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Characterisation of the fisheries catching South Pacific shortfin mako sharks (*Isurus oxyrinchus*) in the Western and Central Pacific Ocean

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Report prepared for WCPFC SC18

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CONTENTS

EXECUTIVE SUMMARY

South Pacific shortfin mako sharks (*Isurus oxyrinchus*) are thought to consist of two stocks a southwest and southeastern stock which are both separated from those in the north Pacific at the Equator. This paper describes the fisheries catching shortfin mako sharks in the Southwestern Pacific Ocean as well as the reported and observed data potentially available for use in a stock assessment.

Currently it appears that there are a reasonable amount of data available for undertaking catch reconstructions and CPUE standardisations for the development of a stock assessment. Overall, the data will be confounded by reporting changes that have come about from regulatory changes and these are apparent throughout the results, and possibly some misidentification of porbeagle sharks. Few CCMs provided data prior to 2000 and most data were from Australia and New Zealand. The spatial extent of the data provisions has increased in the last two decades and is now broadly representative of the fishing effort. However, due to these changes, the catch history of shortfin mako shark is short and not consistently representative through time. In addition, aggregated data are submitted as annual totals for the entire WCPO, and they are not stock specific. These data should in future be separated at the equator.

There is a general increase in the number of observer samples of all kinds over time, and these data are also more detailed in recent years. There are strong trends across most fleets for vessels to discard sharks as CCMs implement WCPFC regulations and some CCMs ban the retention of all sharks within their EEZs. There is also a tendancy for vessels to cut sharks free before they are landed on the vessel, and recently a higher proportion of discards are reported as cut free. Depth of gear and latitude will impact the catch rates of shortfin mako sharks.

Longline gear attributes such as hooks between floats, hooks set, baskets set, bait used, branch line length and distance will likely be informative for CPUE standardisation. However, they are inconsistently reported, both among and within fleets. Generally, there is a trend for more hooks between floats, and a decreases in the hooks set and in the baskets set. The number of shark lines deployed or the number of floats with shark lines should be recorded as currently it is not possible to assess the proportion of shark lines deployed per set. Some observers and fleets are still recording mako sharks to the generic mako code and not specifying these as shortfin or longfin mako sharks. This should be rectified in future.

Shortfin mako sharks are wide ranging across the South Pacific Ocean, and display weak size and seasonal movement patterns, there appears to be a reasonable amount of data from 1990-2020, but the data by fleet are incomplete and poorly reported throughout the history of the fishery for most fleets. Catch reporting has improved across all fleets over time, and has resulted in more data being available in recent years. However, these trends are unlikely to be linked to changes in targeting or stock biomass, but are simply reflective of increased coverage rates.

The data are limited as a result an integrated stock assessment for shortfin mako sharks will be challenging and increase the uncertainty in the outputs. This is likely to be the case for most shark assessments. Added to this is the impact of regulatory changes on fishery dependent data, and generally low observer coverage in longline fleets. Some focused work on how to get better CPUE data for sharks in general would be useful and

it is recommended that a workshop to review the data, data handling protocols and ways to improve data collection.

The following recommendations are proposed for the Scientific Committee to consider:

1. Aggregated data are submitted as annual totals for the WCPFC area only, making them uninformative for a stock specific assessment. Therefore, shortfin mako shark aggregated data (and probably other Key Sharks) should be reported by ocean area not simply as WCPO and, where possible, these data should be retrospectively corrected. As such paragraph 1 bullet point 3 of the scientific data to be provided to the commission should include the following: "**For key sharks estimates of annual catch should be separated into catch north and south of the Equator. The WCPFC secretariat should work with CCMs to get these data retrospectively corrected where possible.**"

2. Observers (or the vessels crew) should record number of shark lines deployed or the number of floats with shark lines.

3. Observers and vessel crew should be encouraged to use mako species specific codes rather than the generic code MAK.

4. Convene a workshop to assess how to get better CPUE data for sharks in general assess the data, data handling protocols and ways to improve data collection.

1. INTRODUCTION

South Pacific mako shark (*Isurus oxyrinchus*) are thought to consist of two stocks, a southwest and southeastern stock which are both separated from those in the north Pacific at the Equator (Francis et al. 2019). This assertion is largely based on genetic analysis (Francis et al. 2019) as well as tagging work in the Eastern Pacific, USA, and New Zealand (Francis et al. 2019; Sippel et al. 2016; Abascal et al. 2011), which showed that mako sharks move extensively across South Pacific Ocean but have not been observed crossing the Equator. Tagging in the southwest Pacific suggested a substantial degree of fidelity to this region, with fish primarily remaining within approximately 150°E-160°W longitude, and 20-40°S latitude. Sippel et al. 2016 also noted that mixing of the northern and southern populations of shortfin mako sharks appears to be more likely in the eastern Pacific than western. Shortfin mako sharks are wide ranging inhabiting both coastal and oceanic habitats (Francis et al. 2019; Gibson et al. 2021). There are some genetic linkages between the southwest Pacific, southern Indian and south Atlantic Oceans (Corrigan et al. 2018).

