheries and the relatively high PRM rates of 32–93% estimated for individuals released from tuna purse seines (Poisson et al., 2014; Hutchinson et al., 2015) resulted in the species being the second most vulnerable of the 32 species assessed.

Hammerhead sharks

All five species of hammerhead sharks (*Sphyrna* spp.) assessed were classified as "most vulnerable", with smooth hammerhead (*S. zygaena*) having the highest vulnerability of all shark species assessed, while scalloped hammerhead (*S. lewini*), scoophead (*S. media*), scalloped bonnethead (*S. corona*) and great hammerhead (*S. mokarran*) also ranked highly. This result lends support to the growing evidence that hammerheads are experiencing unsustainable impacts from fishing, not only throughout the EPO (Pérez-Jiménez, 2014; Zanella et al., 2019) but in all oceans of the world (Pacoureau et al., 2021). The five species assessed are currently listed by the IUCN Red List of Threatened Species as either "Critically Endangered" or "Vulnerable". Furthermore in 2013, three of these species (*S. lewini*, *S. mokarran* and *S. zygaena*) were listed under CITES Appendix II to control international trade of products derived from these species.

Most hammerhead species have a predominant coastal distribution, especially juveniles, that often use shallow coastal habitats as nursery areas (Zanella et al., 2019; López-Angarita et al., 2021; Corgos and Rosende-Pereiro, 2022) and some species tend to form aggregations to feed and/or breed in the EPO (Salinas-de-León et al., 2017). Consequently, they are highly vulnerable to artisanal fisheries, especially gillnets, since their body morphology makes them susceptible to entanglement and the potential for post-release survival is low (Gallagher et al., 2014a; Gallagher and Klimley, 2018).

A particularly significant result from the present assessment was the identification of the two smallest-growing hammerhead species, the scoophead (*S. media*) and scalloped bonnethead (*S. corona*) as being "most vulnerable". In the EPO, both species, and the closely related bonnethead (*S. tiburo*), have a highly restricted coastal distribution between Mexico and northern Peru, with *S. corona* being endemic to this region (Ebert et al., 2021). In a review of historical records from Mexican Pacific waters, Pérez-Jiménez (2014) raised concerns for the potential extirpation of these three species in this region as a result of decades of fishing impacts, with only three individuals of *S. media* and *S. tiburo* recorded from over 207,000 sharks caught in shark surveys conducted in 1962–2010. In the same surveys, he found no record of *S. corona*, which had apparently last been recorded in Mexican waters in 1994 (Balart et al., 1996) and most recently within its entire EPO distribution only from southern Colombia in 2014 (Orozco Guarin, 2014).

The IATTC and national observer programs established for the purse seine and industrial longline fisheries and surveys of Central American artisanal fisheries demonstrate their importance in this instance as we can confirm that *S. media*, *S. corona* and *S. tiburo* have been last recorded in the EPO in 2009, 2021, and 2001, respectively (unpublished IATTC observer data). However, given that only 44 individuals have been recorded, combined for the three species, from over 500,000 observed purse-seine and longline sets, we concur with the concerns raised by Pérez-Jiménez (2014) over the sustainability of the population of these species in the EPO. However, it is also important to consider the many tasks of onboard observers, from recording the operational aspects of the fishery, to recording data for target tuna species and a full suite of bycatch species from marine mammals, sea turtles, sharks and teleosts. Therefore, given the short periods where observers might get to inspect bycatch, the identification of less frequently encountered species—some of which are not currently in observer identification guides—may not be entirely accurate, or these species may be identified to a higher taxonomic resolution (*e.g.*, Sphyrna sp.).

An important point of clarification is that *S. tiburo* was not assessed in the present study due to the presence of only two capture records in EPO fisheries—both from the purse-seine fishery in 1998 and 2001 (unpublished IATTC observer data). It is currently unknown if this low frequency of interaction is due to the species' availability and selectivity by the gear of the assessed fisheries, or the apparent depleted state of its population. Whichever the reason, recent genetic evidence showing the existence of a unique stock in Panama (Gonzalez et al., 2019) suggests that this species should also be regarded as "most vulnerable" in the present study.

A significant caveat to the assessment of *S. media* and *S. corona* is that almost no biological information exists for these species (but see Orozco Guarin, 2014). Therefore, empirical relationships (Froese and Binohlan, 2000) were used to estimate parameter values to characterize growth and reproduction, which almost exclusively relied on maximum recorded length. Furthermore, natural mortality estimates were derived using empirical equations that primarily rely on growth parameters. It is unknown how reliable the estimates for these biological parameters are, hence why they were assigned reliability scores of 1. Despite this high uncertainty, their vulnerability was similar to other *Sphyrna* species that have been the subject of detailed biological studies, and therefore, their classification as "most vulnerable" here is both plausible and precautionary. If these species had been classified as "least vulnerable", they would have been subjected to further investigation based on their extremely low reliability scores and other available information (see Pérez-Jiménez, 2014).

Although data provision for shark interactions is continually improving for IATTC CPCs (see C-21-06 on silky sharks), many relevant components of resolutions that pertain to hammerheads other than the three most commonly-caught species (*S. lewini*, *S. mokarran* and *S. zygaena*) remain as recommendations (Resolution C-05-03) rather than mandates. As a result, the IATTC ultimately relies on the goodwill of CPCs to fulfill these data requests and for coastal States to implement appropriate management measures in coastal fisheries. Some coastal States are making a concerted effort to either improve data collection on sharks or to directly mitigate shark catches through management measures, such as the 3-month seasonal closure to shark fishing by all fisheries in Mexico's EEZ (May– July) 2012 (Sosa-Nishizaki et al., 2020) and by small-scale fisheries in Peru (January–March) since 2016 (Mason et al., 2020).

Thresher sharks

Two the three species of thresher sharks included in the assessment, bigeye thresher (*A. superciliosus*) and pelagic thresher (*A. pelagicus*), were classified as "most vulnerable", primarily due to the high horizontal and vertical overlap of their distributions with that of the industrial longline and purse-seine fisheries additional to the wide size selectivity of the gears that incorporated the complete size range for these species. These results support previous studies using the PSA approach which ranked these species as being among the most vulnerable bycatch species caught by the purse-seine fishery (class 6 vessels) (Duffy et al., 2019) and the industrial longline fishery (Griffiths et al., 2017) in the EPO. Given their high susceptibility to capture by a range of fisheries coupled with their life history traits of being long-lived, slow growing and having low reproductive potential, *A. superciliosus* and *A. pelagicus* are listed by the IUCN as "Vulnerable" and "Endangered", respectively, and are also listed under Appendix II of the Convention on International Trade in Endangered Species (CITES) (CITES, 2016) and Appendix II of the Convention of Migratory Species (CMS) (CMS, 2015).

In contrast, the common thresher (*A. vulpinus*) was classified by EASI-Fish as "least vulnerable", despite high uncertainty in the status value (see Fig. 7). This species was not included in the ERA conducted by Duffy et al. (2019) for the EPO purse-seine fishery but was ranked as highly vulnerable—but lower than *A. superciliosus* and *A. pelagicus*—in the EPO industrial longline fishery (Griffiths et al., 2017). These results of the EASI-Fish assessment compliment those of a stock assessment undertaken on the species in North America in 2018, where it assessed against maximum sustainable yield (MSY)-based biological reference points and was found not to be overfished nor experiencing overfishing (Teo et al., 2018). The reason for this species' classification by EASI-Fish as "least vulnerable" is related to a lower volumetric overlap, particularly with the longline fishery, due it's more coastal distribution and occupation of deeper mesopelagic waters. For example, the mean overlap of the predicted distribution of *A. vulpinus* with that of the longline fishery was 48%, compared to 71% and 73% for *A. superciliosus* and *A. pelagicus*, respectively. Similarly, encounterability with longline gear, which was assumed to fish 0–300 m, was lower for *A. vulpinus* as its preferred maximum depth range—the depths at which the species reached in 80% of its deepest dives— was 300–543 m (Musyl et al., 2011), meaning its normal distribution extended up to 243 m deeper than the assumed deepest hook set by longlines. In contrast, *A. pelagicus* is more pelagic with a narrower depth range of 0–300 m (Arostegui et al., 2020), which lies completely within the depth range of the longline gear resulting in the encounterability parameter being fully realized (i.e., $E_{xj} = 1$).

Despite *A. vulpinus* having comparatively lower vulnerability to industrial fisheries on the high seas compared to *A. superciliosus* and *A. pelagicus*, this species is known to be highly vulnerable to capture, both as a target and bycatch, in coastal domestic fisheries and is frequently caught in gillnet, longline and recreational fisheries from the United States (Heberer et al., 2010) to at least southern Peru (Gonzalez-Pestana et al., 2014). EASI-Fish correctly reflected this inter-specific difference in fisheries overlap with an estimated mean overlap of the artisanal longline fishery with *A. vulpinus* being 31%, compared to 11% and 16% for *A. superciliosus* and *A. pelagicus*, respectively. However, the present study had access to only limited datasets describing the effort footprint of artisanal fisheries in the EPO, with some data requiring manual georeferencing of published effort maps to better characterize the spatial extent of these fisheries. Therefore, the estimated fisheries overlap with *A. vulpinus* and the subsequent estimated fishing mortality is likely to have been substantially underestimated. Similarly, the vulnerability of *A. superciliosus* and *A. pelagicus* is also likely to be underestimated due to incomplete fishing effort data by the artisanal fleets, which in some regions, are increasingly moving offshore to fish. For example, in the Ecuadorian artisanal pelagic longline fishery, *A. pelagicus* is by far the most caught elasmobranch, comprising 22% of the total catch of all tunas, billfish and elasmobranch species combined (Martínez-Ortiz et al., 2015).

Requiem sharks

The requiem sharks (family Carcharhinidae) are among the most speciose family of sharks in the EPO and the wider Pacific Ocean. In general, these species tend to be relatively fast-growing, short-lived and have higher reproductive capacity than pelagic sharks of other families (e.g., Lamnids), and have therefore been shown in ERAs conducted in the EPO (Griffiths et al., 2017; Duffy et al., 2019), Atlantic (Arrizabalaga et al., 2011) and Indian (Murua et al., 2018) oceans to be more resilient to fishing impacts (also see Smith et al., 1998). However, of the 12 carcharhinids assessed—some for the first time in any ERA anywhere in the world—10 species were classified as "most vulnerable". Apart from *C. falciformis* and *C. longimanus* that were discussed earlier in detail, the remaining species have restricted neritic distributions in the eastern tropical Pacific between northern Mexico and Peru, with *Rhizoprionodon longurio* and *Nasolamia velox* being endemic to this region (Ebert et al., 2021) (see Fig. 3). This distribution is the primary reason explaining their high vulnerability since the footprint of most fisheries overlapped significantly with the distribution of these species. Furthermore, these species occupy epipelagic waters, generally less than 200 m (Brunnschweiler et al., 2010; Weigmann, 2016; Morales et al., 2021), which places them within the majority of the depth range of each fishery assessed (i.e., $E_{xj} = 1$).

The most vulnerable of the carcharhinids were small-sized species that generally lacked reliable biological parameters and hence, had very low data reliability scores for most model parameters. These species include the smalltail shark (*C. porosus*), bignose shark (*C. altimus*), whitenose shark (*Nasolamia velox*), and the Pacific sharpnose shark (*Rhizoprionodon longurio*). The high susceptibility values for areal overlap with industrial and artisanal longline fisheries and in some cases for the purse seine fishery, coupled with the low productivity of these species were the primary drivers for their classification as "most vulnerable".

Of these species, *C. porosus* was ranked the fourth most vulnerable of the 32 species assessed, which has not previously been assessed using ERA throughout its range in either the Pacific or Atlantic Ocean. Significant ambiguity has existed in the taxonomy of the species over the past decade with two studies (Castro, 2011; Naylor et al., 2012) confirming that its only synonym, *C. cerdale*, occurs in the EPO, but recent studies (Ehemann et al., 2018; Saldaña-Ruiz et al., 2017) continue to use *C. porosus*. Regardless of current valid nomenclature in the EPO, no published biological information exists from the EPO, but reliable studies have been conducted off northern Brazil on age and growth (Lessa and Santana, 1998) and reproduction (Lessa et al., 1999) that indicate the species is slow-growing, has a lifespan of at least 12 years, and matures late in life at around 6 years of age. The classification of this, and similar species, as "most vulnerable" should serve as an early conservation warning in the EPO given that the capture of predominantly juvenile *C. porosus* by coastal gillnet fisheries have resulted in the extirpation of the species from northeastern and southeastern regions of Brazil, while in northern Brazil where the species is apparently most abundant, the population has declined by more than 90% over the past 10 years (Santana et al., 2020). Furthermore, *C. porosus* occurred relatively rarely in the fisheries assessed in the present study (5 records from the Central American artisanal multi-gear, multi-species fisheries and 33 records from the size class 6 purse-seine fishery) and given the population declines observed in Brazil, this may indicate immediate conservation efforts may be necessary. Considering that the EPO was believed to support a smaller population of *C. porosus* than the Atlantic Ocean (Santana et al., 2020), and that the EPO component is now considered to be an entirely different species (*C. cerdale*), this should warrant urgent investigation, at a minimum, into the distribution of this species as well as its basic population biology. Such regional taxonomic ambiguities of small-sized coastal tropical requiem sharks have already resulted in the extinction of the species now known as *C. obsolerus* from the western central Pacific Ocean as a result of overfishing (White et al., 2019). Therefore, it is imperative that conservation efforts be made to prevent a similar fate for *C. cerdale* and similar small-sized carcharhinids in the EPO.

Mesopelagic sharks

Four species of mesopelagic sharks were assessed in the present study, Crocodile shark (*Pseudocarcharias kamoharai*) and the sleeper sharks; kitefin shark (*Dalatias licha*), velvet dogfish (*Zameus squamulosus*), cookie cutter shark (*Isistius brasiliensis*), of which only *I. brasiliensis* was classified as “Least vulnerable”. Although their horizontal distributions were reasonably wide-ranging and overlapped significantly with longline and purse-seine fisheries they were only recorded from the industrial and artisanal longline fisheries. This is likely a result of their vertical distribution that can frequently extend to over 1000 m during the day where they are not susceptible to capture by purse-seine gear, but they become susceptible to longline when they migrate to epipelagic waters during the night (Crow et al., 2018; Kindong et al., 2021). Presently, these species are classified as “Least Concern” by the IUCN, with the exception of *D. licha* which is “Near Threatened”, presumably due to their occupation of deep waters that limit their interactions with fisheries. Their infrequency of capture has led to few investigations of their biology and those that have been undertaken have encountered difficulty in validating ages. This is because the traditional method of ageing sharks by counting growth increments in vertebrae is often not possible for deepwater sharks such as *D. licha* as their vertebrae are poorly calcified, requiring eye lenses and fin spines to be used as alternative hard parts for ageing (Francis et al., 2018). As a result, the reliability scores for many parameters are reasonably low.

4.2 Less vulnerable shark species

Although the analyses in present study classified 9 species as “least vulnerable”, it is particularly important to briefly mention some of potential reasons for these classifications for 4 species listed by the ICUN as “vulnerable” (*Lamna nasus* and *Carcharodon carcharias*), “near threatened” (*Galeocerdo cuvier*), or “endangered” (*Rhincodon typus*). The primary reason for the “least vulnerable” classification of these species with the exception of *L. nasus*, is due to their predominant neritic distributions that limit their interactions with industrial longline and purse-seine fisheries. These species are however, impacted by coastal artisanal longline and gillnet fleets (García-Rodríguez and Sosa-Nishizaki, 2020; Guzman et al., 2020; Martínez-Ortiz et al., 2015) for which the spatial distribution of effort data is not well represented in the present study, and therefore, the vulnerability of these species is likely underestimated. Furthermore, for *C. carcharias* in particular available occurrence records may be significantly underrepresented for this species due to poor reporting of interactions (García-Rodríguez and Sosa-Nishizaki, 2020) or deliberate non-reporting of illegally retained sharks (Madigan et al., 2021).

In the case of *L. nasus*, its classification as “least vulnerable” is primarily due to its predicted distribution being predominantly throughout the Humboldt Current south of around 20°S (Fig. 3) where there is relatively little industrial longline or purse-seine effort (Fig. 5), coupled with its mesopelagic distribution of greater than 300m (Francis et al., 2015) that extends beyond the effective fishing depths of these fisheries.

Of the four aforementioned species, *R. typus* probably has the most interaction with industrial fisheries, specifically purse-seine, although these interactions are uncommon (Román et al., 2018). Historically, whale sharks were considered to attract tunas in a similar way as floating objects, probably as a result of their large size and slow movement speeds (Fontes et al., 2020), and were occasionally set upon by purse-seine vessels in a similar way as other floating objects. However, such were, and still are, the conservation concerns for this species, the IATTC implemented Resolution C-16-01 and then C-19-06 to prohibit deliberate setting on whale sharks and to use all reasonable steps to ensure the safe release of accidentally encircled animals. As a consequence of their mandated release in the EPO, it was important to consider all available evidence pertaining to post-release mortality for this species to be represented in EASI-Fish. To date tagging studies of whale sharks released from commercial purse-seines in the tropical eastern Atlantic Ocean (11 tags; Escalle et al., 2018) and the Arabian Sea (8 tags) (8 tags; Arrowsmith et al., 2021) demonstrated 100% survival of released sharks. However, because no post-release mortality data is available specifically from EPO fisheries that may slightly differ in their operation to fisheries in other regions (*e.g*., setting on herds of dolphins), we used an arbitrary PRM range of 10–20%. Should the true PRM rate be higher than the values used, which would need to be addressed using a tagging study, the vulnerability of this species would therefore have been underestimated.

4.3 Caveats, recommendations, and directions for future work

The present study formed a sound foundation from which the IATTC can plan future research, monitoring, assessment, or management efforts pertaining to sharks in the EPO. Despite the use of the best available information to parameterize EASI-Fish, the paucity of even the most rudimentary biological or catch information for several species (see Fig. 8) meant that parameter input values and the subsequent vulnerability status for some species was highly uncertain. However, using data reliability scores for key model parameters, the assessment was successful in highlighting key knowledge gaps that should serve as the basis for future work priorities of the IATTC to facilitate incremental improvement in the reliability of species-specific assessments and their outcomes that ultimately guide management. Below, we recommend and discuss some of these priorities.

4.3.1 Exploring the potential efficacy of conservation and management measures

Despite the IATTC’s commitment to uphold the mandates of the Antigua Convention to ensure the ecological sustainability of all species impacted by EPO tuna fisheries, even the initial task of objectively prioritizing potentially vulnerable species is a significant challenge given the dearth of basic biological and ecological information available for most shark species. However, with the development of EASI-Fish we have been able to quantitatively estimate the vulnerability of each shark species and determine how the IATTC and its CPCs may need to proceed to ensure the long-term sustainability of these species. For some species classified as “least vulnerable”, this may be to simply continue to monitor interactions within EPO fisheries through IATTC or national observer programs. However, for other species listed as “most vulnerable” significant research and/or monitoring efforts are required to fill crucial biological and/or ecological data gaps and to improve distributional information to improve SDMs, or to develop management measures to reduce the potential for the populations of some particularly sensitive species to further decline, extirpation, or even extinction due to their restricted endemic distributions in the EPO (e.g., *C. cerdale*).

Developing and implementing CMMs to achieve conservation objectives for shark bycatch species having such diverse life histories and habitat preferences in horizontal (*e.g.,* neritic vs. pelagic) and vertical (*e.g.,* epipelagic vs. mesopelagic) planes while concurrently ensuring the economic viability of EPO fisheries is a significant scientific, logistical and potentially expensive challenge that is unlikely to be achieved by a single “silver bullet” measure (see Dulvy et al., 2017). Although EASI-Fish was used in the present study to simply prioritize vulnerable species, its spatially explicit and flexible structure allows for the exploration of the potential efficacy of CMMs on species’ vulnerability, allowing managers to focus their efforts towards implementing CMMs that show the greatest potential in being effective in meeting the management objectives for the largest number of shark species. Such an exploratory approach was recently successful in a completed collaborative project between the IATTC and the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC) (BYC-11-01, BYC-11-02). In this project, EASI-Fish was used to examine the potential efficacy of 70 management scenarios related to the implementation of a range of potential measures listed under IATTC Resolution C-19-04 (e.g., use of circle hooks, cut fish bait, improved best handling and release practices) to reduce the vulnerability of the critically endangered East Pacific stock of leatherback turtle (*Dermochelys coriacea*) in the EPO, for which an improved SDM was developed using new high resolution data provided by participants of this collaboration.

In the case of shark bycatch in the EPO, there may be several potential CMMs to simulate such as spatial or temporal closures if particular areas and time periods can be identified where a species is most abundant or susceptible to capture, such as breeding, feeding or nursery areas (see López-Angarita et al., 2021; Zanella et al., 2019). Alternatively, changes to gear configurations could be implemented to reduce the selectivity of particular species or size classes of sharks, or if shark interactions cannot be avoided, explore the potential for best handling and release practices to reduce fishing mortality through improved post-release survival. For example, since 2002 the IATTC has mandated a temporal closure of the purse-seine fishery in the EPO to reduce the fishing impacts on target species, which, depending on the status of the target stocks, has ranged from 31 days in 2002–2003 (Resolutions C-02-04 and C-03-03) to 72 days from 2018–2024 (Resolution C-17-01 and C-21-04). In addition, an annual 30-day closure of the area known as the "corralito" (see Resolution C-02-04) has been implemented in an effort to reduce the mortality of juvenile tropical tunas. With regards to sharks in particular, Peru implemented a seasonal fishing closure for its small-scale fisheries in 2016 to reduce the mortality on juvenile hammerhead sharks (Mason et al., 2020), whereas more draconian measures have recently been instigated by Colombia to completely ban all forms of commercial and artisanal fishing for sharks within its EEZ (Castellanos-Galindo et al., 2021). Despite spatial and temporal closure being potentially effective management strategies, a significant socio-economic dilemma persists in the EPO in that some CPCs are developing States where closures are likely to significantly affect the livelihoods of thousands of fishers, which will ultimately have subsequent impacts on local and regional economies, or in contrast, may lead to illegal and unreported fishing and underground trade, criminality, and marginalization (Castellanos-Galindo et al., 2021; Finkbeiner et al., 2017).