Shortfin mako sharks are relatively unproductive as they are late to mature with moderate longevity and low natural mortality (0.10-0.15) (Bishop et al. 2006; Campana et al. 2005). They grow rapidly, initially increasing size quickly, males and females grow at similar rates until male maturity (about 7-years old), after which the relative growth of males declines. Females mature later in life at 19-21 years old. Shortfin mako have been estimated to live for 29 and 28 years for males and females respectively, although in the eastern Pacific female longevity was estimated at 39 years old (Carreon-Zapiain et al. 2018). Validated age estimates from the Atlantic estimated maximum age to be 29 (260 cm FL) and 32 years (335 cm FL) for males and females respectively, with age at maturity estimated at 8 years for males and 18 years for females (Natanson et al. 2006). Bishop et al. (2006) also noted that there appears to be no regional differences in growth rate. The gestation period lasts 15-18 months with developing embryos feeding on unfertilized eggs in the uterus, 4-25 young are born at about 70cm long then the females rest for 18 months after birth before the next batch of eggs are fertilized (Campana et al. 2005).

Longline fisheries targeting tuna and other pelagic species in the Western and Central Pacific Ocean (WCPO) began on an industrial scale in the early 1950s, and since that time have expanded in size and spatial extent of their operations (Williams and Ruaia 2021). Prior to 2000 the bulk of the longline fishing effort was north of the Equator, but in more recent decades effort has been higher to the south. Longline fishing effort targeting tuna now covers almost all of the Pacific Ocean. In addition, swordfish fisheries have been in existence in the Pacific Ocean for decades, beginning in earnest south of the Equator in the early 1990s as did blue shark target fisheries. While some blue shark target fisheries exist in the South Pacific Ocean no mako shark target fisheries exist, much of the shortfin mako catch is made as bycatch in tuna and swordfish target fisheries (Williams and Ruaia 2021).

Historically, bycatch went unreported or were poorly reported on vessel logsheets, particularly for sharks that were finned and discarded (Brouwer and Harley 2015, Brouwer and Hamer 2020). Observer data exist for most longline fisheries in the WCPO. However, for many fleets the programmes are relatively new and coverage levels are low. In addition, the observer effort and fishing effort are unevenly distributed throughout the WCPO (Williams et al. 2020). As a result, historic catch for sharks is ambiguous, and catch histories often need to be reconstructed rather than relying on reported or observed catch

(Peatman et al. 2018, Neubauer et al. 2021a).

As of the 1^{st} of November 2020 all chondrichthyans caught in fisheries managed under the Western and Central Pacific Fisheries Commission (WCPFC) are managed under CMM2019-04 (WCPFC 2019). To ensure the long-term protection and sustainable use of sharks, this Conservation and Management Measure (CMM) aims for a precautionary approach to managing sharks while attempting to focus on an ecosystem approach to fisheries management. The CMM has provisions for full-utilisation or live (safe) release of sharks, some gear restrictions to limit shark bycatch in fisheries targeting tuna and billfish, as well as compulsory reporting of catch (including both retained and discarded catch) of WCPFC Key Sharks (which includes shortfin mako sharks). In addition, there are provisions requiring the WCPFC to undertake periodic stock assessments and maintain a WCPFC Shark Research Plan (SRP). While CMM2019-04 has species specific provisions for some species, there are none for shortfin mako sharks which therefore fall under the general provisions. Shortfin mako sharks in the North and South Pacific are both scheduled for periodic (5-yearly) assessment under the SRP (Brouwer and Hamer 2020).

This paper describes the fisheries catching shortfin mako sharks in the Southwestern Pacific Ocean as well as the reported and observed data potentially available for use in a stock assessment. Note that 2021 data are provisional, as longline data are reported with a 1-year delay due to the long length of the trips. Shortfin mako sharks are predominantly caught in longline fisheries, and these are the focus of this report. These analyses are provided in support of the shortfin mako shark catch reconstruction (Large et al. 2022a) and stock assessment (Large et al. 2022b).

2. METHODS

Data from Members, Cooperating Non-Members and Participating Territories (CCMs) of the WCPFC held by the Pacific Community (SPC) were extracted from various databases at SPC. Longline and purse seine logsheet, as well as observer data and annual catch estimates were requested, including:

- Longline
  - WCPFC public domain yearbook catch and effort data aggregated by year and flag.
  - 5x5° aggregated best estimates by day, flag, latitude and longitude, catch and effort.
  - Operational (logsheet[1]) catch and effort data from 1970-2019, by day, flag, Exclusive Economic Zone (EEZ), latitude and longitude, set type, catch and effort.
  - Observer data[1], including all set, gear, catch, fate and condition information.
  - Length data including length (cm) measurement units for all fish measured.
- Purse-seine
  - WCPFC public domain yearbook catch and effort data aggregated by year and flag.

- 1x1° aggregated best estimates by day, flag, latitude and longitude, set type, catch and effort.
- Operational (logsheet[1]) catch and effort data, by day, flag, EEZ, latitude and longitude, set type, catch and effort.
- Observer data[1] including all set, gear, catch fate and condition information.
- Length data including length (cm) measurement units for all fish measured.

All data were collated and analyses were performed in R (R Core Team 2020). Longline catch and effort, as well as observer data, were plotted spatially. Range checks were performed on the latitude and longitudes to ensure all data were from the WCPO south of the equator, and outliers were removed. Catch and effort data were collated by grid cell (1x1^o or 5x5^o), year and month. Nominal annual and monthly Catch per Unit of Effort (CPUE) was used to derive the catch per 100 hooks for longline and catch per set for purse seine on both the logsheet as well as observer data. No standardised CPUE information is presented here, those analyses are presented in Large et al. (2022a).

The total shortfin mako shark catch by flag and ocean area (EEZ, as well as high seas areas) were calculated from the unraised logsheet data, and summaries of the catch by ocean area are derived from the raised aggregated datasets provided. Observers are instructed to observe every hook to the extent possible, and when breaks occur these are recorded. On longline vessels each fish is identified, measured, sexed, allocated a fate code, and condition code on capture and release (if the fish is observed being released/discarded). The time of capture is recorded, as is the hook number, along with other relevant information. In addition, the set, haul and gear information are recorded separately. The catch and set data sets were merged, and this dataset was then used for all analyses of observer data. Maturity was assumed to mirror that in the north Pacific as specified by Kai et al. (2017) and fish <90cm TL were considered to be juvenile, those 90 - 160cm were considered to be subadults while those >160cm were considered mature.

Shortfin mako shark fate and condition information were extracted from the longline merged dataset. For each fish observed, observers record the fate of the fish and allocate the fate to one of 26 codes (Table 1). The fish condition is recorded at capture and release (if the fish is released) and allocated to one of six codes (Table 2). Fate codes were grouped into four broad groups (Escaped, Discarded, Cut free and Retained; noting that the finned state was included as retained). These data were then collated by year and vessel flag.

Fish are allocated to a hook number within a basket, where the first hook aboard after a float is recorded as hook one. Subsequent hooks are then numbered sequentially to the next float. Hooks on a shark line, that is, those attached directly to the float, are allocated number 99. The hooks between floats is recorded for each set. This allows the mid-point to be known, and all hooks beyond the mid-point were re-numbered from the mid-point back to one. For example, a basket with 10 hooks between floats would have hooks numbered 1-5 and 5-1. The shark hook was allocated a number 0. Therefore, the shallowest hooks have the lowest number, and the deepest hooks the largest. These allocated hook numbers can then be used as a proxy for relative capture depth.

The observers record the float line length (m), branch line length (m), branch line distance

[1]Note: Not all logsheet and observer data are available for stock assessments of elasmobranchs. As a result, the SPC could not release logsheet or observer data from some WCPFC member countries for the shortfin mako shark stock assessment and related analyses.

(m) and the use of lightsticks. The branch line distance is the length of mainline between two branch lines. The observer instructions note that "Distance between branch lines may be hand measured or calculated by the observer using the formula: Line Setting Speed x Branch line Set Interval, or if not available, ask fishing master etc. for the distance between branch lines." Prior to 2016, the number of lightsticks used was the total number used in the set. This changed in 2016 to recording the hook number between floats that lightsticks were recorded on. In reality the take-up of new forms is slow, due to the length of the trips, and this change probably only impacts data after 2018.

Most observer programmes record shortfin mako shark length as upper jaw to fork in tail (UF). A small proportion of observers record other length metrics, such as total length (TL) or pre-caudal length (PC). Total length and PC measurements were converted to UF using the formulae described in Francis and Duffy (2005), and length data were collected by year, flag, sex and hook number. Length was also assessed by flag, 5x5° ocean area and latitude.

3. RESULTS

3.1 Overall catch and effort

Within the WCPFC Convention area south of the Equator, the bulk of the reported longline shortfin mako shark catch comes from the areas south of 30^o south, but to the north, with higher catch reported in the Fiji and American Samoa EEZs and to some extent Australia (Figure 1). Fishing effort is concentrated north of 30^o south (Figure 1). Most of the reported shortfin mako shark catch comes from the New Zealand EEZ and the south central high seas areas to the east of New Zealand, with lower levels of reported catch elsewhere. Reported shortfin mako shark catch on logsheets is higheer in EEZs than the high seas.

Overall, longline effort within the WCPFC Convention area has increased through time. Compared to the WCPFC Convention area north of the Equator, longline effort in the south was low prior to 1995, increased rapidly from about 2000, and since then has been higher south of the Equator (Figure 2). New Zealand, Australia and New Caledonia have been reporting catch continuously since the early 2000s, most of the other CCMs began reporting shortfin mako shark catch in the mid- to late-2000s (Figure 3). For a number of CCMs, such as New Zealand, Australia and the USA, there is a marked decline in reported shortfin mako shark catch since the mid-2000s. For other CCMs, such as the Solomon Islands, shortfin mako shark catch reporting began after 2015. Unfortunately, the annual catch estimates submitted to the WCPFC are all reported as shortfin mako shark in the Convention Area and not separated north and south of the Equator making stock specific annual catch estimates problematic (Figure 4).

Since 2006, the reported longline catch of South Pacific shortfin mako sharks has increased markedly. The catch levels have fluctuated without trend at this elevated level, with the exception of a peak in 2007. The low catch in 2021 is likely due to a delay in longline reporting rather than a reduction in catch (Figure 5). Prior to 2010, catch reporting of South Pacific shortfin mako sharks was low with around >90% of logsheets from the WCPFC Convention area south of the Equator not recording any shortfin mako shark catch (Figure 6). However, since 2010 catch reporting has shown a slight improvement, and in 2020 only about 86% of longline logsheets did not report any shortfin mako shark catch, which is very close to the observed rate where only 12% of observed sets reported shortfin mako shark catch. This is likely a reflection of improved reporting but also relativity low catch rates.

Catch reporting of shortfin mako sharks in the south Pacific has been inconsistent through time. In the 1990s a small amount of catch was reported, mostly within the Australia, New Zealand, New Caledonian and French Polynesian EEZs (Figure 7 top). Through the 2000s catch reporting improved and shortfin mako sharks were reported from some fisheries on the high seas as well as within most EEZs (Figure 7 middle). In the 2010s South Pacific shortfin mako shark catch reporting was widespread and are now reported frequently in logbooks and from all areas where longline fisheries occur (Figure 7 bottom).