Interactions of some gears with some bycatch species is unavoidable and spatial or temporal closures may have unacceptable socio-economic consequences in some regions. Therefore, the only alternative that may allow fisheries to have sustainable interactions with sharks is to implement measures that maximize post-release survival. Resolutions have already been implemented by the IATTC that mandate or recommend the release of sharks (C-16-05 and C-19-06), although these resolutions are not prescriptive as to the specific methods of release. Consequently, C-21-06 calls for research to improve handling and release practices for all impacted shark species. Despite some recent research being conducted in the EPO on the post-release survival of elasmobranchs caught in some purse-seine (Eddy et al., 2016) and artisanal longline (Schaefer et al., 2019; Schaefer et al., 2021) fisheries, clearly further studies are required, and recommended here, for a broader range of shark species across all fisheries and set types.

However, even if studies were currently underway, it is likely that it will take several years to accumulate sufficiently reliable data to guide managers. EASI-Fish has the advantage of rapid exploration of potential spatial and temporal closures and plausible PRM values using previous studies and/or expert opinion to reduce a species' vulnerability, as was demonstrated for the leatherback sea turtle (BYC-11-02) and the spinetail devil ray (Griffiths and Lezama-Ochoa, 2021) in the EPO. Therefore, EASI-Fish could be a useful exploratory tool to employ in the interim period until post-release survival studies are complete to simulate changes to existing, or additional, management measures, either in isolation or in concert, to determine their efficacy for reducing species-specific vulnerability. Furthermore, this desktop approach may concomitantly guide research efforts to consider quantifying the most potentially effective aspects of handling and/or release procedures. As a first step, it is recommended that these more in-depth assessments focus on the most vulnerable species identified in the present study, namely silky shark and hammerhead sharks, some of which have already been identified as a priority for the IATTC to undertake stock assessments (Resolution C-16-05).

4.3.2 Improving spatially-explicit catch and fishing effort

EASI-Fish was developed in an attempt to overcome some of the significant issues for assessing tuna bycatch species that are often data-poor due to poor reporting. The basic premise of EASI-Fish for estimating a proxy for fishing mortality is to determine the extent of three-dimensional overlap of a fishery with the distribution of a species. This requires an understanding of the full extent of the distribution of effort by a fishery, at the finest resolution possible, and where the species of interest is located over the finest time scale used the assessment, which in EASI-Fish is usually an annual time-step. The data required by EASI-Fish to describe the distributions of fishing effort and the species are fundamentally simple, being the presence of one or more units of fishing effort and the presence of the species in each grid cell across the surface of the assessment area. In the present study, these data were primarily derived from reports by fishers and observations recorded by onboard observers.

Industrial longline fishery

An ongoing obstacle for IATTC scientists to undertake detailed scientific analyses on the longline fishery pertains to Resolution C-19-08 that mandates each CPC to provide a minimum of 5% observer coverage of the effort by their longline fleets. However, these data are often not representative of the activities of the fleet (Griffiths et al., 2021), nor does they cover the full spatial footprint of the fleet. Consequently, there was a high reliance in the present study on reported data for developing the effort distribution for the EPO longline fishery. Unfortunately, CPCs commonly report industrial longline effort data at 5° x 5°—the coarsest resolution permitted under Resolution C-03-05—and moreover the same resolution does not require CPCs to report on incidental catches of non-target species, *i.e.,* bycatch (see SAC-12-09). Considering the predictions from the SDMs used in the present study were resolved at 0.5°, the mismatch in spatial resolution can result in a potential overestimate in overlap by a factor of 100. In other words, if an SDM predicted a species to be present in all one hundred 0.5° grid cells contained within a 5° grid cell that is fished, it is precautionarily assumed that fishing is present within each 0.5° grid cell.

A further issue related to the spatial resolution of reported data pertains to the precision of species presence locations. Because the spatial distribution of longline fishing effort covers almost the entire Convention Area, it can be a valuable source of data for developing SDMs because of the broad environmental gradient in which the fishery covers. However, the oceanographic environment can vary significantly within a 5° grid cell for which catch data is reported due to the influence of fronts (Wang et al., 2021), mesoscale eddies (Hasson et al., 2019), and other fine and mesoscale environmental features, thus compromising the potential strength of modelled relationships between a species' relative abundance and environmental variables.

To better define the spatial distribution of fishing effort and to improve the utility of catch data for the longline fishery for, among other things, developing SDMs for bycatch species, data are required at a higher spatial resolution. Although operational level data has recently been mandated for the longline fishery under Resolution C-19-08, observer coverage is often less than the required 5%, which severely hinders the amount and representativeness of data available to characterize this fishery. As a result, for several years the IATTC staff has recommended observer coverage be increased to at least 20% (see

Resolution C-19-08; Griffiths et al., 2021), and reiterated here, to not only improve data quality for reporting but for scientific purposes such as ERA.

Purse-seine fisheries

The most reliable fishing effort for the present study data came from the purse-seine fleet composed of Class 6 vessels that have 100% observer coverage in the EPO and providing precise locations of fishing effort, by set type. Catch data was also of high spatial precision, although as is often the case for shark bycatch data, reported taxonomic resolution was reasonably poor for some particularly vulnerable taxonomic groups. For example, 27,183 of the 113,328 records (24%) where sharks were recorded by observers were not recorded to species, most notably for requiem (3,806; 3%) and hammerhead (2,896; 2%) sharks. The required omission of such a large number of data records greatly diminishes the quality of species prediction maps derived from SDMs, especially if these omitted data contained rarer species, such as the species of small hammerhead and requiem sharks, for which a presence record may be highly valuable from a purely conservation viewpoint to confirm the species is extant. The staff is currently exploring smart species identification tools, such as smartphone applications that employ artificial intelligence and rapid genomic tests to improve species identification in a rapid and accurate manner both in the field and on-board vessels (Project B.1.a).

In contrast to the industrial purse-seine fishery, low observer coverage is a significant issue for the purse-seine fishery comprised of smaller Class 1–5 vessels, where a minimum of 5% observer coverage is required for vessels less than 24 m LOA. In the present study, effort data were derived primarily from observed sets by TUNACONS on a voluntary basis, which covered 12% of the effort by fleet in 2019 (IATTC, unpublished data). As a result, catch composition is unlikely to be representative of the fleet and the distribution of effort was considered to represent the minimum spatial coverage of the fishery. However, the IATTC is working on improving data provision for this and other fleets through a proposed update of its data provision resolution (see SAC-12-09), the development of the FAD form (09-2018), and the implementation of electronic monitoring systems (EMS) (see EMS-01-02).

Artisanal fisheries from EPO coastal nations

Similar to the industrial longline and Class 1–5 purse-seine vessels, little reliable data exist for the artisanal longline and gillnet fisheries throughout the EPO as they are also poorly monitored by national fisheries agencies, if at all (Salas et al., 2007). Despite these vessels being small, their fleet sizes can be large and their impacts on sharks, and other non-target species, have been shown to be significant (Alfaro-Shigueto et al., 2010; Cartamil et al., 2011; Martínez-Ortiz et al., 2015; Sosa-Nishizaki et al., 2020). Hence the importance of compliance with the obligation to report to the IATTC the catch and effort of these vessels as stipulated in resolution C-03-05.

Although the best available information was used to characterize catch and effort from limited reported and observer records and new survey data from the Central American shark sampling project (Oliveros-Ramos et al., 2020), it is unknown to what extent these data represent these fisheries. The recent IATTC-IAC project assessing the vulnerability of the leatherback turtle in the EPO worked directly with representatives from coastal States to maximize the amount of effort data pertaining to artisanal fisheries, where the species is frequently caught. Despite the project accessing data for these fisheries, often only for observed sets that generally represent less than 5% of the total effort, the effort footprint for the artisanal longline and gillnet fisheries was substantially larger compared to the present study. As a result of effort data for the purse-seine, and artisanal longline and gillnet fisheries representing a small fraction of the total effort by these fisheries, the estimated fishing mortality for each species assessed is likely to be underestimated. This is concerning for some species that have a restricted, or even endemic, coastal distribution that are most susceptible to capture by these fisheries, such as the small-sized hammerheads (*S. media*, *S. corona* and *S. tiburo*) and requiem sharks

(*C. porosus*/*C. cerdale*, *R. longurio* and *N. velox*), as their vulnerability may be even greater than reported here. It has been widely acknowledged that poor monitoring and/or reporting of shark catches in artisanal fisheries—often reported as "hammerhead sharks" or even as "sharks"—has greatly hindered regional and global efforts to quantitatively assess the population status of these species (Dulvy et al., 2017; Jorgensen et al., 2022).

Clearly, there is an urgent need for coastal States to establish or improve data collection programs for artisanal fleets to not only facilitate domestic fisheries management but assist the IATTC in fulfilling its responsibilities under the Antigua Convention, which has been hindered in many instances by a lack of data from these fleets. In recent years the IATTC collaborated with Central American IATTC Members in a project funded by the Global Environment Facility (GEF) to develop a data collection program for small coastal shark fisheries (Siu and Aires-da-Silva, 2016; Oliveros-Ramos et al., 2019). Although the project developed a highly successful sampling program that significantly improved our understanding of artisanal fisheries, unfortunately the staff's proposal for the implementation of a long-term sampling program for shark fisheries in Central America has not succeeded in gaining financial support so far (IATTC-98-02c). A subsequent pilot sampling project is currently in development under a phase 2 of the GEF ABNJ project for additional countries including Ecuador, Peru and Mexico, which is hoped to improve our knowledge of artisanal fisheries in those countries (SAC-13-12). However, for the IATTC to be able to undertake future stock or vulnerability assessments on shark species in the EPO as agreed to by its Members (see Resolution C-16-05), a long-term solution to securing sufficient resourcing to facilitate ongoing monitoring programs is required. Furthermore, updating of Resolution C-03-05 on data provision is essential to align with mandates described in the Antigua Convention and IATTC's SSP to include mandates on reporting of, at a minimum, vulnerable species (e.g., elasmobranchs) incidentally caught by the various fisheries operating in the EPO (see C-12-09).

4.3.3 Biological studies

As required by most population models, EASI-Fish incorporates information on the growth and reproductive dynamics (e.g., length at maturity), which is used in per-recruit models in the productivity component of EASI-Fish (Eq. 3 and 8). Unfortunately, the majority of shark bycatch species in the EPO have not been the subject of detailed biological studies for various reasons such as their infrequency of capture, taxonomic ambiguity, low economic importance, and prohibition of retention. Even for many frequently-caught species of economic importance there were insufficient data from the EPO to populate EASI-Fish, so the best available biological information for the same species studied in other regions was used. Although EASI-Fish has the capability of capturing uncertainty in biological parameters, which is reflected in the uncertainty in vulnerability status, and identifying data reliability using the data reliability index, for some rarer species, even the most fundamental biological information such as a length-weight relationship is unavailable. For some small-growing species of hammerhead (*S. media* and *S. corona*) and requiem (*C. altimus*, *N. velox* and *R. longurio*) sharks and even the longfin mako (*I. paucus*) no species-specific information was available for many biological parameters, particularly growth and longevity, which are key inputs for empirical estimators of natural mortality (see Then et al., 2015). Therefore, biological values for closely related species were required to be used, or in the most data-poor cases, estimated using a range of empirical equations (e.g., Froese and Binohlan, 2000) that generalize biological traits across higher taxonomic levels and are therefore, fraught with uncertainty.

Biological studies are the cornerstone of population models that are required to understand the biological productivity of a species and its potential resilience to fishing impacts and are therefore a necessity for providing sound management advice. Unfortunately, these fundamental studies can be time-consuming and costly to conduct and are now often regarded as 'routine' science that often fail to attract research funding (Jorgensen et al., 2022). However, pursuant to Article VII, 1(m) of the Antigua Convention, the IATTC is required to practice the precautionary principle in instances where there is a lack of scientific information on which to base management action. Considering the large number of shark, and likely other, bycatch species that lack sufficient biological data for stock or vulnerability assessments, the next step towards sustainable management of these species may involve a collaboration of the IATTC scientific staff with its Members and CPCs to develop a strategy to undertake studies to fill these important biological data deficiencies. This may involve collaboration with local universities and fisheries agencies to not only reduce operation costs but to instill fisheries research capacity within the next generation of science graduates, particularly in developing coastal States. Such rudimentary studies were incredibly important in the present study for modelling reproductive dynamics of relative rare species including *R. longurio* (Corro-Espinosa et al., 2011) and *S. corona* (Orozco Guarin, 2014). Capacity building has been an important goal of the IATTC's SSP (Goal Q: Provide training opportunities for scientists and technicians of CPCs) and a dedicated fund for developing countries has been established for this purpose (CAF-08-03) and will hopefully play a significant role in filling key biological and fishery knowledge gaps in the near future.

5. CONCLUSIONS

Ensuring the long-term sustainability of all species impacted by fishing activities forms the basis for ecosystem-based approached to fisheries management, and is an explicit objective (Article VII 1(f)) of the IATTC's Antigua Convention (IATTC, 2003). However, quantitatively demonstrating the sustainability of bycatch populations in the EPO, similar to tuna fisheries in other oceans, is greatly hindered by the frequent dearth of information pertaining to the biology, ecology and catch of the diversity of bycatch species and the lack of models that can utilize such limited data to make reliable assessments on the sustainability of these bycatch populations. EASI-Fish was designed by the IATTC staff to overcome many of these issues to quantify the cumulative impacts of multiple fisheries on data-poor species and to transparently determine the vulnerability status of a species' population using biological reference points widely used in fisheries stock assessment. Although EASI-Fish integrates length-structured yield- and spawning biomass per-recruit models it, and other ERA methods, should not be used as a substitute for stock assessment to assess stock status for bycatch species, and be the endpoint for management advice. It does, however, serve an important role in facilitating progress towards attaining the goal of ecological sustainability through the planning of future research and conservation efforts by prioritizing species that are most vulnerable to becoming unstainable under current fishing effort regimes.

This study represents the first comprehensive vulnerability assessment for shark species captured by industrial and artisanal pelagic fisheries in the EPO. We were successful in identifying several priority species for the IATTC to consider the implementation of immediate mitigation measures for particularly vulnerable species, such as the endemic species of hammerheads and requiem sharks, and a strategy for improved collection of biological and catch data to allow re-assessment using EASI-Fish, or for stock assessment where sufficient data are available. A simple and inexpensive initial step in moving forward may be to use EASI-Fish to explore potentially effective conservation and management measures for reducing the vulnerability of priority shark species that are impacted by multiple pelagic fisheries in the EPO that, once sufficiently reliable data are available, can be explored in formal stock assessment models, from which outputs can translate into explicit management action.

ACKNOWLEDGMENTS

The authors wish to thank Alexandre Aires-da-Silva, Marlon Roman, Salvador Sui, and Paulina Llano for reviewing drafts of this paper.

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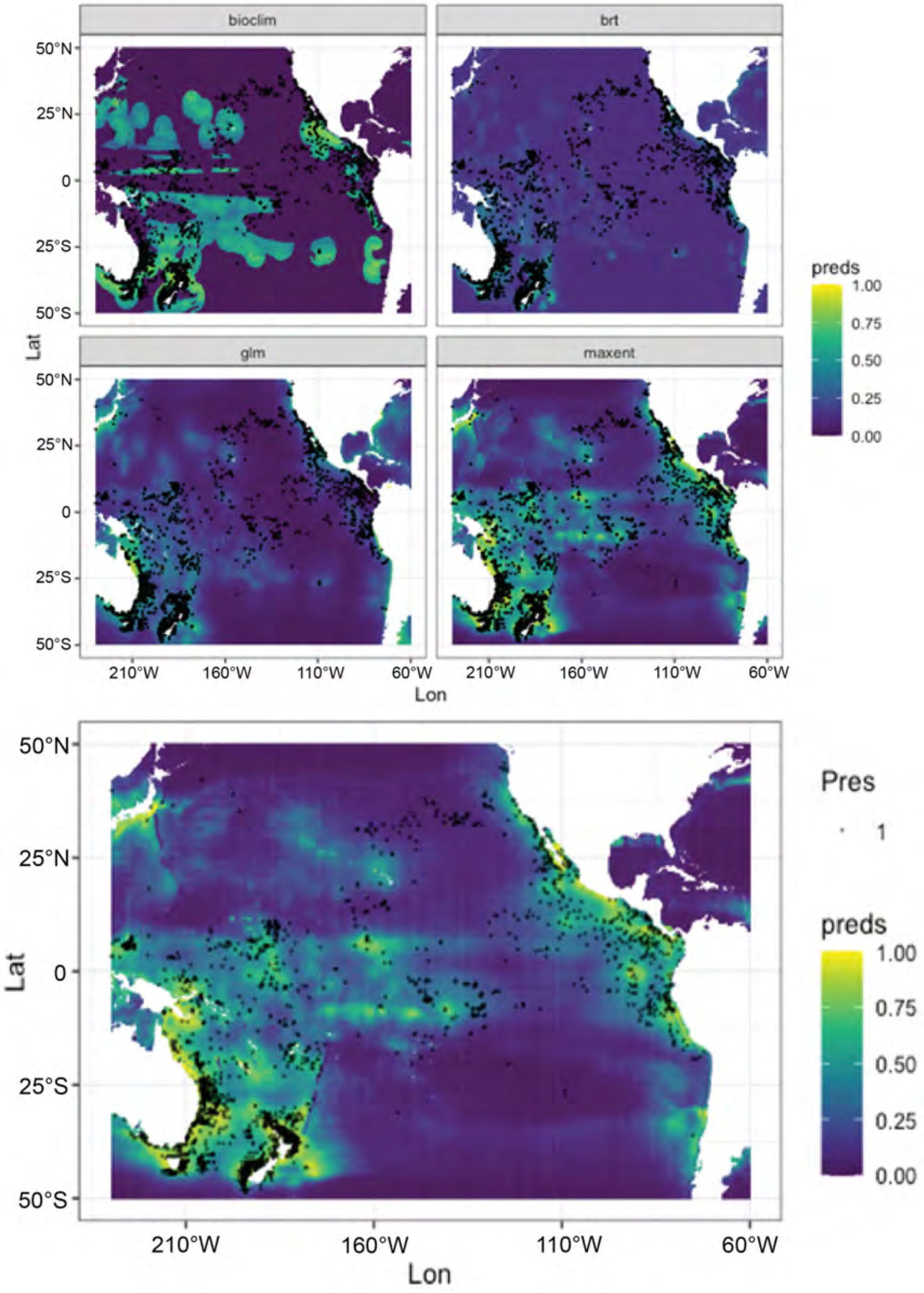


FIGURE 1. Predictions from four species distribution models (SDMs) Bioclim, Boosted Regression Trees (BRT), Generalized Linear Model (GLM) and MaxEnt (top 4 panels) and the final ensemble model (lower panel) using the common thresher (*Alopias vulpinus*) as an example of one species assessed in EASI-Fish. Locations of presence points (Pres) and probability of occurrence (preds) are shown.

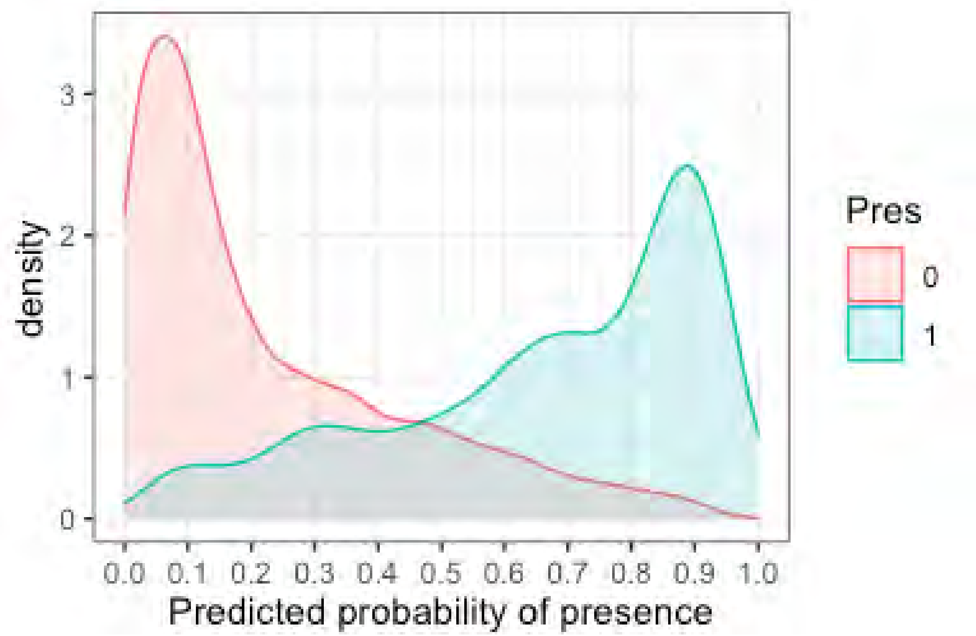


FIGURE 2. Overlayed distributions of the predicted probability of presence for each grid cell using on the ensemble model for presence (Pres = 1) and pseudoabsence (Pres = 0) records using a hypothetical species as an example. The probability of occurrence threshold value (ψ) was calculated at the point of intersection of the two distributions, in this case 0.47.