3.2 Fate and condition

Observer reporting of shortfin mako shark fate and condition has improved over time. Overall, there has been a continuous increase in the number of fate and condition records being reported (Figure 8). In addition, since 2013 a higher number of shortfin mako sharks are being discarded, and since 2016 most of the discards are fish that are cut free, with only a small proportion currently being retained. The low number of samples from 2021 are likely a result of delays in observer data provision as well as lower observer coverage due to the COVID-19 pandemic. For many CCMs prior to 2015 a high proportion of the shortfin mako shark catch was retained, with discarding (including fish being cut free) clearly more apparent in the last five years (Figure 9). There are some exceptions to these trends, French Polynesia and New Caledonia began discarding shortfin mako sharks about a decade before most other countries, as did the USA, while some CCMs such as Japan, Chinese Taipei and Tonga still retain a high proportion of their shortfin mako shark catch. The gap in the most recent period for Australia (in these data and all the following plots) is likely a result of that CCM moving to e-monitoring (EM) and their EM data are not currently available for analysis in this format.

Observer reporting on shortfin mako shark condition at capture shows that most shortfin mako sharks are alive and healthy (condition code A1) at capture on most CCMs vessels, and this trend is relatively consistent across years and fleets (Figure 10). Two exceptions are noted, for New Zealand and Chinese Taipei vessels, where observers have recorded code A0 (“Alive but not categorized”) frequently in the past. Both CCMs observers now use more specific codes. The condition at release information suggests that handling practices may have changed for some fleets. For fleets with a longer observer history it is noticeable that in the past most sharks were discarded dead, but in recent years a high proportion of sharks are released alive and healthy this is particularly noticeable for Fiji, New Caledonia and French Polynesia (Figure 11).

Comparing the fate, condition at capture, and condition at release across fleets overall, in the most recent years most shortfin mako sharks (>70%) are released/discarded, and most of those are simply cut free and not landed on the vessel at all (Figure 12 top). Most shortfin mako sharks are alive and healthy at capture and reporting condition has improved in recent years (Figure 12 middle). Condition at release has improved since about 2008 and currently a high proportion of shortfin mako sharks are released in a live and healthy state (Figure 12 bottom).

3.3 Hook depth

Catch by hook number can be used as a proxy for relative catch depth. The catch by hook number analysis indicated that shortfin mako sharks are caught on the shallowest hooks most frequently and, while they can get caught on the deep hooks, this happens in low numbers. Generally speaking, shortfin mako sharks are caught on the hook numbers 1-4 in a basket, that is, the hooks closest to the float (Figure 13). Shortfin mako sharks are also caught on shark lines (here represented by hook 0). These lines are designed to target sharks and could represent a high proportion of catch. However, we have no information on the number of shark lines deployed per line and, as a result, we could not calculate relative frequencies.

3.4 Length data

South Pacific shortfin mako shark length data have been recorded since 1990, but the sample collections have been variable. Overall, from 1990 to the mid-1990s, the median length of shortfin mako sharks in the South Pacific increased, after which it fluctuated without trend. A small increase in the latest year is likely a result of low sample size (Figure 14 top left). Most shortfin mako sharks are measured to UF (Figure 14 top right). Overall, the number of samples has increased through time but has decreased slightly in the late 2010s, which co-insides with the high proportion of sharks being cut free and therefore not available for measurement (Figure 14 bottom left) and the length frequency seems to be uni-modal with no difference between male and females (Figure 14 bottom right).

Most length samples come from Chinese Taipei, New Zealand, Australia, Fiji and Japan (Figure 15). Australia, Japan and New Zealand and to a lesser extent China and Korea have a high number of small fish in their catch while fish sampled by Chinese Taipei, Fiji French Polynesia, New Caledonia and Tonga tend to be larger. The number of length samples by flag has changed through time (Figure 16), and this likely has influenced the overall trends in length by increasing the median length in the more recent period (Figure 14 top left). In the early 1990s, the median shortfin mako shark size in the Australia, Japan and New Zealand was low, and few other flags had samples from that time, but as fleets fishing closer to the equator began reporting length data the median increased. For many flags the median shortfin mako shark size was relatively consistent through time but for New Zealand and Fiji the median fish size had declined in the most recent period, probably as a result of larger fish being cut free and not available for measurement by the observers.

Shortfin mako shark size does not seem to change with depth, where the catch by hook number analysis showed relatively consistent size-at-catch across the range of hooks sampled (proxy for depth) (Figure 17). In addition, broadly grouping the sets into deep and shallow sets showed little difference in fish size between these two groups (Figure 18).

There are relatively strong trends in shortfin mako shark size with latitude (Figure 19). Shortfin mako sharks in the higher latitudes are smaller than those in the mid-latitudes and the equatorial regions. The largest fish seem to reside in the mid-latitudes most often between 15 and 30^{o} South, but also furthest to the south, with medium sized fish in the Tropics and juveniles in the higher latitudes. Reviewing the catch distribution by maturity reveals that the juvenile fish seem to occur further to the west while the subadults and adult fish are widely distributed (Figure 20).

Assessing the shortfin mako shark catch relative to the target tuna and swordfish stocks as well as blue and porbeagle sharks revealed distinctive trends. Separating the data into deep and shallow sets (based on the number of hooks between floats with those >12 being classes as deep sets) showed that shortfin mako sharks are caught in higher proportions in the shallow sets compared to deep sets (Figure 21). When assessing the catch of sharks only, it is apparent that blue sharks dominate the reported catch and there is a large increase in the proportion of porbeagle sharks reported in the catch in the late 2000s, it is also apparent that there is a reduction in the use of the generic shark code but there is an increase in the use of the the non-specific generic mako code from 2015 (Figure 22). It also appears that since 2015 a high proportion of the generic shark code is now reported as shortfin mako. The deep set data indicate that shortfin mako sharks catch proportions were lower since 2010. Overall the shortfin mako catch proportions have been relatively stable since 2002. There were also very high catch proportions of porbeagle sharks prior to 2000.

For most CCMs, the catch ratios of shortfin mako sharks are relatively consistent through time (Figure 23). These data will however be confounded by where the data come from, with sets in the higher latitudes being shallower than those in the tropics. Prior to 2000, Japan had high catch proportions of shortfin mako sharks, these are lower in the more recent period. New Zealand has had consistently high proportions of shortfin mako and porbeagle sharks compared to the other CCMs, and the remaining CCMs have very low shortfin mako shark catch proportions. The Cook Islands and Papua New Guinea and to a lesser extent Tonga and Chinese Taipei had higher catch of longfin mako sharks.

The depth of the fishing gear is also likely to influence shortfin mako shark catch. New Zealand vessels have consistently set shallower sets than other CCMs. Australia has switched from shallow to deep sets, with most other CCMs having relatively consistent estimated gear depth being used through time (Figure 24). However, these data should be viewed with caution and some vessels may set many hooks per basket, but add additional small floats to the main line to increase buoyancy, and the mainline type may also impact the depth of the gear. Switching from traditional mainline types to mono-filament line is thought to have made the lines more buoyant, while adding weights to the backbone to increase the sink rates to reduce seabird bycatch can result in heavier line and a deeper set.

3.5 Other gear attributes

Assessing all fleets combined (for sets that landed shortfin mako sharks), overall the data will be biased by fleets that have longer reporting histories. Nevertheless, most longline vessels report setting 100-200 baskets, the hooks between float use peaks at 9 - 12, but is also relatively high for 5 - 8 and with fewer vessels using higher hooks between floats between floats and setting 3-4000 hooks (Figure 25). Float lines are mostly 10-30m long, most vessels use shorter branch lines set 30-50m apart. Most vessels will use fewer than 1000 lightisticks on a set and most use mackerel fish bait (Figure 25).

There is a distinctive switch in gear over time (Figure 26). Since the mid-2000s there has been a change for vessels to use more hooks between floats (Figure 26 top left), and to set fewer baskets per line (Figure 26 bottom left). There has also been a switch in the numbers of hooks set with the most recent period being similar to that experienced in then late 1990s with higher numbers of hooks being set (Figure 26 top right). Vessels use less squid bait in the more recent years, and mackerel is the dominant bait being used by vessels catching mako sharks (Figure 26, bottom right).

The combined fleet data are likely influenced by data availability. The fleet specific data show that, while most fleets have been relatively consistent in the number of hooks between floats, New Zealand vessels have moved to using more hooks between floats since 2000 but still use mostly 13-19 hooks between floats, as have Japanese and Australian vessels but to a lesser extent (Figure 27). Fiji, China, Chinese Taipei and Japanese vessels all set more hooks in the more recent period (Figure 28). Australia sets more baskets per line in the more recent years, while New Zealand Sets fewer (Figure 29). Bait use across fleets is variable, but the data for many fleets are sparse (Figure 30). While most fleets tend to use fish bait, there is a strong switch from fish to squid for Korean flagged vessels and since 2007 they have used 100% squid bait.

Figure 31 shows the branchline length and distance, floatline length and light stick use for all fleets combined. These data suggest that branchline length and floatline length have increased in the more recent years, but branchline distance has decreased. The data on lightstick use is poorly reported. Branch line length data are variable between fleets, but for most it has increased slightly in recent years (Figure 32). For most fleets branchline distance has remained relatively low but has been decreasing in Fiji and New Caledonian fleets and increasing on French Polynesian vessels (Figure 33). Floatline length for most fleets has been relatively consistent through the 2000s but is increasing in Fiji and Chinese Taipei since 2010 (Figure 34). It is difficult to assess the fleet specific lightstick use trends, the only vessels showing strong trends are the Chinese Taipei vessels who are increasing their use of lightsticks in the most recent two years, but these data are sparse and should be used with caution (Figure 35).

Comparing the number of hooks between floats to the branch line length and float line length showed very weak trends. Vessels using short branch lines often use a low number of hooks between floats, but not always, and the association between hooks between floats and float line length is weak. Vessels using high hooks between floats tend to have longer branch lines but not necessarily longer float lines (Figure 36). While most vessels (92%) used no lightsticks, a number of vessels (1%) used 100% lightsticks (here 100% lightsticks refers to sets with equal number of lightsticks and hooks per set, and 50% would be 1 ligtsitck on every second hook). Of the vessels that use lightsticks 13% have 100% lightsticks, and 16% had 50% or more (Figure 37).

The use of different hook types revealed that circle are most frequently used on sets catching shortfin mako sharks and there has been an increase in the use of circle hooks and other hook types and a decline in "Japanese hooks" (Figure 38). This trend is true for most fleets and is particularly noticeable for the Fiji and French Polynesian fleets, while the Japanese fleet has consistently used "Japanese hooks" (Figure 39).

3.6 Purse seine gear attributes

There were few shortfin mako shark records in the purse seine catch and, as a result, the trends are reported for all fleets combined only (Figure 40). These data show that there has been an increasing tendency to discard shortfin mako sharks (Figure 40 top left), although actual observed catch is low. Condition at landing and release data are too infrequently recorded to be meaningful (Figure 40 top right and middle left). Only a few length measurements are available and while these are limited they show that smaller mako sharks get caught more frequently in purse seine gear (Figure 40 middle right). Shortfin mako sharks are caught in the greatest numbers on Fish Aggregating Devices (FADs), and when they join tuna feeding on bait fish. They are rarely caught in free school sets with no bait fish, and never in sets associated with whales or whalesharks[2] (Figure 40 bottom left). The catch and CPUE data show that in recent years the purse seine catch of shortfin mako sharks is very low (Figure 40 bottom right).