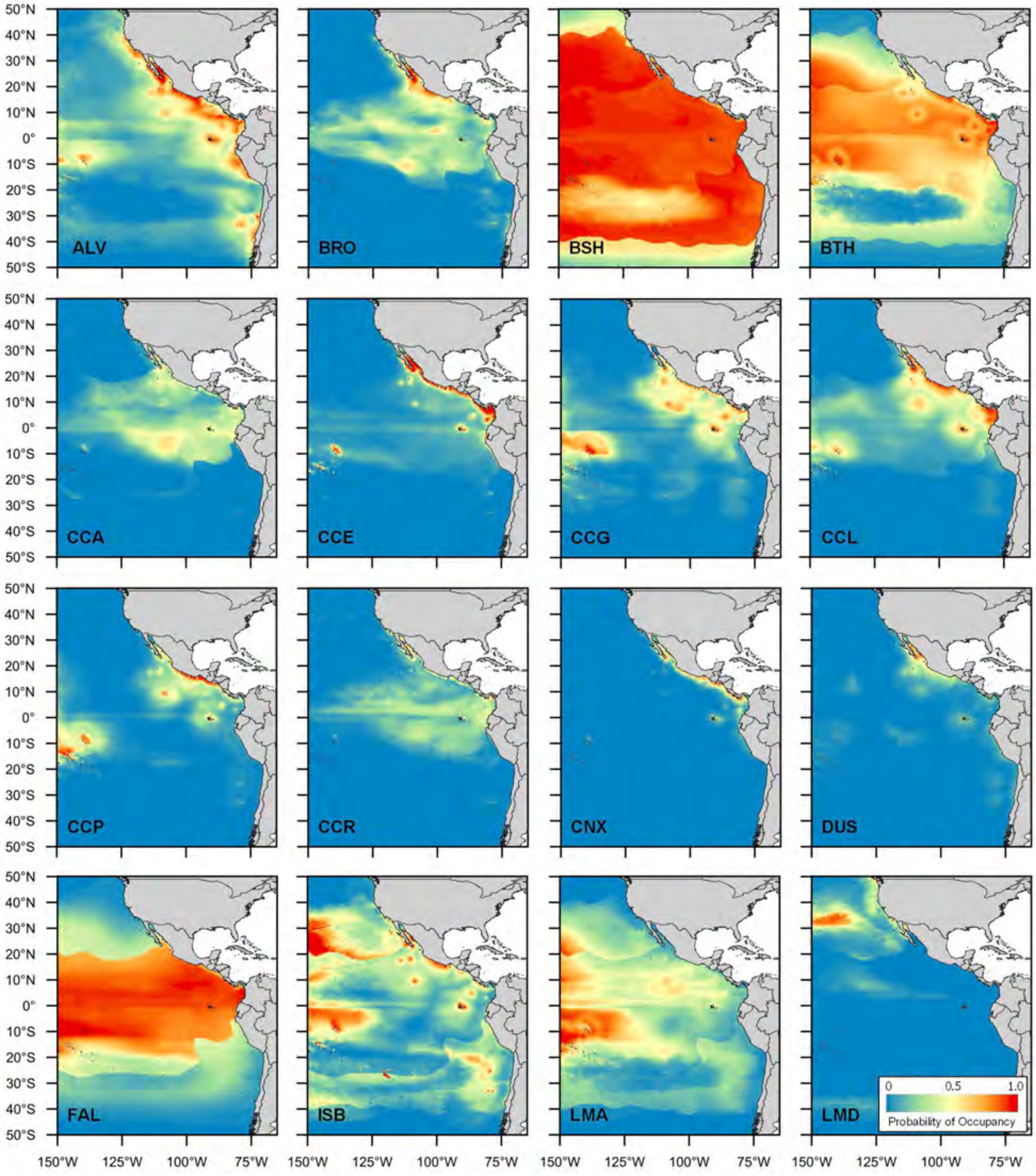


FIGURE 3. Maps showing the predicted distributions of 32 shark species (see Table 3 for species codes) caught in eastern Pacific Ocean pelagic fisheries modelled using presence-only data in an ensemble of species distribution models (Bioclim, Boosted Regression Trees, Generalized Linear Model, and MaxEnt). Colored gradient bar in legend shows probability of occupancy (ψ) of each species in 0.5° x 0.5° cells.

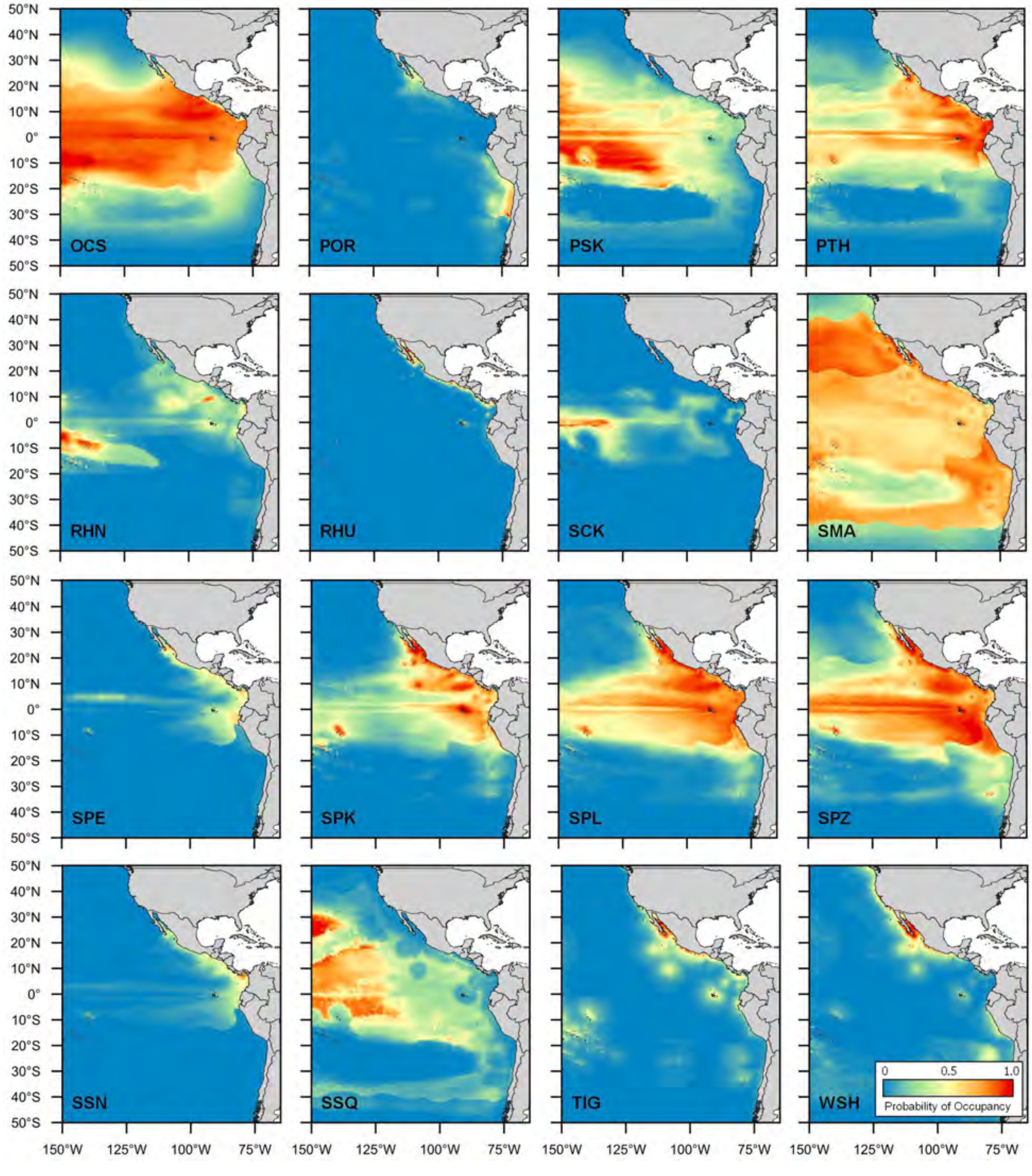


FIGURE 3. continued

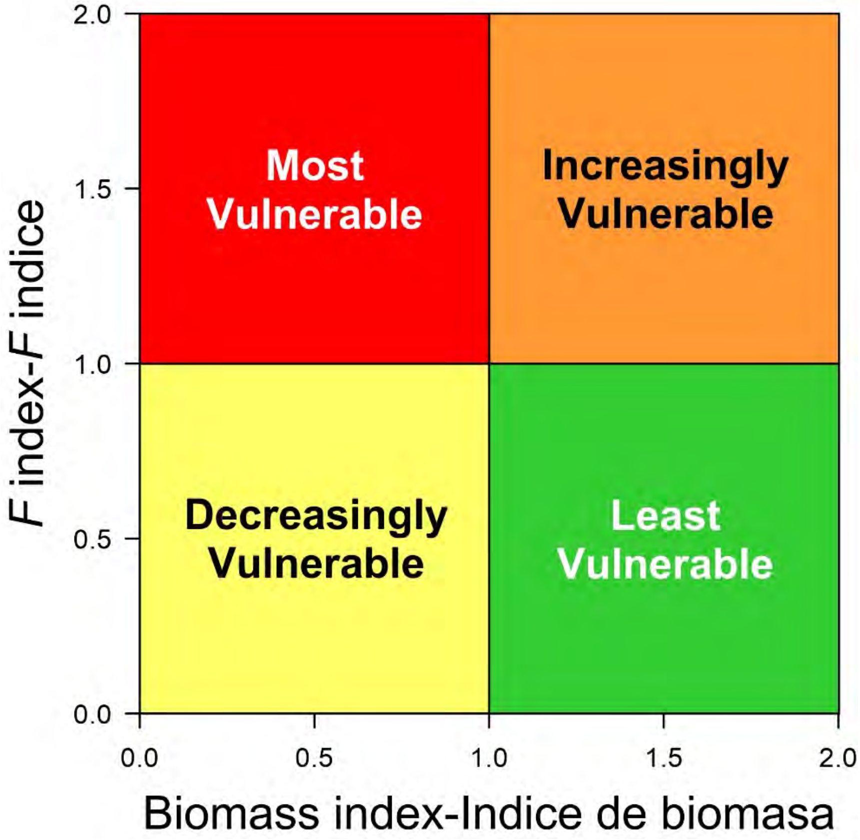


FIGURE 4. Phase plot illustrating how vulnerability status was defined for the shark species assessed using $F_{40\%}$ and $SBR_{40\%}$ from the EASI-Fish model as a reference point on the x and y axis, respectively. Vulnerability was defined by its position within one of four quadrants in the phase plot as: "Least vulnerable" (green, $\tilde{F}_{2019}/F_{40\%}$ <1 and $SBR_{2019}/SBR_{40\%}$ >1), "Increasingly vulnerable" (orange, $\tilde{F}_{2019}/F_{40\%}$ >1 and $SBR_{2019}/SBR_{40\%}$ >1), "Most vulnerable" (red, $\tilde{F}_{2019}/F_{40\%}$ >1 and $SBR_{2019}/SBR_{40\%}$ <1), and "Decreasingly vulnerable" (yellow, $\tilde{F}_{2019}/F_{40\%}$ <1 and $SBR_{2019}/SBR_{40\%}$ <1). Maximum axis limits of 2.0 are for illustrative purposes only.

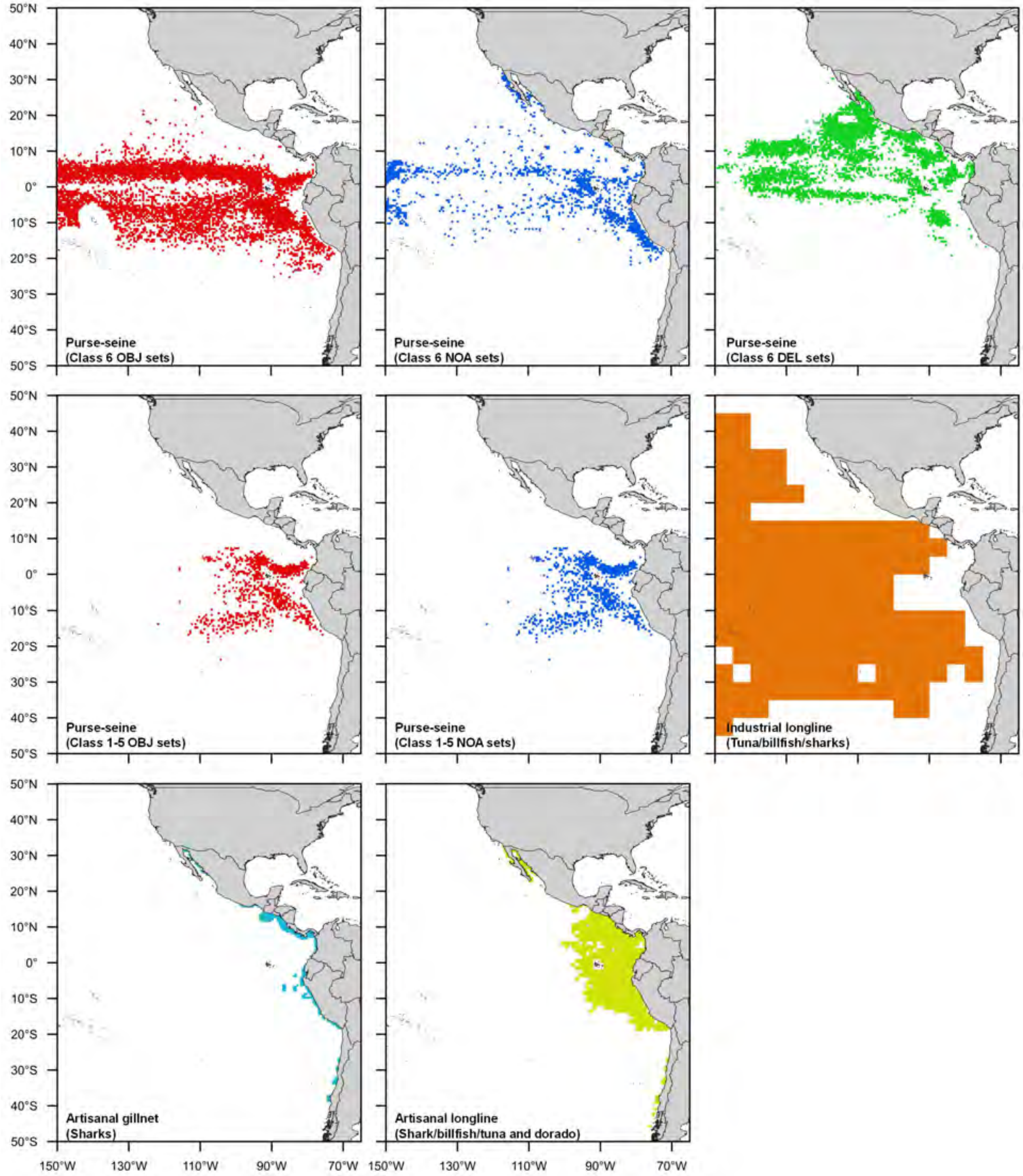


FIGURE 5. Maps showing the distribution of fishing effort (at 0.5° x 0.5° resolution; 5° x 5° and 1° x 1° for the industrial longline fishery) by eight fisheries in the eastern Pacific Ocean in 2019. Set types for the purse-seine fisheries are: i) sets associated with floating objects (OBJ), ii) sets on unassociated schools of tuna (NOA), and iii) sets associated with dolphins (DEL).

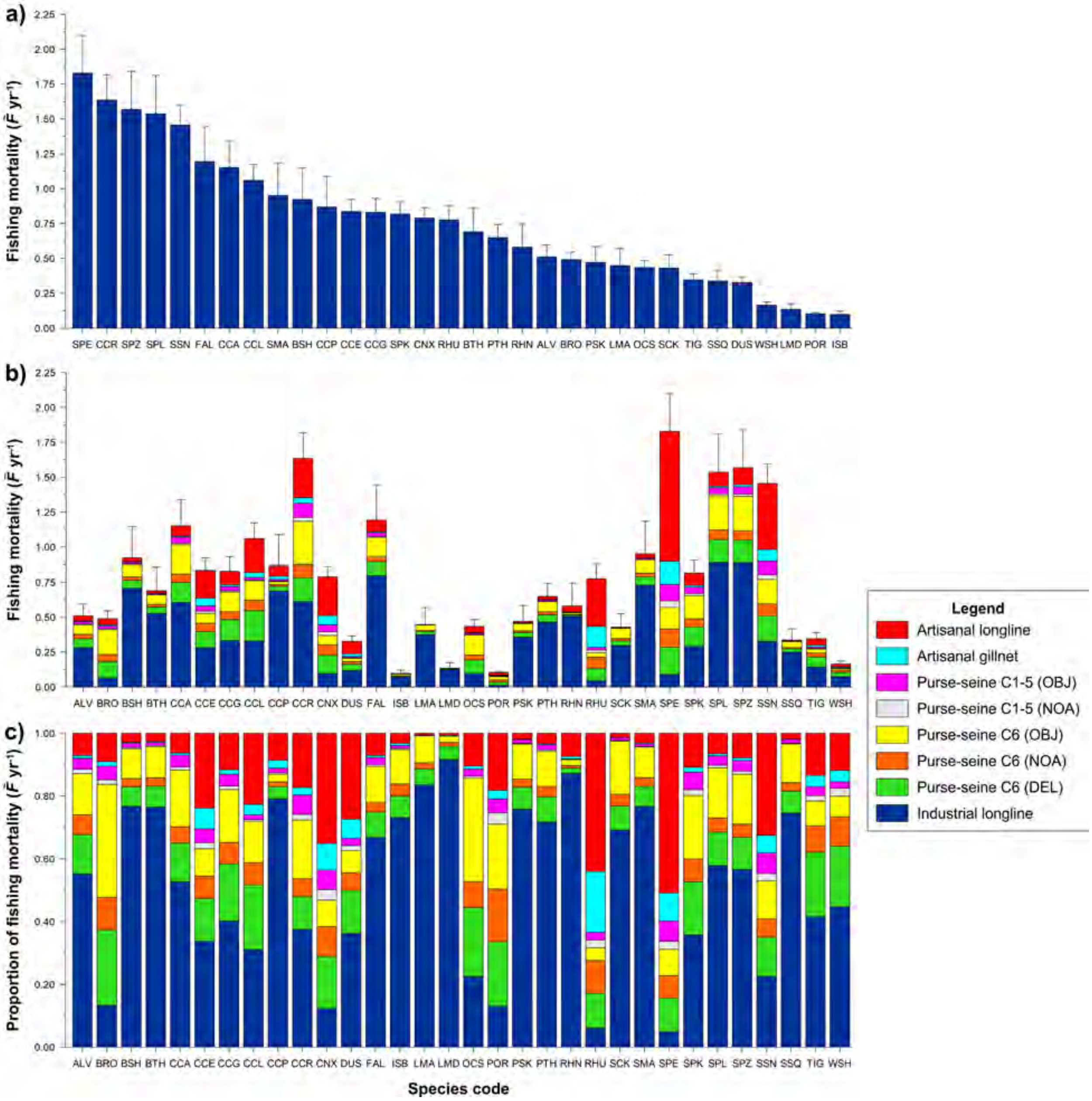


FIGURE 6. Mean (± 1 standard deviation) value of the estimated fishing mortality proxy in 2019 ($\tilde{F}_{2019}$) for each of the 32 shark species (see Table 2 for definitions of 3-alpha abbreviations) caught by pelagic fisheries in the eastern Pacific Ocean as estimated by EASI-Fish represented as: a) all gears combined, with species listed most vulnerable to least vulnerable (top panel), b) the contribution to $\tilde{F}_{2019}$ by fishing gear, and c) the proportional contribution to $\tilde{F}_{2019}$ by fishing gear.

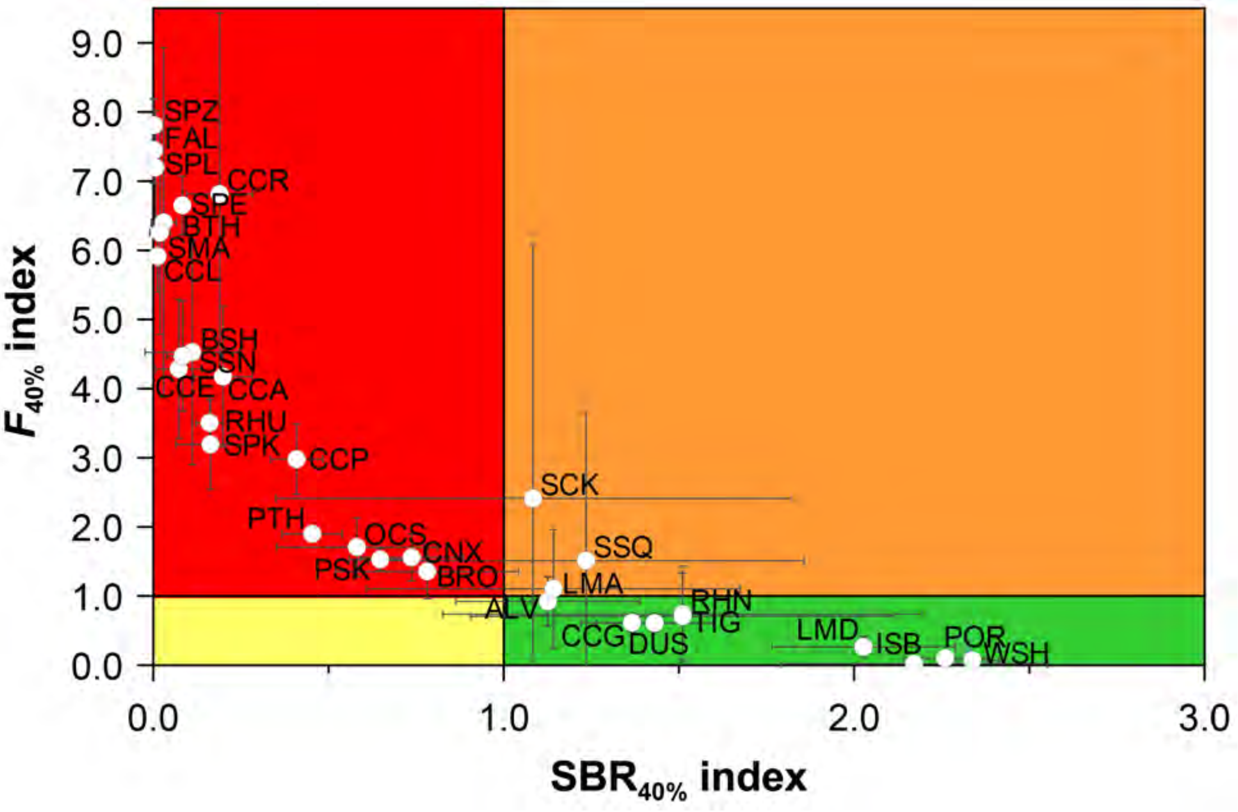
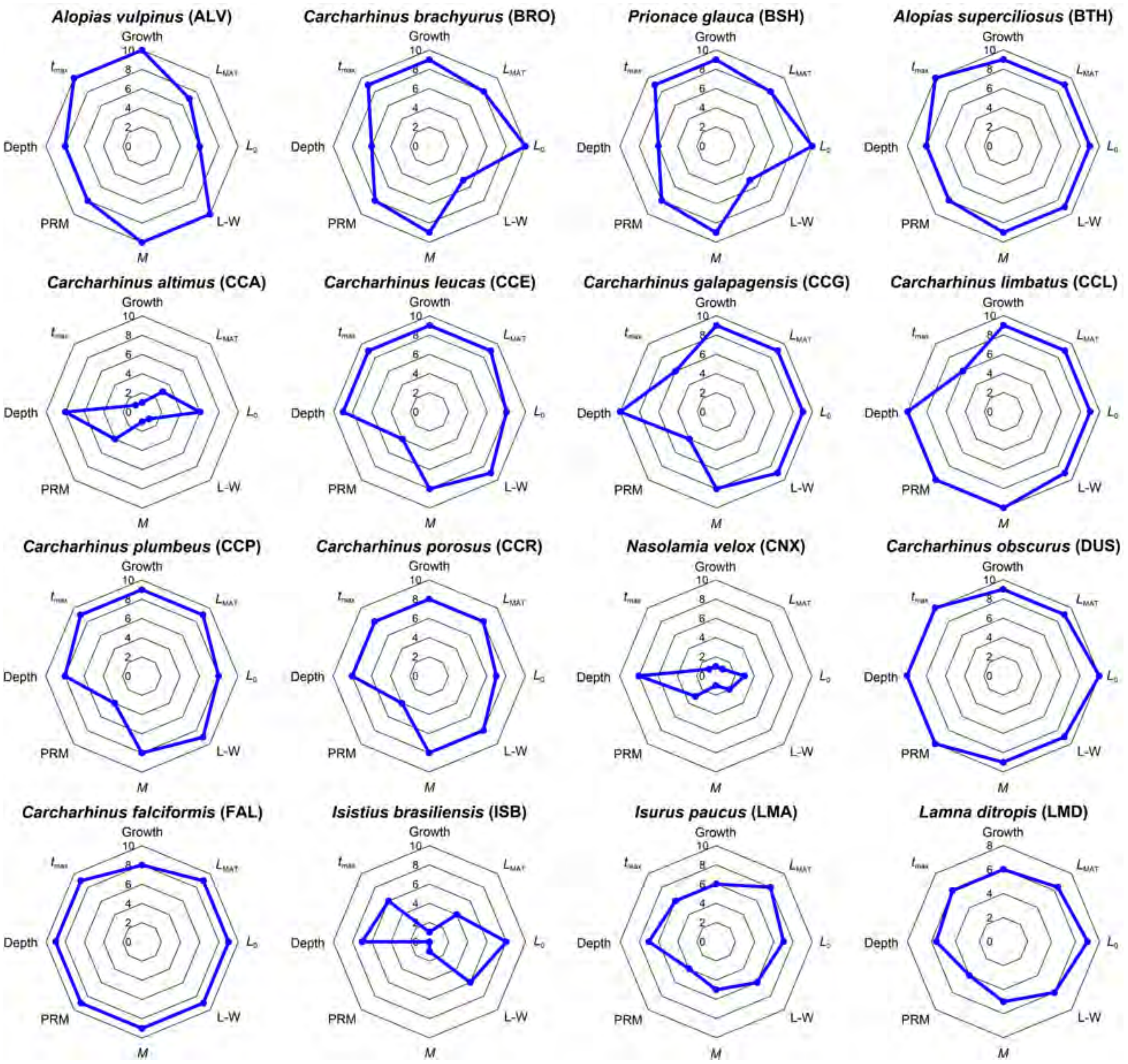


FIGURE 7. Vulnerability phase plot showing the vulnerability status of 32 shark species caught in eastern Pacific Ocean pelagic fisheries assessed by EASI-Fish represented by mean (± standard deviation) estimates the biological reference points $\tilde{F}_{2019}/F_{40\%}$ and $SBR_{2019}/SBR_{40\%}$. Labels adjacent to symbols denote species codes shown Table 6. Vulnerability status values for each species are provided in Table 6**.**


Alopias vulpinus (ALV)

Carcharhinus brachyurus (BRO)

Prionace glauca (BSH)

Alopias superciliosus (BTH)

Carcharhinus altimus (CCA)

Carcharhinus leucas (CCE)

Carcharhinus galapagensis (CCG)

Carcharhinus limbatus (CCL)

Carcharhinus plumbeus (CCP)

Carcharhinus porosus (CCR)

Nasolamia velox (CNX)

Carcharhinus obscurus (DUS)

Carcharhinus falciformis (FAL)

Isistius brasiliensis (ISB)

Isurus paucus (LMA)

Lamna ditropis (LMD)

FIGURE 8. Radar plots showing the relative quality of input values for key biological and ecological parameters used in EASI-Fish models of 32 shark species caught in EPO pelagic fisheries. The parameters are: maximum observed age (t_{max}), von Bertalanffy growth parameters L_∞, K, t_0, (Growth), length-at-maturity (L_{MAT}), length at birth (L_0), length-weight relationship (L-W), instantaneous natural mortality rate (M), post-release mortality rate (PRM), and depth range (Depth). Scale ranges from 0 (data absent for the species and its closely related species) to 10 (high quality species-specific data derived from the EPO).

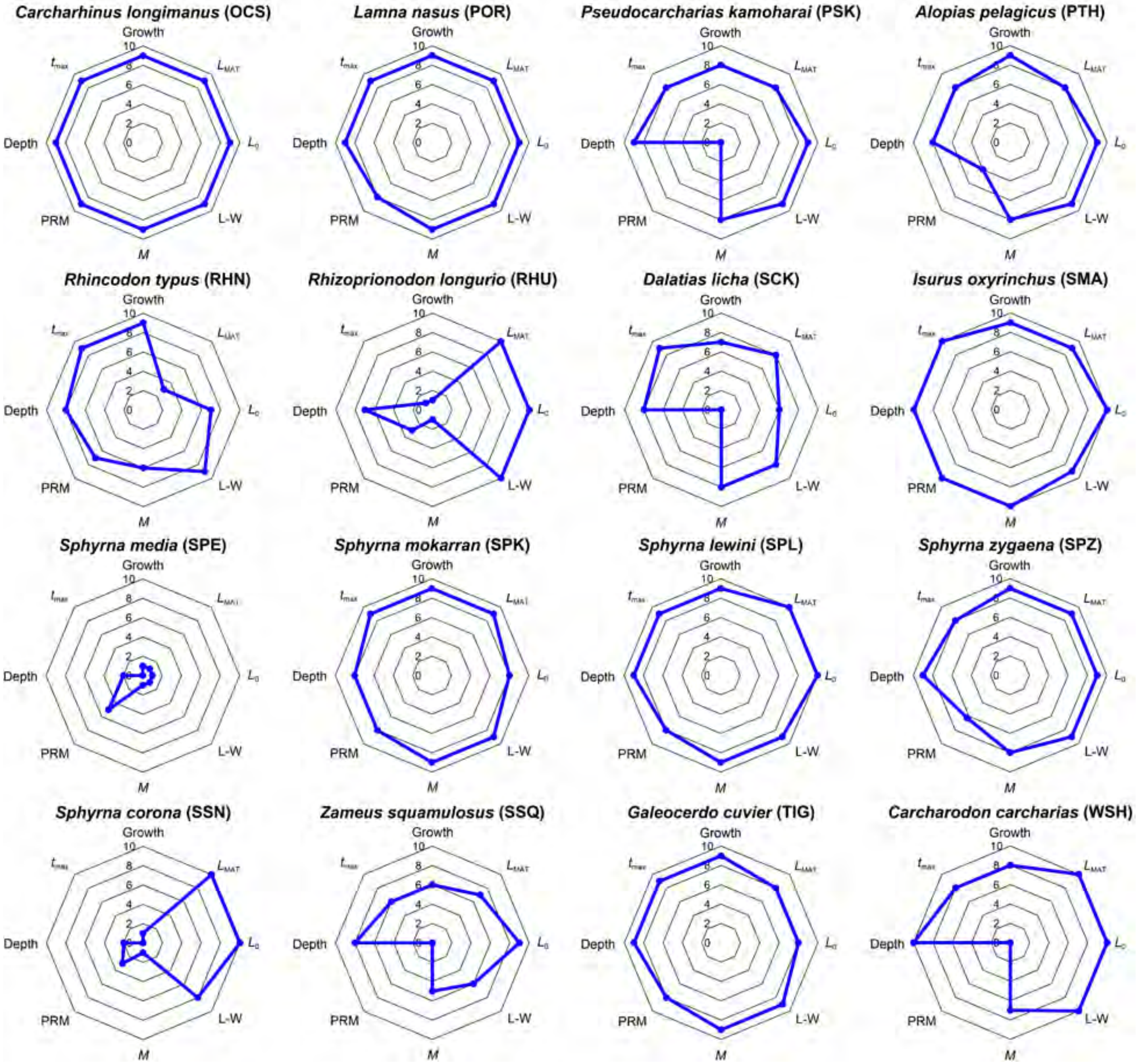


FIGURE 8. continued

TABLE 1. Data sources and period of coverage of fishing effort data used to define the spatial distribution of effort by each fishery in the EPO. Data sources with an asterisk (*) contained fishing effort distribution maps that were manually geo-referenced and the locations of each fishing event attributed to an appropriate grid cell to indicate presence of fishing.

Fishery	Country	Year	Data resolution	Comments and data source
Industrial fisheries				
Longline	IATTC Convention Area	2019	Monthly aggregates of number of hooks deployed at 5°x5° resolution (reports by CPCs); positional set data upscaled to 0.5°x0.5° resolution (observer data).	Unpublished data from logbooks and national observer programs submitted to the IATTC.
	Mexico (Pacific Ocean and Gulf of California)	2006–2009; 2006–2013; 2009–2012; 2018	Positional set data upscaled to 0.5°x0.5° resolution.	Castillo-Geniz et al. (2016)*; Castillo-Geniz et al. (2017)*; Carreón-Zapiain et al. (2018)*; Pacific Large Pelagics Program, INAPESCA*.
	Mexico (Central Pacific coast)	2003–2011	Positional set data upscaled to 0.5°x0.5° resolution.	Hernández and Valdez Flores (2016)*
Purse-seine (Class 6 - all set types)	IATTC Convention Area	2019	Positional set data upscaled to 0.5°x0.5° resolution.	Unpublished data collected by the AIDCP and National observer programs and held by the IATTC.
Purse-seine (Class 1–5 - all set types)	IATTC Convention Area	2019	Positional set data upscaled to 0.5°x0.5° resolution.	Unpublished data from logbooks, national observer programs and the TUNACONS observer program submitted to the IATTC .
Artisanal fisheries				
Surface-set gillnet	Chile (Northern and Central)	2016	Positional set data upscaled to 0.5°x0.5° resolution.	Martínez et al. (2017)*
	Guatemala, El Salvador, Nicaragua, Costa Rica, Panama	2018	Positions of access and unloading points allocated to adjacent 0.5°x0.5° grid cells	Oliveros-Ramos et al. (2019)
	Mexico (Northwestern Gulf of California)	1998–1999	Positions of fishing camps allocated to adjacent 0.5°x0.5° grid cells	Smith et al. (2009)*
	Mexico (Southwestern Gulf of California)	1998–1999	Positions of fishing camps allocated to adjacent 0.5°x0.5° grid cells	Bizzarro et al. (2009a)*
	Mexico (Northeastern Gulf of California)	1998–1999	Positions of fishing camps allocated to adjacent 0.5°x0.5° grid cells	Bizzarro et al. (2009b)*
	Mexico, Panama	2017–2018	Positions of fishing ports allocated to adjacent 0.5°x0.5° grid cells	Ortíz-Álvarez et al. (2020)
	Nicaragua, Costa Rica, Colombia	2016–2017	Positions of fishing ports allocated to adjacent 0.5°x0.5° grid cells	Ortíz-Álvarez et al. (2020)
	Peru and Chile	2005–2007;	Positional set data upscaled to 0.5°x0.5° resolution.	Alfaro-Shigueto et al. (2011)*
	Peru	2007	Positional set data upscaled to 0.5°x0.5° resolution.	Ayala et al. (2008)*
Surface-set longline	Chile (Northern and Central)	2001–2005; 2016	Positional set data upscaled to 0.5°x0.5° resolution.	Donoso and Dutton (2010); Martínez et al. (2017)*
	Chile (Southern)	2002	Positional set data upscaled to 0.5°x0.5° resolution.	Moreno et al. (2006)*
	Chile and Peru	2005–2010	Annual aggregates of number of sets at 0.5°x0.5° resolution.	Doherty et al. (2014)*
	Ecuador	2008–2012	Positional set data upscaled to 0.5°x0.5° resolution.	Martínez-Ortiz et al. (2015)*
	Ecuador, Panama, Costa Rica	2004–2010	Positional set data upscaled to 0.5°x0.5° resolution.	Unpublished IATTC observer data.
	Guatemala, El Salvador, Nicaragua, Costa Rica, Panama	2018	Positions of access and unloading points allocated to adjacent 0.5°x0.5° grid cells	Oliveros-Ramos et al. (2019)
	Mexico (Western Sea of Cortez)	1998–1999	Positions of fishing camps allocated to adjacent 0.5°x0.5° grid cells	Bizzarro et al. (2009a)*
	Mexico (Northeastern Gulf of California)	1998–1999	Positions of fishing camps allocated to adjacent 0.5°x0.5° grid cells	Bizzarro et al. (2009b)*
	Mexico, Panama	2017–2018	Positions of fishing ports allocated to adjacent 0.5°x0.5° grid cells	Ortíz-Álvarez et al. (2020)
	Nicaragua, Costa Rica, Colombia	2016–2017	Positions of fishing ports allocated to adjacent 0.5°x0.5° grid cells	Ortíz-Álvarez et al. (2020)
	Peru	2004–2006; 2007	Positional set data upscaled to 0.5°x0.5° resolution.	Ayala et al. (2008)*; Alfaro-Shigueto et al. (2011)*

TABLE 2. Number of fishing events where either numbers or weight was recorded for each shark species in IATTC data sources for each of the eight pelagic fisheries in the EPO included in the shark vulnerability assessment. Species represented by fewer than 20 fishing records were not included in the EASI-Fish assessment (denoted by broken horizontal line), with the exception of white shark (*Carcharodon carcharias*), which is listed by the IUCN Red List of Threatened Species as “Vulnerable”. The fishery labelled “Artisanal gillnet/longline” represented combined catches for artisanal and longline data collected in the IATTC’s Central American Shark Monitoring Program. Abbreviations are purse seine (PS), Class 6 (C6), Class 1-5 (C1-5), dolphin sets (DEL), non-associated sets (NOA) and sets on floating objects (OBJ).

Code	**Species**	**Common name**	**Industrial longline**	**PS-C6 (DEL)**	**PS-C6 (NOA)**	**PS-C6 (OBJ)**	**PS-C1-5 (NOA)**	**PS-C1-5 (OBJ)**	**Artisanal gillnet/ longline**	**Artisanal longline**	**Total**
BSH	*Prionace glauca*	Blue shark	168621	198	534	340	3	46	4	6228	175974
FAL	*Carcharhinus falciformis*	Silky shark	13440	5761	2722	55272	4	5	484	5335	83023
SMA	*Isurus oxyrinchus*	Shortfin mako shark	18492	48	445	614	6	7		1973	21585
PSK	*Pseudocarcharias kamoharai*	Crocodile shark	17760						2	26	17788
OCS	*Carcharhinus longimanus*	Oceanic whitetip shark	4223	616	324	9977	2	54		49	15245
BTH	*Alopias superciliosus*	Bigeye thresher	8111	621	710	213	8	1	29	241	9934
PTH	*Alopias pelagicus*	Pelagic thresher	6075	515	506	221	11	8	94	2319	9749
SPL	*Sphyrna lewini*	Scalloped hammerhead shark	583	331	476	1851	33	55	1009	762	5100
SPZ	*Sphyrna zygaena*	Smooth hammerhead shark	2340	194	338	1971	15	51	2	76	4987
SSQ	*Zameus squamulosus*	Velvet dogfish	3038								3038
ALV	*Alopias vulpinus*	Common thresher	290	155	216	59	4		99	53	876
CCL	*Carcharhinus limbatus*	Blacktip shark	285	78	24	35	1	1	97	338	859
LMA	*Isurus paucus*	Longfin mako shark	671								671
SPK	*Sphyrna mokarran*	Great hammerhead	72	35	42	213	2	3		68	435
CCG	*Carcharhinus galapagensis*	Galapagos shark	203		5	17			1		226
BRO	*Carcharhinus brachyurus*	Copper shark	8	22	24	114					168
CNX	*Nasolamia velox*	Whitenose shark	43	2	1			5	18	92	161
RHU	*Rhizoprionodon longurio*	Pacific sharpnose shark		1	3				140	5	149
CCE	*Carcharhinus leucas*	Bull shark	2	14	21	17	2		25	39	120
TIG	*Galeocerdo cuvier*	Tiger shark	56		5	1			18	24	104
POR	*Lamna nasus*	Porbeagle	88								88
DUS	*Carcharhinus obscurus*	Dusky shark	45	2	15	10					72
ISB	*Isistius brasiliensis*	Cookie cutter shark	66								66
RHN	*Rhincodon typus*	Whale shark	1		30	29		2			62
SCK	*Dalatias licha*	Kitefin shark	60								60
LMD	*Lamna ditropis*	Salmon shark	43								43
CCR	*Carcharhinus porosus*	Smalltail shark		3		30			5		38
CCP	*Carcharhinus plumbeus*	Sandbar shark		7	18	7					32
CCA	*Carcharhinus altimus*	Bignose shark		3		24					27

Code	Species	Common name	Industrial longline	PS-C6 (DEL)	PS-C6 (NOA)	PS-C6 (OBJ)	PS-C1-5 (NOA)	PS-C1-5 (OBJ)	Artisanal gillnet/ longline	Artisanal longline	Total
SSN	*Sphyrna corona*	Scalloped bonnethead	2	2	5	5			4	4	22
SPE	*Sphyrna media*	Scoophead		1	4	13				2	20
MUU	*Mustelus lunulatus*	Sicklefin smooth-hound							7	12	19
GAG	*Galeorhinus galeus*	Tope shark	19								19
CXP	*Cynoponticus coniceps*	Longnose velvet dogfish	18								18
GNC	*Ginglymostoma cirratum*	Nurse shark							2	13	15
CTK	*Mustelus henlei*	Brown smooth-hound							1	14	15
ODH	*Odontaspis noronhai*	Bigeye sand tiger shark	9								9
WSH	*Carcharodon carcharias*	Great white shark	6		1						7
SUC	*Squatina californica*	Pacific angelshark	4								4
CCT	*Carcharias taurus*	Sand tiger shark	3								3
CCQ	*Carcharhinus sorrah*	Spottail shark	2								2
CTD	*Mustelus dorsalis*	Sharptooth smooth-hound							2		2
DGS	*Squalus acanthias*	Picked/Spiny dogfish	2								2
NGB	*Negaprion brevirostris*	Lemon shark		1	1						2
SPJ	*Sphyrna tiburo*	Bonnethead			1	1					2
ALS	*Carcharhinus albimarginatus*	Silvertip shark								1	1
BSK	*Cetorhinus maximus*	Basking shark			1						1
QYW	*Squalus suckleyi*	Spotted spiny dogfish	1								1
TRB	*Triaenodon obesus*	Whitetip reef shark							1		1

TABLE 31. Number of presence records derived from the Secretariat of the Pacific Community (SPC) (western and central Pacific Ocean), IATTC (eastern Pacific Ocean), and AquaMaps (entire Pacific Ocean) and minimum and maximum probability of occupancy (ψ) threshold values for each of the 32 shark species included in the vulnerability assessment in the EPO.

Code	Scientific name	SPC	IATTC	AquaMaps	Total records	ψ threshold values
ALV	*Alopias vulpinus*	1907	481	335	2723	0.05, 0.40
BRO	*Carcharhinus brachyurus*	0	176	409	585	0.10, 0.30
BSH	*Prionace glauca*	111649	6271	1223	119143	0.30, 0.50
BTH	*Alopias superciliosus*	17351	2866	75	20292	0.20, 0.40
CCA	*Carcharhinus altimus*	0	57	14	71	0.05, 0.20
CCE	*Carcharhinus leucas*	124	124	72	320	0.10, 0.30
CCG	*Carcharhinus galapagensis*	789	111	66	966	0.10, 0.40
CCL	*Carcharhinus limbatus*	1206	296	199	1701	0.15, 0.40
CCP	*Carcharhinus plumbeus*	386	38	67	491	0.15, 0.40
CCR	*Carcharhinus porosus*	0	79	0	79	0.03, 0.20
CNX	*Nasolamia velox*	4	88	0	92	0.02, 0.10
DUS	*Carcharhinus obscurus*	234	76	143	453	0.02, 0.07
FAL	*Carcharhinus falciformis*	110887	8809	126	119822	0.30, 0.50
ISB	*Isistius brasiliensis*	259	59	112	430	0.20, 0.50
LMA	*Isurus paucus*	3849	380	66	4295	0.20, 0.30
LMD	*Lamna ditropis*	221	53	252	526	0.05, 0.10
OCS	*Carcharhinus longimanus*	18593	5098	525	24216	0.20, 0.40
POR	*Lamna nasus*	5134	32	133	5299	0.05, 0.10
PSK	*Pseudocarcharias kamoharai*	6640	1432	44	8116	0.05, 0.25
PTH	*Alopias pelagicus*	3405	1635	46	5086	0.10, 0.40
RHN	*Rhincodon typus*	3731	201	130	4062	0.10, 0.20
RHU	*Rhizoprionodon longurio*	0	124	0	124	0.03, 0.20
SCK	*Dalatias licha*	0	18	0	18	0.02, 0.10
SMA	*Isurus oxyrinchus*	27243	3077	58768	89088	0.25, 0.40
SPE	*Sphyrna media*	0	55	0	55	0.03, 0.25
SPK	*Sphyrna mokarran*	525	367	107	999	0.10, 0.40
SPL	*Sphyrna lewini*	890	2017	352	3259	0.10, 0.50
SPZ	*Sphyrna zygaena*	739	1993	195	2927	0.20, 0.50
SSN	*Sphyrna corona*	0	50	0	50	0.03, 0.20
SSQ	*Zameus squamulosus*	3997	796	42	4835	0.15, 0.25
TIG	*Galeocerdo cuvier*	932	95	450	1477	0.05, 0.20
WSH	*Carcharodon carcharias*	79	79	594	752	0.07, 0.25

TABLE 4. Biological parameters for 32 shark species assessed using EASI-Fish including length type (fork length–FL, precaudal length–PCL, total length–TL), maximum recorded age (t_{max}), von Bertalanffy growth parameters (L_{∞}, K, t_0), length-weight relationship parameters a and b, length-at-maturity (L_{MAT}), and natural mortality (M). L_{MAT} values reflect either the length-at-50% maturity (L_{50}) or the length at first maturity (L_m). Values for M show the fixed value used in stock assessment (source shown), or the mean value derived from various mortality estimators ("M method") defined in Table S2. Values shown in parentheses are the minimum and maximum values uniform (^{U}) distribution priors used in 10,000 iterations of Monte Carlo simulations. Sources of biological parameters are shown in Table S5.