3.7 Nominal CPUE map

Shortfin mako shark catch rates were higher south of 20°S and within and to the east of the New Zealand EEZ (Figure 41). However, the catch rates change seasonally (Figure 42) and shortfin mako shark catch rates are highest and centred further to the south in the first quarter, decreasing and moving north the Austral winter and into the Austral Spring.

4. DISCUSSION

Currently it appears that there are a reasonable amount of observer and logsheet effort data available for undertaking catch reconstructions and CPUE standardisations for the development of a stock assessment. However, the data are patchy in space and time and by fleets, and therefore we can expect any catch reconstruction to have a high uncertainty. Brouwer and Hamer (2020) summarised these data as part of the WCPFC SRP. That analysis showed that there are longline observer data from 1990-2019, longline logsheet data from the mid-1990s-2019; there are no purse seine logsheet records and very few purse seine observations of shortfin mako sharks. There are good biological data for shortfin mako sharks (e.g. Clarke et al. 2015; Bishop et al. 2006; Campana et al. 2005 and Francis and Duffy 2005). There are also length samples from the 1990s to present. However, as noted above, they are limited mostly to the New Zealand fleet with a few samples from other fleets such as Australia, China, Chinese Taipei, Fiji and Japan.

The WCPFC does not hold any new age and growth samples for analyses. The two main sources of information about age and growth of shortfin mako shark in the South Pacific have limitations, and age and growth data are still required. Further, ageing methods have not been validated. The Bishop et al. (2006) investigation assessed shortfin mako sharks from a limited area (the New Zealand EEZ) but had a wide size range of individuals. An expanded analysis would be useful. Until then, a sensitivity to the age and growth parameters derived from this study should be included in the assessment to assess the impact of growth and longevity on the assessment results.

The SRP information sheet summarises the known biological parameters and fishery data for South Pacific shortfin mako sharks (Brouwer and Hamer 2020). The WCPFC recognise that South Pacific shortfin mako sharks comprise a single stock separated from shortfin mako sharks in the north Pacific at the Equator. They are relatively unproductive as they are late to mature with moderate longevity and low natural mortality. Females in particular are late to mature only maturing at around 19-21 years old.

[2] In the WCPFC Convention Area purse seine vessels have been prohibited from setting on cetaceans since 2013, and whalesharks since 2014.

The SRP report card presented in Brouwer and Hamer (2020), indicates that a data rich assessment could be possible given the data availability. However, this does not assess the quality of these data nor their use for an assessment. These issues will be discussed in more detail by Large et al. (2022a) and Large et al. (2022b). The report card notes that gaps in the observer data may inhibit catch history estimation, and this issue will be explicitly investigate by Large et al. (2022a), in a similar manner to that which was done for the blue shark stock assessment in 2021 (Neubauer et al. 2021a, Neubauer et al. 2021b). Noting this, broadly speaking, it appears that there are enough data to explore undertaking an integrated assessment, provided that these data are of a high enough quality and that the catch reconstruction can deliver a reliable long-term catch time series.

While the WCPFC SRP provided broad data compilations, the data in the characterisation presented here are more detailed. As part of this investigation it was determined that the WCPFC aggregated data, while somewhat extensive, are not particularly useful as they are not split between the north and south Pacific Ocean. As a result, a South Pacific mako shark assessment cannot use these data without making assumptions about the level of effort expended north and south of the Equator and redistributing the catch between the two. While this would be easy for some fleets that fish only above or below the equator, for those that straddle it splitting the catch cannot be reliably done. Ocean area specific data reporting will be essential in future.

Overall, the data will be confounded by reporting changes that have come about from regulatory changes and these are apparent throughout the results. Through the history of the WCPFC there have been a number of CMMs directed at sharks, a number of which have had implications for shark reporting. CMM2006-05 included voluntary shark reporting requirements for key sharks, but no key sharks were defined in that measure. Despite CMM2006-05 coming into force, the reported catch of shortfin mako sharks increased substantially. However, there were still a lot of logsheets where no shortfin mako sharks were reported. CMM2009-04 included specific reference to WCPFC Key Sharks which included shortfin mako sharks. As a result of that (and probably the development of new logsheets that specifically included shortfin mako shark), the proportion of shortfin mako sharks in the logsheets increased, and the proportion of logsheets with zero shortfin mako sharks has declined in recent years from around 95% prior to 2010 to around 86% currently. The recent trend is very close to the observed rate where only 12% of observed sets reported shortfin mako shark catch. Changes in where the data were coming from have also occurred. Few CCMs provided data prior to 2000 and most data were from Australia and New Zealand. The spatial extent of the data provisions has increased in the last two decades and is now broadly representative of the fishing effort. However, due to these changes, the catch history of shortfin mako shark is not consistently representative through time. The result of these changes in data reporting appear as increased catch and the increased spatial extent of the fishery, which is misleading. Lastly, aggregated data are submitted as annual totals for the entire WCPO, and they are not stock specific. These data should in future be separated at the equator.