Species	**Length type**	**t_{max} (yrs)**	**L_{inf} (yr^{-1})**	**K (yr^{-1})**	**t_0 (yr^{-1})**	**L-W a L-W b**	**L_{MAT} (cm)**	**M (yr^{-1})**	**M method**
Alopias vulpinus	FL	22	251.9	0.129	-2.88	0.00001882 2.519	160.0 ^{L_m}	0.23 (0.19–0.29)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharhinus brachyurus	TL	31	308.0	0.150	-1.90	0.0104 2.900	222.2 $^{L_{50}}$	0.192 (0.14–0.23)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Prionace glauca	PCL	28.6	267.2	0.134	-1.13	0.00000538 3.102	156.6 $^{L_{50}}$	0.19 (0.15–0.23)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Alopias superciliosus	PCL	20	224.6	0.092	-4.21	0.0000687 2.769	178.0 $^{L_{50}}$	0.22 (0.14–0.32)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharhinus altimus	TL	21	303.2	0.100	-2.30	0.000001016 3.461	225.0 $^{L_{50}}$	0.22 (0.15–0.30)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharhinus leucas	TL	27	350.7	0.082	-2.49	0.00000427 3.070	257.0 $^{L_{50}}$	0.17 (0.12–0.24)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharhinus galapagensis	TL	15	230.0	0.541	-0.78	0.0000057 3.028	215.0 ^{L_m}	0.50 (0.29–0.81)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharhinus limbatus	TL	24	263.6	0.142	-2.40	0.00000437 3.061	200.2 $^{L_{50}}$	0.22 (0.18–0.27)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharhinus plumbeus	TL	23	223.0	0.100	-4.50	0.00000189 3.230	175.0 $^{L_{50}}$	0.21 (0.15–0.28)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharhinus porosus	TL	12	136.3	0.076	-3.28	0.013 2.759	70.0 ^{L_m}	0.33 (0.11–0.50)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Nasolamia velox	TL	15	153.3	0.190	-0.57	0.0024 3.142	90.0 ^{L_m}	0.33 (0.29–0.41)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharhinus obscurus	TL	29	456.0	0.046	-4.23	0.00000203 3.216	281.0 $^{L_{50}}$	0.15 (0.07-0.22)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharhinus falciformis	TL	16	332.0	0.084	-2.76	0.0000273 2.860	215.0 $^{L_{50}}$	0.18	Clarke et al. (2018)
Isistius brasiliensis	TL	7	43.80	0.410	-0.90	0.00000372 3.120	39.0 ^{L_m}	0.68 (0.61-0.82)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Isurus paucus	TL	31	384.6	0.090	-5.50	0.0000167 2.847	230.0 $^{L_{50}}$	0.16 (0.14-0.21)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Lamna ditropis	PCL	20	207.4	0.170	-2.30	0.000044 2.875	164.7 $^{L_{50}}$	0.26 (0.22-0.32)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharhinus longimanus	TL	18	309.4	0.085	-2.50	0.0000166 2.891	193.4 $^{L_{50}}$	0.18 (0.10-0.26)^{U}	Tremblay-Boyer et al. (2019)

Species	**Length type**	**t_{max} (yrs)**	**L_{inf} (yr^{-1})**	**K (yr^{-1})**	**t_0 (yr^{-1})**	**L-W *a* L-W *b***	**L_{MAT} (cm)**	***M* (yr^{-1})**	***M* method**
Lamna nasus	FL	35	210.9	0.086	-3.50	0.00000891 3.128	175.0 ^{L_m}	0.147 (0.12-0.19)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Pseudocarcharias kamoharai	FL	13	120.7	0.186	-2.20	0.00009 2.312	84.9 $^{L_{50}}$	0.36 (0.28-0.47)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Alopias pelagicus	TL	24	328.1	0.121	-4.95	0.000159 2.613	285.3 $^{L_{50}}$	0.21 (0.18-0.27)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Rhincodon typus	TL	42	1560.7	0.042	-0.78	0.0000121 2.862	810.0 $^{L_{50}}$	0.108 (0.06-0.16)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Rhizoprionodon longurio	TL	15	113.0	0.190	-0.62	0.00000035 3.539	92.9 $^{L_{50}}$	0.33 (0.29-0.41)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Dalatias licha	TL	11	122.0	0.205	-1.98	0.00000003 3.786	132.57 $^{L_{50}}$	0.41 (0.31-0.55)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Isurus oxyrinchus	PCL	31	308.3	0.090	-2.5.0	0.0000167 2.847	256 $^{L_{50}}$	0.13 (0.13-0.21)^{U}	ISC (2018)
Sphyrna media	TL	14.5	153.3	0.200	-0.54	0.00000015 3.750	76.7 ^{L_m}	0.34 (0.30-0.42)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Sphyrna mokarran	TL	39	402.7	0.079	-2.00	0.00000123 3.240	227.9 $^{L_{50}}$	0.13 (0.11-0.17)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Sphyrna lewini	TL	21	289.6	0.161	-1.00	0.00000399 3.030	219.4 $^{L_{50}}$	0.23 (0.21-0.30)^{U}	López-Martínez et al. (2020)
Sphyrna zygaena	TL	25	375.2	0.111	-1.31	0.0000024 3.150	200.0 $^{L_{50}}$	0.15 (0.15-0.26)^{U}	Tsai et al. (2018)
Sphyrna corona	TL	9	94.7	0.320	-1.00	0.00000015 3.750	56.9 $^{L_{50}}$	0.54 (0.48-0.66)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Zameus squamulosus	TL	54	96.1	0.072	-6.13	0.002 3.234	71.5 ^{L_m}	0.11 (0.08-0.13)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Galeocerdo cuvier	TL	33	441.1	0.060	-2.50	0.000000142 3.669	330.0 ^{L_m}	0.14 (0.09-0.20)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J
Carcharodon carcharias	FL	44	466.8	0.100	-3.70	0.00000758 3.080	417.0 ^{L_m}	0.14 (0.10-0.15)^{U}	H_{tmax}, H_{nls}, P_{nls}, P_{LKT}, J

TABLE 5. Natural mortality (*M*) estimators used in the present study. A flow diagram showing the hierarchical selection of estimators depending on data available is shown in Fig. S4.

Estimator	Equation	Citation
$\text{Hoenig}_{\text{tmax}}$	$M = \frac{4.3}{t_{max}}$	Hoenig (1983)
$\text{Hoenig}_{\text{nls}}$	$M = 4.899 t_{max}^{-0.916}$	Then *et al.* (2015)
Jensen (*J*)	$M = 1.60\ K$	Jensen (1996)
$\text{Pauly}_{\text{nls}}$	$M = 4.118 K^{0.73} L_{\infty}^{-0.33}$	Then *et al.* (2015)
$\text{Pauly}_{\text{LKT}}$	$\log M = -0.0066 - 0.279 \ln L_{\infty} + 0.6543 \ln K + 0.4634 \ln T$	Pauly (1980)
Pauly_{KT}	$M = K e^{-0.22 + 0.3 \ln T}$	Froese and Pauly (2017)
Pauly_{LT}	$M = 10^{0.566 - 0.718 \ln L_{\infty}} + 0.02T$	Froese and Pauly (2017)

M = instantaneous natural mortality rate (yr^{-1})
t_{max} = maximum observed age of animals in the stock.
L_{∞} = the average length of an animal if it lived to an infinite age, and known as the asymptotic length of an animal in the von Bertalanffy growth function.
K= the curvature parameter of the von Bertalanffy growth function (yr^{-1}).
T= mean water temperature (°C) at the location and depth range inhabited by the species.

TABLE 6. Estimated mean (+/- standard deviation) values for proxy fishing mortality ($\tilde{F}_{2019}$), spawning stock biomass-per-recruit (SBR_{2019}), and biological reference points ($F_{40\%}$ and $\mathrm{SBR}_{40\%}$) for 32 shark species in 2019 caught in pelagic fisheries of the eastern Pacific Ocean. Red, orange and green colors indicate scenarios where the stock was classified as “most vulnerable”, “increasingly vulnerable” or “least vulnerable”, respectively. Specific model parameter values used in each scenario are shown in Table 2.

Code	**Species**	$F_{2019}/F_{40\%}$	$F_{2019}/F_{40\%}$ **Std Dev**	$\mathrm{SBR}_{2019}/\mathrm{SBR}_{40\%}$	$\mathrm{SBR}_{2019}/\mathrm{SBR}_{40\%}$ **Std Dev**
ALV	*Alopias vulpinus*	0.924	0.355	1.126	0.262
BRO	*Carcharhinus brachyurus*	1.356	0.396	0.782	0.262
BSH	*Prionace glauca*	4.526	1.623	0.111	0.134
BTH	*Alopias superciliosus*	6.404	2.526	0.030	0.036
CCA	*Carcharhinus altimus*	4.173	1.014	0.199	0.084
CCE	*Carcharhinus leucas*	4.284	1.006	0.073	0.066
CCG	*Carcharhinus galapagensis*	0.615	0.131	1.366	0.146
CCL	*Carcharhinus limbatus*	5.911	0.520	0.012	0.007
CCP	*Carcharhinus plumbeus*	2.980	0.508	0.409	0.075
CCR	*Carcharhinus porosus*	6.814	2.616	0.189	0.094
CNX	*Nasolamia velox*	1.559	0.339	0.737	0.147
DUS	*Carcharhinus obscurus*	0.610	0.133	1.431	0.167
FAL	*Carcharhinus falciformis*	7.447	0.477	0.002	0.001
ISB	*Isistius brasiliensis*	0.021	0.020	2.171	0.381
LMA	*Isurus paucus*	1.104	0.858	1.142	0.533
LMD	*Lamna ditropis*	0.264	0.154	2.026	0.262
OCS	*Carcharhinus longimanus*	1.706	0.427	0.581	0.229
POR	*Lamna nasus*	0.102	0.051	2.260	0.121
PSK	*Pseudocarcharias kamoharai*	1.529	0.159	0.648	0.089
PTH	*Alopias pelagicus*	1.903	0.084	0.446	0.037
RHN	*Rhincodon typus*	0.738	0.694	1.510	0.684
RHU	*Rhizoprionodon longurio*	3.504	0.380	0.161	0.039
SCK	*Dalatias licha*	2.411	3.670	1.083	0.734
SMA	*Isurus oxyrinchus*	6.254	1.468	0.019	0.029
SPE	*Sphyrna media*	6.648	0.422	0.083	0.011
SPK	*Sphyrna mokarran*	3.192	0.649	0.163	0.099
SPL	*Sphyrna lewini*	7.196	0.821	0.006	0.003
SPZ	*Sphyrna zygaena*	7.808	0.382	0.002	0.001
SSN	*Sphyrna corona*	4.470	0.794	0.084	0.046
SSQ	*Zameus squamulosus*	1.512	2.147	1.235	0.622
TIG	*Galeocerdo cuvier*	0.708	0.624	1.511	0.606
WSH	*Carcharodon carcharias*	0.070	0.032	2.337	0.076

APPENDIX 1. Susceptibility parameter values (see Eq. 1) for the 32 species included in the EASI-Fish vulnerability assessment of sharks caught by EPO pelagic fisheries in 2019. All parameter values were fixed in the model except for *G* and P_{xj}, which were allowed to vary following a uniform distribution prior between the values shown in parentheses.

		Industrial longline						**Purse-seine - Class 6 (DEL)**						**Purse-seine - Class 6 (NOA)**					
Code	**Scientific name**	***Gx/G***	***Dx***	***Axj***	***Exj***	***Cxj***	***Pxj***	***Gx/G***	***Dx***	***Axj***	***Exj***	***Cxj***	***Pxj***	***Gx/G***	***Dx***	***Axj***	***Exj***	***Cxj***	***Pxj***
ALV	*Alopias vulpinus*	0.39-0.59	1	1	0.55-1	76-252	1	0.13-0.29	0.80	1	0.37-0.67	50-252	1	0.06-0.16	0.80	1	0.37-0.67	50-252	1
BRO	*Carcharhinus brachyurus*	0.66-0.71	1	1	0.83-1	189-280	1	0.28-0.29	0.80	1	0.56-1	74-308	1	0.12-0.14	0.80	1	0.56-1	74-308	1
BSH	*Prionace glauca*	0.59-0.68	1	1	0.63-1	34-267	1	0.10-0.13	0.80	1	0.42-1	35-267	1	0.04-0.06	0.80	1	0.42-1	35-267	1
BTH	*Alopias superciliosus*	0.68-0.79	1	1	0.55-1	69-225	1	0.14-0.20	0.80	1	0.37-0.67	69-225	1	0.06-0.08	0.80	1	0.37-0.67	69-225	1
CCA	*Carcharhinus altimus*	0.50-0.67	1	1	0.82-1	60-303	1	0.26-0.30	0.80	1	0.52-1	60-303	1	0.11-0.15	0.80	1	0.52-1	60-303	1
CCE	*Carcharhinus leucas*	0.16-0.48	1	1	1-1	56-351	1	0.25-0.25	0.80	1	0.98-1	100-294	1	0.13-0.15	0.80	1	0.98-1	100-294	1
CCG	*Carcharhinus galapagensis*	0.65-0.65	1	1	1-1	137-256	1	0.26-0.36	0.80	1	0.70-1	83-230	1	0.12-0.12	0.80	1	0.70-1	83-230	1
CCL	*Carcharhinus limbatus*	0.45-0.62	1	1	1-1	115-264	1	0.31-0.41	0.80	1	1-1	73-235	1	0.14-0.14	0.80	1	1-1	73-235	1
CCP	*Carcharhinus plumbeus*	0.64-0.73	1	1	1-1	81-223	1	0.25-0.28	0.80	1	0.71-1	117-146	1	0.11-0.11	0.80	1	0.71-1	117-146	1
CCR	*Carcharhinus porosus*	0.44-0.63	1	1	1-1	28-136	1	0.21-0.27	0.80	1	1-1	28-136	1	0.10-0.17	0.80	1	1-1	28-136	1
CNX	*Nasolamia velox*	0.11-0.16	1	1	1-1	53-153	1	0.22-0.24	0.80	1	1-1	53-153	1	0.13-0.14	0.80	1	1-1	53-153	1
DUS	*Carcharhinus obscurus*	0.19-0.42	1	1	1-1	136-240	1	0.18-0.37	0.80	1	1-1	101-137	1	0.09-0.15	0.80	1	1-1	101-137	1
FAL	*Carcharhinus falciformis*	0.74-0.79	1	1	1-1	48-158	1	0.21-0.25	0.80	1	1-1	48-271	0.32-0.93	0.08-0.10	0.80	1	1-1	48-271	0.32-0.93
ISB	*Isistius brasiliensis*	0.65-0.78	1	1	0.08-0.43	20-44	1	0.08-0.15	0.80	1	0.05-0.29	14-44	1	0.06-0.06	0.80	1	0.05-0.29	14-44	1
LMA	*Isurus paucus*	0.93-0.98	1	1	0.38-1	122-331	1	0.16-0.20	0.80	1	0.25-0.65	122-385	1	0.07-0.07	0.80	1	0.25-0.65	122-385	1
LMD	*Lamna ditropis*	0.46-0.48	1	1	0.30-0.75	100-207	1	0.02-0.05	0.80	1	0.20-0.50	67-207	1	0.01-0.01	0.80	1	0.20-0.50	67-207	1
OCS	*Carcharhinus longimanus*	0.74-0.79	1	1	0.95-1	64-293	0.15-0.20	0.17-0.23	0.80	1	0.63-1	64-283	0.85-1	0.07-0.09	0.80	1	0.63-1	64-283	0.85-1
POR	*Lamna nasus*	0.12-0.14	1	1	0.43-1	126-156	1	0.07-0.10	0.80	1	0.29-0.67	58-211	1	0.07-0.07	0.80	1	0.29-0.67	58-211	1
PSK	*Pseudocarcharias kamoharai*	0.72-0.88	1	1	0.51-0.51	40-121	1	0.15-0.20	0.80	1	0.34-0.34	40-121	1	0.06-0.07	0.80	1	0.34-0.34	40-121	1
PTH	*Alopias pelagicus*	0.71-0.75	1	1	1-1	155-328	1	0.17-0.30	0.80	1	0.67-0.8	155-328	1	0.07-0.12	0.80	1	0.67-0.80	155-328	1
RHN	*Rhincodon typus*	0.70-0.83	1	1	0.30-1	64-1561	1	0.24-0.26	0.80	1	0.20-1	64-1561	0.10-0.20	0.13-0.13	0.80	1	0.20-1	64-1561	0.10-0.20
RHU	*Rhizoprionodon longurio*	0.04-0.09	1	1	1-1	31-113	1	0.13-0.15	0.80	1	1-1	31-113	1	0.13-0.13	0.80	1	1-1	31-113	1
SCK	*Dalatias licha*	0.85-0.88	1	1	0.15-1	52-139	1	0.22-0.22	0.80	1	0.09-1	35-139	1	0.10-0.13	0.80	1	0.09-1	35-139	1
SMA	*Isurus oxyrinchus*	0.67-0.68	1	1	0.75-1	60-308	1	0.12-0.14	0.80	1	0.50-1	60-308	1	0.05-0.06	0.80	1	0.50-1	60-308	1
SPE	*Sphyrna media*	0.07-0.14	1	1	1-1	30-153	1	0.23-0.31	0.80	1	1-1	30-153	1	0.18-0.19	0.80	1	1-1	30-153	1
SPK	*Sphyrna mokarran*	0.56-0.69	1	1	1-1	142-283	1	0.23-0.32	0.80	1	0.67-1	80-330	1	0.10-0.15	0.80	1	0.67-1	80-330	1
SPL	*Sphyrna lewini*	0.65-0.73	1	1	1-1	47-290	1	0.20-0.31	0.80	1	0.73-1	47-290	1	0.09-0.14	0.80	1	0.73-1	47-290	1
SPZ	*Sphyrna zygaena*	0.68-0.73	1	1	1-1	55-340	1	0.20-0.29	0.80	1	1-1	55-375	1	0.09-0.13	0.80	1	1-1	55-375	1
SSN	*Sphyrna corona*	0.16-0.52	1	1	1-1	22-95	1	0.24-0.28	0.80	1	1-1	22-95	1	0.13-0.13	0.80	1	1-1	22-95	1
SSQ	*Zameus squamulosus*	0.74-0.89	1	1	0.15-1	30-96	1	0.16-0.19	0.80	1	0.10-0.67	25-96	1	0.06-0.07	0.80	1	0.10-0.67	25-96	1
TIG	*Galeocerdo cuvier*	0.23-0.39	1	1	0.33-1	80-242	1	0.18-0.35	0.80	1	0.22-1	80-441	1	0.09-0.14	0.80	1	0.22-1	80-441	1
WSH	*Carcharodon carcharias*	0.09-0.41	1	1	0.75-1	147-467	1	0.14-0.21	0.80	1	0.50-1	147-467	1	0.06-0.11	0.80	1	0.50-1	147-467	1

APPENDIX 1. continued

		Purse-seine - Class 6 (OBJ)						Purse-seine - Class 1-5 (NOA)						Purse-seine - Class 1-5 (OBJ)					
Code	**Scientific name**	***Gx/G***	***Dx***	***Axj***	***Exj***	***Cxj***	***Pxj***	***Gx/G***	***Dx***	***Axj***	***Exj***	***Cxj***	***Pxj***	***Gx/G***	***Dx***	***Axj***	***Exj***	***Cxj***	***Pxj***
ALV	*Alopias vulpinus*	0.19-0.24	0.80	1	0.37-0.67	50-252	1	0.01-0.06	0.80	1	0.22-0.40	50-252	1	0.05-0.15	0.80	1	0.22-0.40	50-252	1
BRO	*Carcharhinus brachyurus*	0.40-0.42	0.80	1	0.56-1	74-308	1	0.03-0.03	0.80	1	0.33-0.60	74-308	1	0.08-0.11	0.80	1	0.33-0.60	74-308	1
BSH	*Prionace glauca*	0.15-0.20	0.80	1	0.42-1	35-267	1	0.01-0.01	0.80	1	0.25-1	35-267	1	0.04-0.05	0.80	1	0.25-1	35-267	1
BTH	*Alopias superciliosus*	0.21-0.29	0.80	1	0.37-0.67	69-225	1	0.01-0.02	0.80	1	0.22-0.40	100-216	1	0.05-0.07	0.80	1	0.22-0.40	100-216	1
CCA	*Carcharhinus altimus*	0.36-0.43	0.80	1	0.52-1	60-303	1	0.02-0.05	0.80	1	0.28-0.95	60-303	1	0.10-0.21	0.80	1	0.28-0.95	60-303	1
CCE	*Carcharhinus leucas*	0.08-0.25	0.80	1	0.98-1	100-294	1	0.04-0.05	0.80	1	0.59-1	100-294	1	0.06-0.14	0.80	1	0.59-1	100-294	1
CCG	*Carcharhinus galapagensis*	0.25-0.32	0.80	1	0.70-1	83-230	1	0.03-0.03	0.80	1	0.42-1	83-230	1	0.08-0.1	0.80	1	0.42-1	83-230	1
CCL	*Carcharhinus limbatus*	0.17-0.31	0.80	1	1-1	73-235	1	0.04-0.06	0.80	1	0.86-1	168-212	1	0.11-0.13	0.80	1	0.86-1	168-212	1
CCP	*Carcharhinus plumbeus*	0.14-0.22	0.80	1	0.71-1	117-146	1	0.00-0.02	0.80	1	0.43-1	81-223	1	0.00-0.07	0.80	1	0.43-1	81-223	1
CCR	*Carcharhinus porosus*	0.34-0.45	0.80	1	1-1	28-136	1	0.02-0.06	0.80	1	1-1	28-136	1	0.10-0.20	0.80	1	1-1	28-136	1
CNX	*Nasolamia velox*	0.08-0.16	0.80	1	1-1	53-153	1	0.04-0.07	0.80	1	0.59-1	53-153	1	0.06-0.14	0.80	1	0.59-1	53-153	1
DUS	*Carcharhinus obscurus*	0.09-0.21	0.80	1	1-1	101-137	1	0.03-0.06	0.80	1	0.60-1	101-137	1	0.05-0.08	0.80	1	0.60-1	101-137	1
FAL	*Carcharhinus falciformis*	0.30-0.36	0.80	1	1-1	48-271	0.32-0.93	0.02-0.02	0.80	1	0.73-1	48-271	0.32-0.32	0.07-0.09	0.80	1	0.73-1	48-271	0.32-0.93
ISB	*Isistius brasiliensis*	0.16-0.19	0.80	1	0.05-0.29	14-44	1	0.01-0.01	0.80	1	0.03-0.17	14-44	1	0.01-0.04	0.80	1	0.03-0.17	14-44	1
LMA	*Isurus paucus*	0.29-0.31	0.80	1	0.25-0.65	122-385	1	0	0.80	1	0.14-0.37	122-385	1	0.01-0.03	0.80	1	0.14-0.37	122-385	1
LMD	*Lamna ditropis*	0.01-0.03	0.80	1	0.20-0.50	67-207	1	0	0.80	1	0.12-0.30	67-207	1	0-0	0.80	1	0.12-0.3	67-207	1
OCS	*Carcharhinus longimanus*	0.25-0.32	0.80	1	0.63-1	64-283	0.85-1	0.02-0.02	0.80	1	0.38-1	140-270	0.85-0.85	0.06-0.08	0.80	1	0.38-1	140-270	0.85-1
POR	*Lamna nasus*	0.07-0.10	0.80	1	0.29-0.67	58-211	1	0.02-0.03	0.80	1	0.17-0.40	58-211	1	0.02-0.04	0.80	1	0.17-0.4	58-211	1
PSK	*Pseudocarcharias kamoharai*	0.23-0.32	0.80	1	0.34-0.34	40-121	1	0.01-0.01	0.80	1	0.20-0.20	40-121	1	0.05-0.05	0.80	1	0.20-0.20	40-121	1
PTH	*Alopias pelagicus*	0.25-0.38	0.80	1	0.67-0.80	155-328	1	0.02-0.03	0.80	1	0.40-0.48	155-328	1	0.06-0.10	0.80	1	0.40-0.48	155-328	1
RHN	*Rhincodon typus*	0.23-0.32	0.80	1	0.20-1	64-1561	0.1-0.2	0.02-0.04	0.80	1	0.12-1	120-1300	0.1-0.1	0.04-0.10	0.80	1	0.12-1	120-1300	0.10-0.20
RHU	*Rhizoprionodon longurio*	0.01-0.10	0.80	1	1-1	31-113	1	0.01-0.06	0.80	1	1-1	31-113	1	0.00-0.06	0.80	1	1-1	31-113	1
SCK	*Dalatias licha*	0.43-0.51	0.80	1	0.09-1	35-139	1	0.00-0.02	0.80	1	0.05-0.51	35-139	1	0.03-0.08	0.80	1	0.05-0.51	35-139	1
SMA	*Isurus oxyrinchus*	0.18-0.21	0.80	1	0.50-1	60-308	1	0.01-0.01	0.80	1	0.30-1	120-195	1	0.04-0.05	0.80	1	0.30-1	120-195	1
SPE	*Sphyrna media*	0.19-0.24	0.80	1	1-1	30-153	1	0.06-0.08	0.80	1	1-1	30-153	1	0.14-0.20	0.80	1	1-1	30-153	1
SPK	*Sphyrna mokarran*	0.30-0.34	0.80	1	0.67-1	80-330	1	0.02-0.06	0.80	1	0.40-1	80-330	1	0.08-0.17	0.80	1	0.40-1	80-330	1
SPL	*Sphyrna lewini*	0.30-0.42	0.80	1	0.73-1	47-290	1	0.02-0.04	0.80	1	0.44-1	47-290	1	0.07-0.13	0.80	1	0.44-1	47-290	1
SPZ	*Sphyrna zygaena*	0.30-0.42	0.80	1	1-1	55-375	1	0.02-0.03	0.80	1	0.83-1	55-375	1	0.07-0.11	0.80	1	0.83-1	55-375	1
SSN	*Sphyrna corona*	0.14-0.36	0.80	1	1-1	22-95	1	0.04-0.06	0.80	1	1-1	22-95	1	0.14-0.15	0.80	1	1-1	22-95	1
SSQ	*Zameus squamulosus*	0.26-0.34	0.80	1	0.10-0.67	25-96	1	0.00-0.01	0.80	1	0.06-0.40	25-96	1	0.05-0.06	0.80	1	0.06-0.40	25-96	1
TIG	*Galeocerdo cuvier*	0.06-0.15	0.80	1	0.22-1	80-441	1	0.03-0.04	0.80	1	0.13-1	80-441	1	0.04-0.08	0.80	1	0.13-1	80-441	1
WSH	*Carcharodon carcharias*	0.05-0.07	0.80	1	0.50-1	147-467	1	0.02-0.04	0.80	1	0.30-1	147-467	1	0.02-0.04	0.80	1	0.30-1	147-467	1

APPENDIX 1. continued

		Artisanal gillnet						Artisanal longline					
Code	**Scientific name**	***Gx/G***	***Dx***	***Axj***	***Exj***	***Cxj***	***Pxj***	***Gx/G***	***Dx***	***Axj***	***Exj***	***Cxj***	***Pxj***
ALV	*Alopias vulpinus*	0.01-0.05	1	1	0.18-0.33	80-252	1	0.09-0.42	1	1	0.18-0.33	88-252	1
BRO	*Carcharhinus brachyurus*	0.02-0.04	1	1	0.28-0.50	74-308	1	0.16-0.20	1	1	0.28-0.50	74-308	1
BSH	*Prionace glauca*	0.01-0.01	1	1	0.21-0.83	34-267	1	0.07-0.09	1	1	0.21-0.83	34-267	1
BTH	*Alopias superciliosus*	0.01-0.01	1	1	0.18-0.33	69-225	1	0.10-0.12	1	1	0.18-0.33	69-225	1
CCA	*Carcharhinus altimus*	0.02-0.03	1	1	0.22-0.75	60-303	1	0.18-0.32	1	1	0.22-0.75	60-303	1
CCE	*Carcharhinus leucas*	0.04-0.14	1	1	0.49-1	56-351	1	0.33-0.44	1	1	0.49-1	91-315	1
CCG	*Carcharhinus galapagensis*	0.03-0.04	1	1	0.35-1	83-230	1	0.23-0.28	1	1	0.35-1	83-230	1
CCL	*Carcharhinus limbatus*	0.03-0.08	1	1	0.71-1	73-264	1	0.25-0.41	1	1	0.71-1	73-264	1
CCP	*Carcharhinus plumbeus*	0.04-0.07	1	1	0.36-1	81-223	1	0.13-0.23	1	1	0.36-1	81-223	1
CCR	*Carcharhinus porosus*	0.02-0.07	1	1	1-1	28-136	1	0.18-0.40	1	1	1-1	28-136	1
CNX	*Nasolamia velox*	0.07-0.16	1	1	0.48-1	53-153	1	0.40-0.42	1	1	0.48-1	53-153	1
DUS	*Carcharhinus obscurus*	0.03-0.09	1	1	0.50-1	101-456	1	0.21-0.27	1	1	0.50-1	101-456	1
FAL	*Carcharhinus falciformis*	0.01-0.01	1	1	0.61-1	48-332	1	0.13-0.14	1	1	0.61-1	48-302	1
ISB	*Isistius brasiliensis*	0.02-0.02	1	1	0.03-0.14	14-44	1	0.06-0.10	1	1	0.03-0.14	14-44	1
LMA	*Isurus paucus*	0	1	1	0.11-0.30	122-385	1	0.02-0.05	1	1	0.11-0.30	122-385	1
LMD	*Lamna ditropis*	0	1	1	0.10-0.25	67-207	1	0.01-0.01	1	1	0.10-0.25	67-207	1
OCS	*Carcharhinus longimanus*	0.01-0.01	1	1	0.32-1	64-309	1	0.11-0.13	1	1	0.32-1	64-309	1
POR	*Lamna nasus*	0.02-0.02	1	1	0.14-0.33	58-211	1	0.12-0.13	1	1	0.14-0.33	58-211	1
PSK	*Pseudocarcharias kamoharai*	0.00-0.01	1	1	0.17-0.17	40-121	1	0.06-0.10	1	1	0.17-0.17	40-121	1
PTH	*Alopias pelagicus*	0.01-0.02	1	1	0.33-0.40	155-328	1	0.11-0.2	1	1	0.33-0.40	155-328	1
RHN	*Rhincodon typus*	0.02-0.03	1	1	0.10-1	64-1561	1	0.22-0.25	1	1	0.10-1	64-1561	1
RHU	*Rhizoprionodon longurio*	0.11-0.26	1	1	1-1	31-113	1	0.35-0.40	1	1	1-1	31-113	1
SCK	*Dalatias licha*	0	1	1	0.04-0.39	35-139	1	0.05-0.11	1	1	0.04-0.39	35-139	1
SMA	*Isurus oxyrinchus*	0.01-0.01	1	1	0.25-1	60-308	1	0.08-0.09	1	1	0.25-1	60-292	1
SPE	*Sphyrna media*	0.17-0.19	1	1	1-1	30-153	1	0.68-0.68	1	1	1-1	30-153	1
SPK	*Sphyrna mokarran*	0.02-0.04	1	1	0.33-1	70-403	1	0.16-0.38	1	1	0.33-1	110-280	1
SPL	*Sphyrna lewini*	0.02-0.03	1	1	0.36-1	47-290	1	0.14-0.25	1	1	0.36-1	47-290	1
SPZ	*Sphyrna zygaena*	0.02-0.02	1	1	0.69-1	55-375	1	0.14-0.22	1	1	0.69-1	65-315	1
SSN	*Sphyrna corona*	0.03-0.17	1	1	1-1	22-95	1	0.28-0.62	1	1	1-1	22-95	1
SSQ	*Zameus squamulosus*	0.00-0.01	1	1	0.05-0.33	25-96	1	0.06-0.09	1	1	0.05-0.33	25-96	1
TIG	*Galeocerdo cuvier*	0.03-0.10	1	1	0.11-1	80-441	1	0.20-0.29	1	1	0.11-1	80-248	1
WSH	*Carcharodon carcharias*	0.03-0.06	1	1	0.25-1	147-467	1	0.12-0.15	1	1	0.25-1	147-467	1

APPENDIX 2. Justifications and assumptions for the use of parameter values (see Table 2) for describing the susceptibility of capture of 32 shark species in the eight fisheries included in the EASI-Fish assessment for the eastern Pacific Ocean in 2019.

Species	Fishery	Resolution of grid cells for (G_x)	Fishing season duration (D_x)	Seasonal availability (A_{xj})	Encounterability (E_{xj})	Contact selectivity (C_{xj})	Post-release mortality (PCM) (P_{xj})
ALV	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m like *A. superciliosus* (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (76-460 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 62.5% PRM in Pacific industrial longlines (Musyl et al., 2011).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m like *A. superciliosus* (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (50-457 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 0-26% PRM in a recreational line fishery (Heberer et al., 2010; Sepulveda et al., 2015).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m like *A. superciliosus* (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (50-457 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 0-26% PRM in a recreational line fishery (Heberer et al., 2010; Sepulveda et al., 2015).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m like *A. superciliosus* (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (50-457 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 0-26% PRM in a recreational line fishery (Heberer et al., 2010; Sepulveda et al., 2015).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-120 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m like *A. superciliosus* (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths in purse-seine Class 6 sets (50-457 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 0-26% PRM in a recreational line fishery (Heberer et al., 2010; Sepulveda et al., 2015).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-120 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m like *A. superciliosus* (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths in purse-seine Class 6 sets (50-457 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 0-26% PRM in a recreational line fishery (Heberer et al., 2010; Sepulveda et al., 2015).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–100 m (Martínez et al., 2017). Species assumed to primarily inhabit 0m to 400 (± 300-543) m like *A. superciliosus* (Musyl et al., 2011).	In absence of observed length data, knife-edge selectivity assumed from size at birth (80 cm TL) to L_{∞}.	Assumed no release of marketable species. If released from gillnets, potential PRM for *Alopias* spp. likely to near 100% (Caretta et al., 2004).
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0m to 400 (± 300-543) m like *A. superciliosus* (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (88-324 cm TL) (IATTC/WWF observer data).	Assumed no release of marketable species, but noting potential for 62.5% PRM in Pacific industrial longlines (Musyl et al., 2011).
BRO	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0m to 360 (± 200-360) m (Weigmann, 2016).	Knife-edge selectivity from smallest to largest observed lengths (189-280cm PCL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 5.1% (95% CI 0.6-17.3%) PRM from industrial pelagic longlines based on closely related species, *C. obscurus* (Sulikowski et al., 2020).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0m to 360 (± 200-360) m (Weigmann, 2016).	In absence of observed length data, knife-edge selectivity assumed from size at birth (74 cm TL) to L_{∞}.	Assumed 100% PRM in absence of PRM data from purse-seine sets, but noting PRM of closely related *C. falciformis* was 69–82% (Eddy et al., 2016; Hutchinson et al., 2015) in Pacific purse-seine sets.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0m to 360 (± 200-360) m (Weigmann, 2016).	In absence of observed length data, knife-edge selectivity assumed from size at birth (74 cm TL) to L_{∞}.	Assumed 100% PRM in absence of PRM data from purse-seine sets, but noting PRM of closely related *C. falciformis* was 69–82% (Eddy et al., 2016; Hutchinson et al., 2015) in Pacific purse-seine sets.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0m to 360 (± 200-360) m (Weigmann, 2016).	In absence of observed length data, knife-edge selectivity assumed from size at birth (74 cm TL) to L_{∞}.	Assumed 100% PRM in absence of PRM data from purse-seine sets, but noting PRM of closely related *C. falciformis* was 69–82% (Eddy et al., 2016; Hutchinson et al., 2015) in Pacific purse-seine sets.
	Purse-seine	0.5°x0.5°	72-d	Year-round	NOA sets fish 0-150 m. Species	In absence of observed length data,	Assumed 100% PRM in absence of PRM data from purse-seine sets, but

	C1–5 (NOA)		closure (Class-4-5)		assumed to primarily inhabit 0m to 360 (± 200-360) m (Weigmann, 2016).	knife-edge selectivity assumed from size at birth (74 cm TL) to L_{∞}.	noting PRM of closely related *C. falciformis* was 69–82% (Eddy et al., 2016; Hutchinson et al., 2015) in Pacific purse-seine sets.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0m to 360 (± 200-360) m (Weigmann, 2016).	In absence of observed length data, knife-edge selectivity assumed from size at birth (74 cm TL) to L_{∞}.	Assumed 100% PRM in absence of PRM data from purse-seine sets, but noting PRM of closely related *C. falciformis* was 69–82% (Eddy et al., 2016; Hutchinson et al., 2015) in Pacific purse-seine sets.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–100 m (Martínez et al., 2017). Species assumed to primarily inhabit 0m to 360 (± 200-360) m (Weigmann, 2016).	In absence of observed length data, knife-edge selectivity assumed from size at birth (74 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0m to 360 (± 200-360) m (Weigmann, 2016).	In absence of observed length data, knife-edge selectivity assumed from size at birth (74 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14% PRM from industrial pelagic longlines based on closely related species, *C. obscurus* (Sulikowski et al., 2020).
BSH	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0m to 150 (± 100-480) m (Musyl et al., 2011).	Logistic selectivity from dominant north Pacific fleet (ISC, 2017).	Assumed no release of marketable species, but noting potential for 33-38% PRM from industrial pelagic longlines (Campana et al., 2015; Hutchinson et al., 2021).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0m to 150 (± 100-480) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (35-350 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0m to 150 (± 100-480) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (35-350 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0m to 150 (± 100-480) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (35-350 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0m to 150 (± 100-480) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (100-220 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0m to 150 (± 100-480) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (100-220 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0m to 150 (± 100-480) m (Musyl et al., 2011).	In absence of observed length data, knife-edge selectivity assumed from size at birth (34 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0m to 150 (± 100-480) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (29-335 cm TL) (IATTC/WWF observer data).	Assumed no release of marketable species, but noting potential for 33-38% PRM from industrial pelagic longlines (Campana et al., 2015; Hutchinson et al., 2021).
BTH	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (15-457 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 12% PRM from industrial pelagic longlines (Hutchinson et al., 2021)
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (56-420 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine	0.5°x0.5°	72-d	Year-round	NOA sets fish 0-150 m. Species	Knife-edge selectivity from smallest	Assumed no release of marketable species. No PRM data available to

	C6 (NOA)		closure		assumed to primarily inhabit 0m to 400 (± 300-543) m (Musyl et al., 2011).	to largest observed lengths (56-420 cm TL) (IATTC observer data).	indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (56-420 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (100-216 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0m to 400 (± 300-543) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (100-216 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0m to 400 (± 300-543) m (Musyl et al., 2011).	In absence of observed length data, knife-edge selectivity assumed from size at birth (69 cm TL) to L_{∞}.	Assumed no release of marketable species. If released from gillnets, potential PRM for *Alopias* spp. likely to near 100% (Caretta et al., 2004).
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0m to 400 (± 300-543) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (50-370 cm TL) (IATTC/WWF observer data).	Assumed no release of marketable species, but noting potential for 12% PRM from industrial pelagic longlines (Hutchinson et al., 2021)
CCA	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species inhabits 25m to 200 (± 125-362) m (Anderson and Stevens, 1996).	In absence of observed length data, knife-edge selectivity assumed from size at birth (60 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species inhabits 25m to 200 (± 125-362) m (Anderson and Stevens, 1996).	In absence of observed length data, knife-edge selectivity assumed from size at birth (60 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species inhabits 25m to 200 (± 125-362) m (Anderson and Stevens, 1996).	In absence of observed length data, knife-edge selectivity assumed from size at birth (60 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species inhabits 25m to 200 (± 125-362) m (Anderson and Stevens, 1996).	In absence of observed length data, knife-edge selectivity assumed from size at birth (60 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species inhabits 25m to 200 (± 125-362) m (Anderson and Stevens, 1996).	In absence of observed length data, knife-edge selectivity assumed from size at birth (60 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species inhabits 25m to 200 (± 125-362) m (Anderson and Stevens, 1996).	In absence of observed length data, knife-edge selectivity assumed from size at birth (60 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species inhabits 25m to 200 (± 125-362) m (Anderson and Stevens, 1996).	In absence of observed length data, knife-edge selectivity assumed from size at birth (60 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species inhabits 25m to 200 (± 125-362) m (Anderson and Stevens, 1996).	In absence of observed length data, knife-edge selectivity assumed from size at birth (60 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020)
CCE	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species inhabits Species inhabits 0 m to 70 (± 50-205) m (Brunnschweiler et al., 2010).	In absence of observed length data, knife-edge selectivity assumed from size at birth (56 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020).

	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species inhabits 0 m to 70 (± 50-205) m (Brunnschweiler et al., 2010).	Knife-edge selectivity from smallest to largest observed lengths (100-294 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species inhabits 0 m to 70 (± 50-205) m (Brunnschweiler et al., 2010).	Knife-edge selectivity from smallest to largest observed lengths (100-294 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species inhabits 0m to 70 (± 70-205) m (Brunnschweiler et al., 2010).	Knife-edge selectivity from smallest to largest observed lengths (100-294 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species inhabits 0 m to 70 (± 50-205) m (Brunnschweiler et al., 2010).	Knife-edge selectivity from smallest to largest observed lengths (100-294 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species inhabits 0 m to 70 (± 50-205) m (Brunnschweiler et al., 2010).).	Knife-edge selectivity from smallest to largest observed lengths (100-294 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species inhabits 0 m to 70 (± 50-205) m (Brunnschweiler et al., 2010).	In absence of observed length data, knife-edge selectivity assumed from size at birth (56 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species inhabits 0 m to 70 (± 50-205) m (Brunnschweiler et al., 2010).	Knife-edge selectivity from smallest to largest observed lengths (91-315 cm TL) (IATTC/WWF observer data).	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020)
CCG	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species inhabits 0 m to 110 (± 90-286) m (Morales et al., 2021).	Knife-edge selectivity from smallest to largest observed lengths (137-256 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species inhabits 0 m to 110 (± 90-286) m (Morales et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (83 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species inhabits 0 m to 110 (± 90-286) m (Morales et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (83 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species inhabits 0 m to 110 (± 90-286) m (Morales et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (83 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species inhabits 0 m to 110 (± 90-286) m (Morales et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (83 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species inhabits 0 m to 110 (± 90-286) m (Morales et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (83 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species inhabits 0 m to 110 (± 90-286) m (Morales et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (83 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species inhabits 0 m to 110 (± 90-286) m (Morales et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (83 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020)
CCL	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species inhabits 0 m to 30 (± 20-140) m (Weigmann, 2016).	Knife-edge selectivity from smallest to largest observed lengths (115-292 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species inhabits 0 m to 30 (± 20-140) m (Weigmann, 2016).	Knife-edge selectivity from smallest to largest observed lengths (40-235 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).