In addition to changes in logsheet reporting, observer data are improving, and catch retention is changing. There is a general increase in the number of observer samples of all kinds over time, and these data are also more detailed in recent years. There are strong trends across most fleets for vessels to discard sharks as CCMs implement WCPFC regulations and some CCMs ban the retention of all sharks within their EEZs. There is also a tendency for vessels to cut sharks free before they are landed on the vessel, and a higher proportion of discards are reported as cut free recently, particularly in the most recent four to five years. Life state reporting is also improving with most shortfin mako sharks currently being released alive and healthy. There does appear to be an issue with some of the older observer data where high proportions of porbeagle sharks are reported in some years prior to 2000. These could be misidentified mako sharks, particularly any porbeagle records north of 25^{o}S. The reason for the sudden change in the proportion of probeagle to shortfin mako is unclear, but it does seem to coincide with the release of observer shark identification guides. The logsheet data show similar trends but they also show that there is a reduction in the use of the generic shark code a high proportion of which seems to be reported as shortfin mako since 2015. But at that time there is also an increase in the proportion of porbeagle shark reports as an increase in the use of the generic mako code (MAK). Additionally, some observers and fleets are still recording mako sharks to the generic mako code and not specifying these as shortfin or longfin mako sharks. This should be rectified in future. But overall since about 2015 there is a large reduction in the number of reported sharks, which coincided to the increases of mako and blue sharks being cut free (Brouwer et al. 2021).

South Pacific shortfin mako shark length data are difficult to interpret, due to changes in overall reporting and the time periods covered by the data from different flags. As with other observer data, length data are improving in terms of the quantity of data being reported in the more recent years. While this may complicate interpreting length trends over time, these data may be useful for fleet specific selectivity estimation. For shortfin mako sharks there is an additional complication where the large fish are strong and aggressive and likely break free form a line when caught as a result they could be under sampled and the truncated length data could reflect this. This was noted by Howard (2015) who recorded strong declines in shortfin mako shark catch when nylon leaders are used. In addition, the increased trends to cut sharks free rather than bringing them onto the vessel will skew the length frequencies in recent years.

An additional factor is the WCPFC CMM for sharks (WCPFC 2019), this CMM restricts vessels from using both shark lines and wire traces on branchlines. While both of these will reduce the retained catch of shortfin mako sharks, the removal of wire traces will also reduce the retention of the larger sharks which will break free of the line. These trends will impact CPUE and length analysis as well as the selectivity for the assessment model. Both depth of the gear and latitude will likely impact the ability of the gear to catch shortfin mako sharks, as well as the size of the fish caught, and these should be taken into account when attempting to standardise the CPUE data. Similarly, the gear depth, year and fleet change the ratio of shortfin mako sharks to target tuna and swordfish catch which, in turn, will influence catch reconstructions that use catch ratios. The number of shark lines deployed or the number of floats with shark lines should be recorded as currently it is not possible to assess the proportion of shark lines deployed per set.

Other longline gear attributes such as hooks between floats, hooks set, number of baskets, bait used, branch line length and distance will likely be informative for CPUE standardisation. However, they are inconsistently reported, both between and within fleets. Generally, there is a trend for more hooks between floats, and decreases in the hooks set and in the number of baskets. This suggests that in the last decade longline vessels catching shortfin mako sharks are setting longer and shallower lines. Lightstick use may be less informative as these are poorly reported and there was a reporting change on the observer form in 2016 (which probably were not widely used until 2018). On the older forms lightsticks were reported as the total number on a set, whereas in the new forms lighsticks are recorded on the number of hooks between floats. While this is unlikely to impact this analysis, in future analyses lightsticks would need to be converted from the number per basket to the number per set.

Finding links between gear attributes proved difficult; there was a weak relationship between the number of light sticks and the hooks set. This analysis showed that while the number of hooks set has no bearing on the lightstick use, the small number of vessels that use them, use lightsticks at relatively high ratios to the hooks set. The relationship between floatline length, branchline length and hooks set is opaque. There is a weak indication that vessels with higher hooks between floats will have longer branch lines, but not necessarily longer floatlines. Short branch lines are mostly associated with low hooks between floats. Some estimate of set depth may be useful to include in the CPUE standardisations as Howard (2015) showed that increasing set depth lowered catch rates of some sharks, although shortfin mako shark shark catch rates increased if deep sets were made at night, indicating that this issues is complex and single gear changes are unlikely to be effective for all sharks.

The issue of hook type has been assessed for many years as changing hook type can reduce sea turtle (and potentially shark) bycatch, as well as improve the survivability of individuals that are caught (Kim et al. 2006; Swimmer et al. 2011). Some investigations showed a stronger reduction in shortfin mako shark catch when vessels changed from fish to squid bait rather than changing from "Japanese hooks" and J-hooks to circle hooks while both Howard (2015) and Andraka et al. (2013) noted increased catch of shortfin mako sharks on circle hooks. However, others suggest the survivability is higher for released individuals caught on circle hooks (Swimmer et al. 2011). A review undertaken by Godin et al. (2012) found that using circle hooks on pelagic longlines does not have a major effect on shark catch rates, but does reduce at-vessel mortality compared to J-hooks. The increase in the use of circle hooks noted here in the last few years could be one of the reasons that we also noted an increase in shortfin mako sharks being released alive and healthy recently in the WCPO. The trend of increased circle hook use and increased proportions of the catch being released is likely to benefit the South Pacific shortfin mako shark stock, and the analysis by Kaplan and Cox (2007) showed that a combined policy of using circle hooks and releasing sharks lead to net increases in blue shark abundance.