	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species inhabits 0 m to 30 (± 20-140) m (Weigmann, 2016).	Knife-edge selectivity from smallest to largest observed lengths (40-235 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species inhabits 0 m to 30 (± 20-140) m (Weigmann, 2016).	Knife-edge selectivity from smallest to largest observed lengths (40-235 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species inhabits 0 m to 30 (± 20-140) m (Weigmann, 2016).	Knife-edge selectivity from smallest to largest observed lengths (168-212 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species inhabits 0 m to 30 (± 20-140) m (Weigmann, 2016).	Knife-edge selectivity from smallest to largest observed lengths (168-212 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species inhabits 0 m to 30 (± 20-140) m (Weigmann, 2016).	In absence of observed length data, knife-edge selectivity assumed from size at birth (73 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species inhabits 0 m to 30 (± 20-140) m (Weigmann, 2016).	Knife-edge selectivity from smallest to largest observed lengths (40-270 cm TL) (IATTC/WWF observer data).	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020)
CCP	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species inhabits 0 m to 70 (± 50-280) m (Andrzejaczek et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (81 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species inhabits 0 m to 70 (± 50-280) m (Andrzejaczek et al., 2018).	Knife-edge selectivity from smallest to largest observed lengths (117-146 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species inhabits 0 m to 70 (± 50-280) m (Andrzejaczek et al., 2018).	Knife-edge selectivity from smallest to largest observed lengths (117-146 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species inhabits 0 m to 70 (± 50-280) m (Andrzejaczek et al., 2018).	Knife-edge selectivity from smallest to largest observed lengths (117-146 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species inhabits 0 m to 70 (± 50-280) m (Andrzejaczek et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (81 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species inhabits 0 m to 70 (± 50-280) m (Andrzejaczek et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (81 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species inhabits 0 m to 70 (± 50-280) m (Andrzejaczek et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (81 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species inhabits 0 m to 70 (± 50-280) m (Andrzejaczek et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (81 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020)
CCR	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species inhabits 0 m to 32 (± 20-84) m (Compagno, 1984).	In absence of observed length data, knife-edge selectivity assumed from size at birth (28 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species inhabits 0 m to 32 (± 20-84) m (Compagno, 1984).	In absence of observed length data, knife-edge selectivity assumed from size at birth (28 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species inhabits 0 m to 32 (± 20-84) m (Compagno, 1984).	In absence of observed length data, knife-edge selectivity assumed from size at birth (28 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine	0.5°x0.5°	72-d	Year-round	OBJ sets fish 0-200 m. Species inhabits	In absence of observed length data,	Assumed no release of marketable species, but noting potential for 58%

	C6 (OBJ)		closure		0 m to 32 (± 20-84) m (Compagno, 1984).	knife-edge selectivity assumed from size at birth (28 cm TL) to L_{∞}.	PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species inhabits 0 m to 32 (± 20-84) m (Compagno, 1984).	In absence of observed length data, knife-edge selectivity assumed from size at birth (28 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species inhabits 0 m to 32 (± 20-84) m (Compagno, 1984).	In absence of observed length data, knife-edge selectivity assumed from size at birth (28 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of *Carcharhinus* spp. from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species inhabits 0 m to 32 (± 20-84) m (Compagno, 1984).	In absence of observed length data, knife-edge selectivity assumed from size at birth (28 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species inhabits 0 m to 32 (± 20-84) m (Compagno, 1984).	In absence of observed length data, knife-edge selectivity assumed from size at birth (28 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020)
CNX	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species inhabits 15 m to 25 (± 20-192) m (Froese and Pauly, 2022).	In absence of observed length data, knife-edge selectivity assumed from size at birth (53 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of a larger related species *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species inhabits 15 m to 25 (± 20-192) m (Froese and Pauly, 2022).	In absence of observed length data, knife-edge selectivity assumed from size at birth (53 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of a larger *Carcharhinus* species from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species inhabits 15 m to 25 (± 20-192) m (Froese and Pauly, 2022).	In absence of observed length data, knife-edge selectivity assumed from size at birth (53 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of a larger *Carcharhinus* species from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species inhabits 15 m to 25 (± 20-192) m (Froese and Pauly, 2022).	In absence of observed length data, knife-edge selectivity assumed from size at birth (53 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of a larger *Carcharhinus* species from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species inhabits 15 m to 25 (± 20-192) m (Froese and Pauly, 2022).	In absence of observed length data, knife-edge selectivity assumed from size at birth (53 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of a larger *Carcharhinus* species from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species inhabits 15 m to 25 (± 20-192) m (Froese and Pauly, 2022).	In absence of observed length data, knife-edge selectivity assumed from size at birth (53 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of a larger *Carcharhinus* species from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species inhabits 15 m to 25 (± 20-192) m (Froese and Pauly, 2022).	In absence of observed length data, knife-edge selectivity assumed from size at birth (53 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species inhabits 15 m to 25 (± 20-192) m (Froese and Pauly, 2022).	In absence of observed length data, knife-edge selectivity assumed from size at birth (53 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of a larger related species *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020).
DUS	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0m to 125 (± 100-200) m (Hoffmayer et al., 2014).	Knife-edge selectivity from smallest to largest observed lengths (136-240 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 14 % PRM from industrial pelagic longlines (Sulikowski et al., 2020).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0m to 125 (± 100-200) m (Hoffmayer et al., 2014).	Knife-edge selectivity from smallest to largest observed lengths (80-137 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0m to 125 (± 100-200) m (Hoffmayer et al., 2014).	Knife-edge selectivity from smallest to largest observed lengths (80-137 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine	0.5°x0.5°	72-d	Year-round	OBJ sets fish 0-200 m. Species	Knife-edge selectivity from smallest	Assumed no release of marketable species, but noting potential for 58%

	C6 (OBJ)		closure		assumed to primarily inhabit 0m to 125 (± 100-200) m (Hoffmayer et al., 2014).	to largest observed lengths (80-137 cm TL) (IATTC observer data).	PRM from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0m to 125 (± 100-200) m (Hoffmayer et al., 2014).	Knife-edge selectivity from smallest to largest observed lengths in purse-seine Class 6 sets (80-137 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0m to 125 (± 100-200) m (Hoffmayer et al., 2014).	Knife-edge selectivity from smallest to largest observed lengths in purse-seine Class 6 sets (80-137 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 58% PRM from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0m to 125 (± 100-200) m (Hoffmayer et al., 2014).	In absence of observed length data, knife-edge selectivity assumed from size at birth (101 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0m to 125 (± 100-200) m (Hoffmayer et al., 2014).	In absence of observed length data, knife-edge selectivity assumed from size at birth (101 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM from industrial pelagic longlines (Sulikowski et al., 2020).
FAL	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 100 (± 70-165) m (Musyl et al. 2003).	Logistic selectivity from EPO fleet (Aires-da-Silva et al. 2014). Sizes of 32–158 cm TL recorded by observers.	Assumed no release of marketable species, despite potential for 15.2% post-release mortality from longlines (Schaefer et al. 2021).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 70-165) m (Musyl et al. 2003).	Logistic selectivity from EPO fleet (Aires-da-Silva et al. 2014). Sizes of 25–271 cm TL recorded by IATTC observers.	IATTC Resolution C-16-06 prohibits retention. PRM from purse-seine 32-93% (Poisson et al. 2014, Hutchinson et al. 2015).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 70-165) m (Musyl et al. 2003).	Logistic selectivity from EPO fleet (Aires-da-Silva et al. 2014). Sizes of 25–271 cm TL recorded by IATTC observers.	IATTC Resolution C-16-06 prohibits retention. PRM from purse-seine 32-93% (Poisson et al. 2014, Hutchinson et al. 2015).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 100 (± 70-165) m (Musyl et al. 2003).	Logistic selectivity from EPO fleet (Aires-da-Silva et al. 2014). Sizes of 25–271 cm TL recorded by IATTC observers.	IATTC Resolution C-16-06 prohibits retention. PRM from purse-seine 32-93% (Poisson et al. 2014, Hutchinson et al. 2015).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 70-165) m (Musyl et al. 2003).	Selectivity mirrors EPO C6 NOA fleet	IATTC Resolution C-16-06 prohibits retention. PRM from purse-seine 32-93% (Poisson et al. 2014, Hutchinson et al. 2015).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 100 (± 70-165) m (Musyl et al. 2003).	Selectivity mirrors EPO C6 NOA fleet	IATTC Resolution C-16-06 prohibits retention. PRM from purse-seine 32-93% (Poisson et al. 2014, Hutchinson et al. 2015).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 100 (± 70-165) m (Musyl et al. 2003).	Knife-edge selectivity from size at birth (48 cm TL).	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 100 (± 70-165) m (Musyl et al. 2003).	Logistic selectivity from EPO fleet (Aires-da-Silva et al. 2014). Sizes of 20–302 cm TL recorded by IATTC/WWF observers.	Assumed no release of marketable species, despite potential for 15.2% post-release mortality from longlines (Schaefer et al. 2021).
ISB	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 100m (± 700-3800) m (Jahn and Haedrich, 1988).	Knife-edge selectivity from smallest to largest observed lengths (20-49 cm TL) (IATTC observer data).	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from longline fisheries.
	Purse-seine	0.5°x0.5°	72-d	Year-round	DEL sets fish 0-150 m. Species	In absence of observed length data,	Assumed this non-marketable species is discarded but assumed 100%

	C6 (DEL)		closure		assumed to primarily inhabit 0 m to 100m (± 700-3800) m (Jahn and Haedrich, 1988).	knife-edge selectivity assumed from size at birth (14 cm TL) to L_{∞}.	mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100m (± 700-3800) m (Jahn and Haedrich, 1988).	In absence of observed length data, knife-edge selectivity assumed from size at birth (14 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 100m (± 700-3800) m (Jahn and Haedrich, 1988).	In absence of observed length data, knife-edge selectivity assumed from size at birth (14 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100m (± 700-3800) m (Jahn and Haedrich, 1988).	In absence of observed length data, knife-edge selectivity assumed from size at birth (14 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 100m (± 700-3800) m (Jahn and Haedrich, 1988).	In absence of observed length data, knife-edge selectivity assumed from size at birth (14 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 100m (± 700-3800) m (Jahn and Haedrich, 1988).	In absence of observed length data, knife-edge selectivity assumed from size at birth (14 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 100m (± 700-3800) m (Jahn and Haedrich, 1988).	In absence of observed length data, knife-edge selectivity assumed from size at birth (14 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from longline fisheries.
LMA	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 15m to 400 (± 300-760) m (Hueter et al., 2017).	Knife-edge selectivity from smallest to largest observed lengths (61-331 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting PRM for closely related *I. oxyrinchus* was 6-22% from industrial pelagic longlines (Miller et al., 2020; Hutchinson et al., 2021).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 15 m to 400 (± 300-760) m (Hueter et al., 2017).	In absence of observed length data, knife-edge selectivity assumed from size at birth (122 cm TL) to L_{∞}.	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 15m to 400 (± 300-760) m (Hueter et al., 2017).	In absence of observed length data, knife-edge selectivity assumed from size at birth (122 cm TL) to L_{∞}.	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 15m to 400 (± 300-760) m (Hueter et al., 2017).	In absence of observed length data, knife-edge selectivity assumed from size at birth (122 cm TL) to L_{∞}.	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 15m to 400 (± 300-760) m (Hueter et al., 2017).	In absence of observed length data, knife-edge selectivity assumed from size at birth (122 cm TL) to L_{∞}.	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 15m to 400 (± 300-760) m (Hueter et al., 2017).	In absence of observed length data, knife-edge selectivity assumed from size at birth (122 cm TL) to L_{∞}.	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 15m to 400 (± 300-760) m	In absence of observed length data, knife-edge selectivity assumed from size at birth (122 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.

					(Hueter et al., 2017).		
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 15m to 400 (± 300-760) m (Hueter et al., 2017).	In absence of observed length data, knife-edge selectivity assumed from size at birth (122 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting PRM for closely related *I. oxyrinchus* was 6-22% from industrial pelagic longlines (Miller et al., 2020; Hutchinson et al., 2021).
LMD	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 500 (± 400-1000) m (Hulbert et al., 2005).	Knife-edge selectivity from smallest to largest observed lengths (100-274 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting PRM for closely related *I. nasus* was 3.7–50.7% from industrial pelagic longlines (Hoolihan et al., 2011; Campana et al., 2015).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 500 (± 400-1000) m (Hulbert et al., 2005).	In absence of observed length data, knife-edge selectivity assumed from size at birth (67 cm PCL) to L_{∞}.	Assumed no release of marketable species but if released, assume 100% PRM given no PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 500 (± 400-1000) m (Hulbert et al., 2005).	In absence of observed length data, knife-edge selectivity assumed from size at birth (67 cm PCL) to L_{∞}.	Assumed no release of marketable species but if released, assume 100% PRM given no PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 500 (± 400-1000) m (Hulbert et al., 2005).	In absence of observed length data, knife-edge selectivity assumed from size at birth (67 cm PCL) to L_{∞}.	Assumed no release of marketable species but if released, assume 100% PRM given no PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 500 (± 400-1000) m (Hulbert et al., 2005).	In absence of observed length data, knife-edge selectivity assumed from size at birth (67 cm PCL) to L_{∞}.	Assumed no release of marketable species but if released, assume 100% PRM given no PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 500 (± 400-1000) m (Hulbert et al., 2005).	In absence of observed length data, knife-edge selectivity assumed from size at birth (67 cm PCL) to L_{∞}.	Assumed no release of marketable species but if released, assume 100% PRM given no PRM data available to indicate potential survival rate if released from purse-seine sets.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 500 (± 400-1000) m (Hulbert et al., 2005).	In absence of observed length data, knife-edge selectivity assumed from size at birth (67 cm PCL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 500 (± 400-1000) m (Hulbert et al., 2005).	In absence of observed length data, knife-edge selectivity assumed from size at birth (67 cm PCL) to L_{∞}.	Assumed no release of marketable species, but noting PRM for closely related I. nasus was 3.7–50.7% from industrial pelagic longlines (Hoolihan et al., 2011; Campana et al., 2015).
OCS	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 120 (± 100-317) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (50-293 cm TL) (IATTC observer data).	IATTC Resolution C-11-10 prohibits retention. PRM estimated from PSATs 15-19% from industrial pelagic longlines (Musyl et al., 2011; Hutchinson et al., 2021). Assumed uniform PRM distribution of 15-20%.
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 120 (± 100-317) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (20-283 cm TL) (IATTC observer data).	IATTC Resolution C-11-10 prohibits retention. PRM estimated from PSATs 93% in Atlantic industrial purse-seine fishery (Bach et al., 2021). Assumed uniform PRM distribution of 85-100%.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 120 (± 100-317) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (20-283 cm TL) (IATTC observer data).	IATTC Resolution C-11-10 prohibits retention. PRM estimated from PSATs 93% in Atlantic industrial purse-seine fishery (Bach et al., 2021). Assumed uniform PRM distribution of 85-100%.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 120 (± 100-317) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (20-283 cm TL) (IATTC observer data).	IATTC Resolution C-11-10 prohibits retention. PRM estimated from PSATs 93% in Atlantic industrial purse-seine fishery (Bach et al., 2021). Assumed uniform PRM distribution of 85-100%.
	Purse-seine	0.5°x0.5°	72-d	Year-round	NOA sets fish 0-150 m. Species	Knife-edge selectivity from smallest	IATTC Resolution C-11-10 prohibits retention. PRM estimated from PSATs

	C1–5 (NOA)		closure (Class-4-5)		assumed to primarily inhabit 0 m to 120 (± 100-317) m (Musyl et al., 2011).	to largest observed lengths (140-270 cm TL) (IATTC observer data).	93% in Atlantic industrial purse-seine fishery (Bach et al., 2021). Assumed uniform PRM distribution of 85-100%.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 120 (± 100-317) m (Musyl et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (140-270 cm TL) (IATTC observer data).	IATTC Resolution C-11-10 prohibits retention. PRM estimated from PSATs 93% in Atlantic industrial purse-seine fishery (Bach et al., 2021). Assumed uniform PRM distribution of 85-100%.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 120 (± 100-317) m (Musyl et al., 2011).	In absence of observed length data, knife-edge selectivity assumed from size at birth (64 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 120 (± 100-317) m (Musyl et al., 2011).	In absence of observed length data, knife-edge selectivity assumed from size at birth (64 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 15-19% PRM from industrial pelagic longlines (Musyl et al., 2011; Hutchinson et al., 2021).
POR	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 450 (± 300-700) m (Francis et al., 2015).	Knife-edge selectivity from smallest to largest observed lengths (126-156 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting but noting potential for 3.7–50.7% PRM from industrial pelagic longlines (Hoolihan et al., 2011; Campana et al., 2015).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 450 (± 300-700) m (Francis et al., 2015).	In absence of observed length data, knife-edge selectivity assumed from size at birth (58 cm FL) to L_{∞}.	Assumed no release of marketable species but if released, assume 100% PRM given no PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 450 (± 300-700) m (Francis et al., 2015).	In absence of observed length data, knife-edge selectivity assumed from size at birth (58 cm FL) to L_{∞}.	Assumed no release of marketable species but if released, assume 100% PRM given no PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 450 (± 300-700) m (Francis et al., 2015).	In absence of observed length data, knife-edge selectivity assumed from size at birth (58 cm FL) to L_{∞}.	Assumed no release of marketable species but if released, assume 100% PRM given no PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 450 (± 300-700) m (Francis et al., 2015).	In absence of observed length data, knife-edge selectivity assumed from size at birth (58 cm FL) to L_{∞}.	Assumed no release of marketable species but if released, assume 100% PRM given no PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 450 (± 300-700) m (Francis et al., 2015).	In absence of observed length data, knife-edge selectivity assumed from size at birth (58 cm FL) to L_{∞}.	Assumed no release of marketable species but if released, assume 100% PRM given no PRM data available to indicate potential survival rate if released from purse-seine sets.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 450 (± 300-700) m (Francis et al., 2015).	In absence of observed length data, knife-edge selectivity assumed from size at birth (58 cm FL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 450 (± 300-700) m (Francis et al., 2015).	In absence of observed length data, knife-edge selectivity assumed from size at birth (58 cm FL) to L_{∞}.	Assumed no release of marketable species, but noting but noting potential for 3.7–50.7% PRM from industrial pelagic longlines (Hoolihan et al., 2011; Campana et al., 2015).
PSK	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species inhabits 0-590 m (Ebert et al., 2021).	Knife-edge selectivity from smallest to largest observed lengths (40-127 cm TL) (IATTC observer data).	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from longline fisheries.
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species inhabits 0-590 m (Ebert et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (40 cm FL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine	0.5°x0.5°	72-d	Year-round	NOA sets fish 0-150 m. Species	In absence of observed length data,	Assumed this non-marketable species is discarded but assumed 100%

	C6 (NOA)		closure		inhabits 0-590 m (Ebert et al., 2021).	knife-edge selectivity assumed from size at birth (40 cm FL) to L_{∞}.	mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species inhabits 0-590 m (Ebert et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (40 cm FL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species inhabits 0-590 m (Ebert et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (40 cm FL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species inhabits 0-590 m (Ebert et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (40 cm FL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species inhabits 0-590 m (Ebert et al., 2021).	In absence of observed length data, knife-edge selectivity assumed from size at birth (40 cm FL) to L_{∞}.	Assumed this non-marketable species is discarded, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species inhabits 0-590 m (Ebert et al., 2021).	Knife-edge selectivity from smallest to largest observed lengths (48-105 cm FL) (IATTC/WWF observer data).	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from longline fisheries.
PTH	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 50 m to 200 (± 150-300) m (Arostegui et al., 2020).	Knife-edge selectivity from smallest to largest observed lengths (56-560 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 12% PRM of closely related *A. superciliosus* from industrial pelagic longlines (Hutchinson et al., 2021)
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 50 m to 200 (± 150-300) m (Arostegui et al., 2020).	Knife-edge selectivity from smallest to largest observed lengths (62-396 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 50 m to 200 (± 150-300) m (Arostegui et al., 2020).	Knife-edge selectivity from smallest to largest observed lengths (62-396 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 50 m to 200 (± 150-300) m (Arostegui et al., 2020).	Knife-edge selectivity from smallest to largest observed lengths (62-396 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 50 m to 200 (± 150-300) m (Arostegui et al., 2020).	Knife-edge selectivity from smallest to largest observed lengths (160-330 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 50 m to 200 (± 150-300) m (Arostegui et al., 2020).	Knife-edge selectivity from smallest to largest observed lengths (160-330 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 50 m to 200 (± 150-300) m (Arostegui et al., 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (155 cm TL) to L_{∞}.	Assumed no release of marketable species. If released from gillnets, potential PRM for *Alopias* spp. likely to near 100% (Caretta et al., 2004).
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 50 m to 200 (± 150-300) m (Arostegui et al., 2020).	Knife-edge selectivity from smallest to largest observed lengths (63-390 cm TL) (IATTC/WWF observer data).	Assumed no release of marketable species, but noting 12% PRM of closely related *A. superciliosus* from industrial pelagic longlines (Hutchinson et al., 2021)
RHN	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 200 (± 100-1000) m (Tyminski et al., 2015).	In absence of observed length data, knife-edge selectivity assumed from size at birth (64 cm TL) to L_{∞}.	IATTC Resolution C-19-06 prohibits retention in purse-seine fishery only. However, it is assumed longline-caught whale sharks are released but 100% PRM assumed in absence of data.

	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 200 (± 100-1000) m (Tyminski et al., 2015).	Knife-edge selectivity from smallest to largest observed lengths (57-2000 cm TL) (IATTC observer data).	IATTC Resolution C-19-06 mandates safe release. PRM 0% from purse-seines in Indian Ocean (Escalle et al., 2018) but in absence of data from the EPO, PRM was precautionarily assumed to be 10–20%.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 200 (± 100-1000) m (Tyminski et al., 2015).	Knife-edge selectivity from smallest to largest observed lengths (57-2000 cm TL) (IATTC observer data).	IATTC Resolution C-19-06 mandates safe release. PRM 0% from purse-seines in Indian Ocean (Escalle et al., 2018) but in absence of data from the EPO, PRM was precautionarily assumed to be 10–20%.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 200 (± 100-1000) m (Tyminski et al., 2015).	Knife-edge selectivity from smallest to largest observed lengths (57-2000 cm TL) (IATTC observer data).	IATTC Resolution C-19-06 mandates safe release. PRM 0% from purse-seines in Indian Ocean (Escalle et al., 2018) but in absence of data from the EPO, PRM was precautionarily assumed to be 10–20%.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 200 (± 100-1000) m (Tyminski et al., 2015).	Knife-edge selectivity from smallest to largest observed lengths (120-1300 cm TL) (IATTC observer data).	IATTC Resolution C-19-06 mandates safe release. PRM 0% from purse-seines in Indian Ocean (Escalle et al., 2018) but in absence of data from the EPO, PRM was precautionarily assumed to be 10–20%.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 200 (± 100-1000) m (Tyminski et al., 2015).	Knife-edge selectivity from smallest to largest observed lengths (120-1300 cm TL) (IATTC observer data).	IATTC Resolution C-19-06 mandates safe release. PRM 0% from purse-seines in Indian Ocean (Escalle et al., 2018) but in absence of data from the EPO, PRM was precautionarily assumed to be 10–20%.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 200 (± 100-1000) m (Tyminski et al., 2015).	In absence of observed length data, knife-edge selectivity assumed from size at birth (64 cm TL) to L_{∞}.	Assumed species is released, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so assumed PRM of 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 200 (± 100-1000) m (Tyminski et al., 2015).	In absence of observed length data, knife-edge selectivity assumed from size at birth (64 cm TL) to L_{∞}.	Assumed longline-caught whale sharks are released but 100% PRM assumed in absence of data.
RHU	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species inhabits 0-100 m (Alatorre-Ramirez et al., 2013).	In absence of observed length data, knife-edge selectivity assumed from size at birth (31 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 14 % PRM of a larger related species *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 27 (± 10-100) m (Alatorre-Ramirez et al., 2013).	In absence of observed length data, knife-edge selectivity assumed from size at birth (31 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of a larger *Carcharhinus* species from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 27 (± 10-100) m (Alatorre-Ramirez et al., 2013).	In absence of observed length data, knife-edge selectivity assumed from size at birth (31 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of a larger *Carcharhinus* species from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 27 (± 10-100) m (Alatorre-Ramirez et al., 2013).	In absence of observed length data, knife-edge selectivity assumed from size at birth (31 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of a larger *Carcharhinus* species from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 27 (± 10-100) m (Alatorre-Ramirez et al., 2013).	In absence of observed length data, knife-edge selectivity assumed from size at birth (31 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of a larger *Carcharhinus* species from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 27 (± 10-100) m (Alatorre-Ramirez et al., 2013).	In absence of observed length data, knife-edge selectivity assumed from size at birth (31 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting potential for 58% PRM of a larger *Carcharhinus* species from Pacific industrial purse-seine sets (Hutchinson et al., 2021).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 27 (± 10-100) m	In absence of observed length data, knife-edge selectivity assumed from size at birth (31 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.

					(Alatorre-Ramirez et al., 2013).		
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 27 (± 10-100) m (Alatorre-Ramirez et al., 2013).	Knife-edge selectivity from smallest to largest observed lengths (112-148 cm TL) (IATTC/WWF observer data).	Assumed no release of marketable species, but noting potential for 14 % PRM of a larger related species *C. obscurus* from industrial pelagic longlines (Sulikowski et al., 2020).
SCK	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 37 m to 300 (± 200-1800) m (Francis et al., 2018).	Knife-edge selectivity from smallest to largest observed lengths (52-153 cm TL) (IATTC observer data).	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from longline fisheries.
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 37 m to 300 (± 200-1800) m (Francis et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (35 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 37 m to 300 (± 200-1800) m (Francis et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (35 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 37 m to 300 (± 200-1800) m (Francis et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (35 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 37 m to 300 (± 200-1800) m (Francis et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (35 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 37 m to 300 (± 200-1800) m (Francis et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (35 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 37 m to 300 (± 200-1800) m (Francis et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (35 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 37 m to 300 (± 200-1800) m (Francis et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (35 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from longline fisheries.
SMA	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 150 (± 100-400) m (Nasby-Lucas et al., 2019).	Knife-edge selectivity from smallest to largest observed lengths (30-366 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting potential for 6-22% PRM from industrial pelagic longlines (Miller et al., 2020; Hutchinson et al., 2021)
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 150 (± 100-400) m (Nasby-Lucas et al., 2019).	Knife-edge selectivity from smallest to largest observed lengths (42-350 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 150 (± 100-400) m (Nasby-Lucas et al., 2019).	Knife-edge selectivity from smallest to largest observed lengths (42-350 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 150 (± 100-400) m (Nasby-Lucas et al., 2019).	Knife-edge selectivity from smallest to largest observed lengths (42-350 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Purse-seine	0.5°x0.5°	72-d	Year-round	NOA sets fish 0-150 m. Species	Knife-edge selectivity from smallest	Assumed no release of marketable species. No PRM data available to

	Purse-seine C1–5 (NOA)		72-d closure (Class-4-5)		assumed to primarily inhabit 0 m to 150 (± 100-400) m (Nasby-Lucas et al., 2019).	to largest observed lengths (120-195 cm TL) (IATTC observer data).	indicate potential survival rate if released from purse-seine sets.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 150 (± 100-400) m (Nasby-Lucas et al., 2019).	Knife-edge selectivity from smallest to largest observed lengths (120-195 cm TL) (IATTC observer data).	Assumed no release of marketable species. No PRM data available to indicate potential survival rate if released from purse-seine sets.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 150 (± 100-400) m (Nasby-Lucas et al., 2019).	In absence of observed length data, knife-edge selectivity assumed from size at birth (59 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 150 (± 100-400) m (Nasby-Lucas et al., 2019).	Knife-edge selectivity from smallest to largest observed lengths (30-292 cm TL) (IATTC/WWF observer data).	Assumed no release of marketable species, but noting potential for 6-22% PRM from industrial pelagic longlines (Miller et al., 2020; Hutchinson et al., 2021)
SPE	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 30 (± 20-100) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (30 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM of a larger related species *Sphyrna mokarran* from industrial longlines (Drymon and Wells, 2017).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 30 (± 20-100) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (30 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 30 (± 20-100) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (30 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 30 (± 20-100) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (30 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 30 (± 20-100) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (30 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 30 (± 20-100) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (30 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 30 (± 20-100) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (30 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 30 (± 20-100) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (30 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM of a larger related species *Sphyrna mokarran* from industrial longlines (Drymon and Wells, 2017).
SPK	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 60 (± 50-300) m (Gallagher and Klimley, 2018).	Knife-edge selectivity from smallest to largest observed lengths (142-283 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM from industrial longlines (Drymon and Wells, 2017).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 60 (± 50-300) m (Gallagher and Klimley, 2018).	Knife-edge selectivity from smallest to largest observed lengths (80-330 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 60 (± 50-300) m (Gallagher and Klimley, 2018).	Knife-edge selectivity from smallest to largest observed lengths (80-330 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).

	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 60 (± 50-300) m (Gallagher and Klimley, 2018).	Knife-edge selectivity from smallest to largest observed lengths (80-330 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 60 (± 50-300) m (Gallagher and Klimley, 2018).	Knife-edge selectivity from smallest to largest observed lengths (80-330 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 60 (± 50-300) m (Gallagher and Klimley, 2018).	Knife-edge selectivity from smallest to largest observed lengths (80-330 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 60 (± 50-300) m (Gallagher and Klimley, 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (70 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 60 (± 50-300) m (Gallagher and Klimley, 2018).	Knife-edge selectivity from smallest to largest observed lengths (110-280 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM from industrial longlines (Drymon and Wells, 2017).
SPL	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 100 (± 80-275) m (Bessudo et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (90-306 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM of a related species *Sphyrna mokarran* from industrial longlines (Drymon and Wells, 2017).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 80-275) m (Bessudo et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (49-400 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM in EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 80-275) m (Bessudo et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (49-400 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM in EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 100 (± 80-275) m (Bessudo et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (49-400 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM in EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 80-275) m (Bessudo et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (49-400 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM in EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 100 (± 80-275) m (Bessudo et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (49-400 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM in EPO industrial purse-seine sets (Eddy et al., 2016).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 100 (± 80-275) m (Bessudo et al., 2011).	In absence of observed length data, knife-edge selectivity assumed from size at birth (47 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 100 (± 80-275) m (Bessudo et al., 2011).	Knife-edge selectivity from smallest to largest observed lengths (47-311 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM of a related species *Sphyrna mokarran* from industrial longlines (Drymon and Wells, 2017).
SPZ	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to	Knife-edge selectivity from smallest to largest observed lengths (96-340	Assumed no release of marketable species, but noting 100% PRM of a related species *Sphyrna mokarran* from industrial longlines (Drymon and

					60 (± 50-144) m (Francis, 2016).	cm TL) (IATTC observer data).	Wells, 2017).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 60 (± 50-144) m (Francis, 2016).	Knife-edge selectivity from smallest to largest observed lengths (55-400 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 60 (± 50-144) m (Francis, 2016).	Knife-edge selectivity from smallest to largest observed lengths (55-400 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 60 (± 50-144) m (Francis, 2016).	Knife-edge selectivity from smallest to largest observed lengths (55-400 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 60 (± 50-144) m (Francis, 2016).	Knife-edge selectivity from smallest to largest observed lengths (55-400 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 60 (± 50-144) m (Francis, 2016).	Knife-edge selectivity from smallest to largest observed lengths (55-400 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 60 (± 50-144) m (Francis, 2016).	In absence of observed length data, knife-edge selectivity assumed from size at birth (55 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 60 (± 50-144) m (Francis, 2016).	Knife-edge selectivity from smallest to largest observed lengths (65-315 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 100% PRM of a related species *Sphyrna mokarran* from industrial longlines (Drymon and Wells, 2017).
SSN	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 22 (± 15-95) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (22 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM of a related species *Sphyrna mokarran* from industrial longlines (Drymon and Wells, 2017).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 22 (± 15-95) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (22 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 22 (± 15-95) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (22 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 22 (± 15-95) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (22 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 22 (± 15-95) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (22 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 22 (± 15-95) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (22 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM for *Sphyrna lewini* released from EPO industrial purse-seine sets (Eddy et al., 2016).
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 22 (± 15-95) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (22 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 22 (± 15-95) m (Brennan, 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (22 cm TL) to L_{∞}.	Assumed no release of marketable species, but noting 100% PRM of a related species *Sphyrna mokarran* from industrial longlines (Drymon and Wells, 2017).
SSQ	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 400 (± 300-2000) m (Crow et al.,	Knife-edge selectivity from smallest to largest observed lengths (30-213 cm TL) (IATTC observer data).	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from longline fisheries.

					2018).		
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 400 (± 300-2000) m (Crow et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (24 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 400 (± 300-2000) m (Crow et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (24 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 400 (± 300-2000) m (Crow et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (24 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 400 (± 300-2000) m (Crow et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (24 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 400 (± 300-2000) m (Crow et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (24 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 400 (± 300-2000) m (Crow et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (24 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so PRM likely 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 400 (± 300-2000) m (Crow et al., 2018).	In absence of observed length data, knife-edge selectivity assumed from size at birth (24 cm TL) to L_{∞}.	Assumed this non-marketable species is discarded but assumed 100% mortality in absence of PRM data from longline fisheries.
TIG	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 100 (± 80-904) m (Lipscombe et al., 2020).	Knife-edge selectivity from smallest to largest observed lengths (60-242 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 0% PRM from longlines in South Atlantic (Afonso and Hazin, 2014).
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 80-904) m (Lipscombe et al., 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (80 cm TL) to L_{∞}.	Assumed this large species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 80-904) m (Lipscombe et al., 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (80 cm TL) to L_{∞}.	Assumed this large species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 100 (± 80-904) m (Lipscombe et al., 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (80 cm TL) to L_{∞}.	Assumed this large species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 80-904) m (Lipscombe et al., 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (80 cm TL) to L_{∞}.	Assumed this large species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 100 (± 80-904) m (Lipscombe et al., 2020).	In absence of observed length data, knife-edge selectivity assumed from size at birth (80 cm TL) to L_{∞}.	Assumed this large species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Artisanal	0.5°x0.5°	Year-	Year-round	Gillnets fish 0–42 m (Martínez et al.,	In absence of observed length data,	Assumed species is released, but noting at-vessel mortality of pelagic sharks

	gillnet		round		2017). Species assumed to primarily inhabit 0 m to 100 (± 80-904) m (Lipscombe et al., 2020).	knife-edge selectivity assumed from size at birth (80 cm TL) to L_{∞}.	in gillnets >91% (Ellis et al., 2017), so assumed PRM of 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 100 (± 80-904) m (Lipscombe et al., 2020).	Knife-edge selectivity from smallest to largest observed lengths (52-248 cm TL) (IATTC observer data).	Assumed no release of marketable species, but noting 0% PRM from longlines in South Atlantic (Afonso and Hazin, 2014).
WSH	Industrial longline	5°x5°	Year-round	Year-round	Deep sets fish 0-300 m. Species assumed to primarily inhabit 0 m to 100 (± 80-400) m (Weng et al., 2007).	In absence of observed length data, knife-edge selectivity assumed from size at birth (146 cm FL) to L_{∞}.	Assumed no retention of this protected species release, but assumed 100% mortality in absence of PRM data from longline fisheries.
	Purse-seine C6 (DEL)	0.5°x0.5°	72-d closure	Year-round	DEL sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 80-400) m (Weng et al., 2007).	In absence of observed length data, knife-edge selectivity assumed from size at birth (146 cm FL) to L_{∞}.	Assumed this large and rarely encountered species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (NOA)	0.5°x0.5°	72-d closure	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 80-400) m (Weng et al., 2007).	In absence of observed length data, knife-edge selectivity assumed from size at birth (146 cm FL) to L_{∞}.	Assumed this large and rarely encountered species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C6 (OBJ)	0.5°x0.5°	72-d closure	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 100 (± 80-400) m (Weng et al., 2007).	In absence of observed length data, knife-edge selectivity assumed from size at birth (146 cm FL) to L_{∞}.	Assumed this large and rarely encountered species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (NOA)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	NOA sets fish 0-150 m. Species assumed to primarily inhabit 0 m to 100 (± 80-400) m (Weng et al., 2007).	In absence of observed length data, knife-edge selectivity assumed from size at birth (146 cm FL) to L_{∞}.	Assumed this large and rarely encountered species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Purse-seine C1–5 (OBJ)	0.5°x0.5°	72-d closure (Class-4-5)	Year-round	OBJ sets fish 0-200 m. Species assumed to primarily inhabit 0 m to 100 (± 80-400) m (Weng et al., 2007).	In absence of observed length data, knife-edge selectivity assumed from size at birth (146 cm FL) to L_{∞}.	Assumed this large and rarely encountered species is discarded but assumed 100% mortality in absence of PRM data from purse-seine fisheries.
	Artisanal gillnet	0.5°x0.5°	Year-round	Year-round	Gillnets fish 0–42 m (Martínez et al., 2017). Species assumed to primarily inhabit 0 m to 100 (± 80-400) m (Weng et al., 2007).	In absence of observed length data, knife-edge selectivity assumed from size at birth (146 cm FL) to L_{∞}.	Assumed species is released, but noting at-vessel mortality of pelagic sharks in gillnets >91% (Ellis et al., 2017), so assumed PRM of 100%.
	Artisanal longline	0.5°x0.5°	Year-round	Year-round	Surface sets fish 0-100 m (Andraka et al., 2013). Species assumed to primarily inhabit 0 m to 100 (± 80-400) m (Weng et al., 2007).	In absence of observed length data, knife-edge selectivity assumed from size at birth (146 cm FL) to L_{∞}.	Assumed no retention of this protected species release, but assumed 100% mortality in absence of PRM data from longline fisheries.

APPENDIX 3. Sources of biological parameters used in EASI-Fish for assessing the 32 shark species caught in the pelagic fisheries in the eastern Pacific Ocean, including maximum recorded age ($t_{\max}$), the growth parameters (L_∞, K, t_0), length-weight (L-W) relationship parameters *a* and *b*, length-at-maturity (L_{MAT}), and length-at-birth (L_0).

Species	$t_{\max}$ (years)	L_∞, K, t_0	L-W *a* & b	L_{MAT} (cm)	L_0 (cm)
Alopias vulpinus	Smith et al. (2008)	Teo et al. (2016)	Kohler et al. (1995)	Smith et al. (2008)	Smith et al. (2008)
Carcharhinus brachyurus	Drew et al. (2017)	Drew et al. (2017)	Torres (1991)	Lucifora et al. (2005)	Lucifora et al. (2005)
Prionace glauca	Joung et al. (2018)	Joung et al. (2018)	ISC (2017)	Fujinami et al. (2017)	Fujinami et al. (2017)
Alopias superciliosus	Liu et al. (1998)	Liu et al. (1998)	Liu et al. (1998)	Liu et al. (1998)	Chen et al. (1997)
Carcharhinus altimus	Ebert et al. (2021)	Froese and Pauly (2022)	Froese and Pauly (2022)	Compagno et al. (1995)	White et al. (2006)
Carcharhinus leucas	Tillett et al. (2011)	Tillett et al. (2011)	Froese and Pauly (2022)	Pirog et al. (2019)	Neer et al. (2005)
Carcharhinus galapagensis	Cortés (2000)	De Crosta (1984)	Wetherbee et al. (1996)	Wetherbee et al. (1996)	Wetherbee et al. (1996)
Carcharhinus limbatus	Harry et al. (2019)	Harry et al. (2019)	Harry et al. (2019)	Harry et al. (2019)	Harry et al. (2019)
Carcharhinus plumbeus	Romine et al. (2006)	Joung et al. (2004)	Joung et al. (2004)	Joung and Chen (1995)	Joung et al. (2004)
Carcharhinus porosus	Lessa and Santana (1998)	Lessa and Santana (1998)	Lessa et al. (1999)	Lessa et al. (1999)	Lessa et al. (1999)
Nasolamia velox	Froese and Pauly (2022)	Froese and Pauly (2022)	Raeisi et al. (2017)	Froese and Pauly (2022)	Froese and Pauly (2022)
Carcharhinus obscurus	Joung et al. (2015)	Joung et al. (2015)	Joung et al. (2015)	Chen (2004)	Joung et al. (2015)
Carcharhinus falciformis	Sánchez-de Ita et al. (2011)	Joung et al. (2008)	Oshitani et al. (2003)	Joung et al. (2008)	Oshitani et al. (2003)
Isistius brasiliensis	Froese and Pauly (2022)	Froese and Pauly (2022)	Froese and Pauly (2022)	Jahn and Haedrich (1988)	Gadig and Gomes (2002)
Isurus paucus	Ardizzone et al. (2006)	Semba et al. (2009)	Bishop et al. (2006)	Ruiz-Abierno et al. (2021)	Gilmore (1993)
Lamna ditropis	Goldman and Musick (2006)	Goldman and Musick (2006)	Goldman (2002)	Goldman and Musick (2006)	Goldman (2002)
Carcharhinus longimanus	Joung et al. (2016)	Joung et al. (2016)	Joung et al. (2016)	Joung et al. (2016)	Joung et al. (2016)
Lamna nasus	Francis (2015)	Francis (2015)	Francis et al. (2008)	Francis (2015)	Francis and Stevens (2000)
Pseudocarcharias kamoharai	Lessa et al. (2016)	Lessa et al. (2016)	Liu and Dai (2008)	Wu et al. (2020)	Fujita (1981)
Alopias pelagicus	Drew et al. (2015)	Drew et al. (2015)	Liu et al. (1999)	Drew et al. (2015)	Drew et al. (2015)
Rhincodon typus	Wintner (2000)	Hsu et al. (2014)	Hsu et al. (2012)	Hsu et al. (2014)	Hsu et al. (2014)
Rhizoprionodon longurio	Froese and Pauly (2022)	Froese and Pauly (2022)	Márquez–Farias et al. (2005)	Corro-Espinosa et al. (2011)	Márquez–Farias et al. (2005)
Dalatias licha	Francis et al. (2018)	da Silva (1988)	Kousteni (2021)	Francis et al. (2018)	Francis et al. (2018)
Isurus oxyrinchus	Ardizzone et al. (2006)	Semba et al. (2009)	Bishop et al. (2006)	Semba et al. (2011)	Semba et al. (2009)
Sphyrna media	Froese and Pauly (2022)	Froese and Pauly (2022)	Froese and Pauly (2022)	Froese and Pauly (2022)	Murch (2022)
Sphyrna mokarran	Harry et al. (2011)	Harry et al. (2011)	Stevens and Lyle (1989)	Harry et al. (2011)	Harry et al. (2011)
Sphyrna lewini	Drew et al. (2015)	Drew et al. (2015)	Stevens and Lyle (1989)	Estupiñán-Montaño et al. (2021)	Estupiñán-Montaño et al. (2021)
Sphyrna zygaena	Rosa et al. (2017)	Chow (2004)	Chow (2004)	Nava Nava and Márquez-Farías (2014)	Nava Nava and Márquez-Farías (2014)
Sphyrna corona	Froese and Pauly (2022)	Froese and Pauly (2022)	Guzman et al. (2020)	Orozco Guarin (2014)	Orozco Guarin (2014)
Zameus squamulosus	Irvine et al. (2006)	Irvine et al. (2006)	Irvine et al. (2006)	Crow et al. (2018)	Crow et al. (2018)
Galeocerdo cuvier	Holmes et al. (2015)	Holmes et al. (2015)	Holmes et al. (2015)	Whitney and Crow (2007)	Whitney and Crow (2007)
Carcharodon carcharias	Natanson and Skomal (2015)	Natanson and Skomal (2015)	Natanson and Skomal (2015)	Tanaka et al. (2011)	Natanson and Skomal (2015)