Purse seine catch rates of shortfin mako sharks are low and as a result the data are uninformative. It is recommended that the purse seine data be excluded from the catch reconstruction and assessment data sets. Shortfin mako shark catch rates were higher in the southeast south of 30^oS and to the east of the New Zealand EEZ. However, the catch rates vary seasonally and are lowest and occurred further to the north in the Austral winter. Catch rates increased and shifted south through the Spring and Summer. While these trends imply that some seasonal movement patterns are prevalent, they are not definitive, and both the catch data presented here and tagging data (Sippel et al. 2016) show that seasonal movements of the whole population do not seem to occur.

In conclusion, shortfin mako sharks are wide ranging across the South Pacific Ocean, and display weak size and seasonal movement patterns but the patterns seen here are consistent with those in other studies that used tagging data (e.g. Francis et al. 2019). They do not seem to cross the Equator into the north Pacific. Overall, there appears to be a reasonable amount of data from 1990-2021, but the data by fleet are inconsistently reported, which may prove challenging when CPUE standardisations are performed.

Added to this, a change in reporting, where catch reporting has improved across all fleets over time, has resulted in more shark catch being reported in recent years. However, these trends are unlikely to be linked to changes in targeting or stock biomass, but are simply reflective of more reported data. For most fleets after 2015, most shortfin mako sharks are released, and a high proportion of releases are alive and healthy at release. Length data are recorded and are available, but not for all fleets, and not consistently through time. In addition, the largest individuals are likely to break free particularly from gear set with nylon traces. As a result, length data can be used to assess selectivity, noting the bias for lower proportions of larger sharks being retained, but they are probably not useful as indicators of trends in biomass or other temporal trends for most fleets. Shortfin mako sharks are landed in both shallow and deep sets, but most frequently caught on the shallow hooks and comprise a higher proportion of the catch in shallow sets. Relative to tuna, the catch proportion of shortfin mako sharks differs by fleet, and is closely associated with set depth. Both observed and reported data are available for CPUE standardisation, but note that past management interventions may complicate the CPUE standardisation. Gear attributes (e.g. hooks between floats and float line length) are more likely to be informative than specified targeting information as targeting is poorly reported, but targeting could be inferred through cluster analysis of the target tuna and swordfish catch. The data are limited as a result an integrated stock assessment for shortfin mako sharks will be challenging and increase the uncertainty in the outputs. This is likely to be the case for most shark assessments. Added to this is the impact of regulatory changes on fishery dependent data, and generally low observer coverage in longline fleets. Some focused work in how to get better CPUE data for sharks in general and it is recommended that a workshop to review the data, data handling protocols and ways to improve data collection.

5. RECOMMENDATIONS

The following recommendations are proposed for the SC to consider:

1. Aggregated data are submitted as annual totals for the WCPFC area only, making them uninformative for a stock specific assessment. Therefore, shortfin mako shark aggregated data (and probably other Key Sharks) should be reported by ocean area not simply as WCPO and, where possible, these data should be retrospectively corrected. As such paragraph 1 bullet point 3 of the scientific data to be provided to the commission should include the following: "**For key sharks estimates of annual catch should be separated into catch north and south of the Equator. The WCPFC secretariat should work with CCMs to get these data retrospectively corrected where possible.**"

2. Observers (or the vessels crew) should record number of shark lines deployed or the number of floats with shark lines.

3. Observers and vessel crew should be encouraged to use mako species specific codes rather than the generic code MAK.

4. Convene a workshop to assess how to get better CPUE data for sharks in general assess the data, data handling protocols and ways to improve data collection.

6. ACKNOWLEDGMENTS

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TABLES

Table 1: Fate codes used by observers in the WCPFC regional observer programme. Fate codes are used to descibe whether the fish was retained (RET), discarded (DIS), released, (REL), cut free (CUT).

Code	Description	Group
RGG	Retained gilled and gutted (for sale)	RET
RGT	Retained gilled gutted and tailed (for sale)	RET
RWW	Retained whole	RET
RPT	Retained partial (e.g. fillet, loin, trunk)	RET
RFR	Retained both fins and trunk (sharks)	RET
RHG	Retained headed and gutted (billfish)	RET
RSD	Retained but shark damaged	RET
RCC	Retained for crew consumption	RET
RGO	Retained gutted only.	RET
ROR	Retained other reason (specify)	RET
DFR	Discarded trunk fins retained (sharks)	RET
DGD	Discarded gear damage (tuna only)	DIS
DSD	Discarded shark damage	DIS
DWD	Discarded whale damage	DIS
DUS	Discarded uneconomic species	DIS
DDL	Discarded too difficult to land	CUT
DSO	Discarded struck off	CUT
DCF	Discarded cut free	CUT
DDH	Discarded de hooked	CUT
DTS	Discarded too small (target species)	DIS
DPQ	Discarded poor quality	DIS
DOR	Discarded other reason (specify)	DIS
ESC	Escaped	ESC
DPA	Discarded protected species, Alive	DIS
DPD	Discarded protected species, Dead	DIS
DPU	Discarded protected species, Unknown	DIS

Table 2: Condition codes used by observers in the WCPFC regional observer programme. Condition codes are used to describe the animal's health status; and recorded when it is first caught and again if it is discarded / released.

Code	Description
A0	Alive (not categorized)
A1	Alive, healthy
A2	Alive injured, distressed
A3	Alive, but dying
D	Dead
U	Condition unknown

Table 3: Purse seine set association codes used by observers in the WCPFC regional observer programme.

Code	Description
1	Unassociated

Table 3: *(continued)*

Code	Description
2	Feeding on baitfish
3	Drifting log, debris or dead animal
4	Drifting raft, FAD or Payao
5	Anchored raft, FAD or Payao
6	Live whale
7	Live whale shark
8	Other

FIGURES

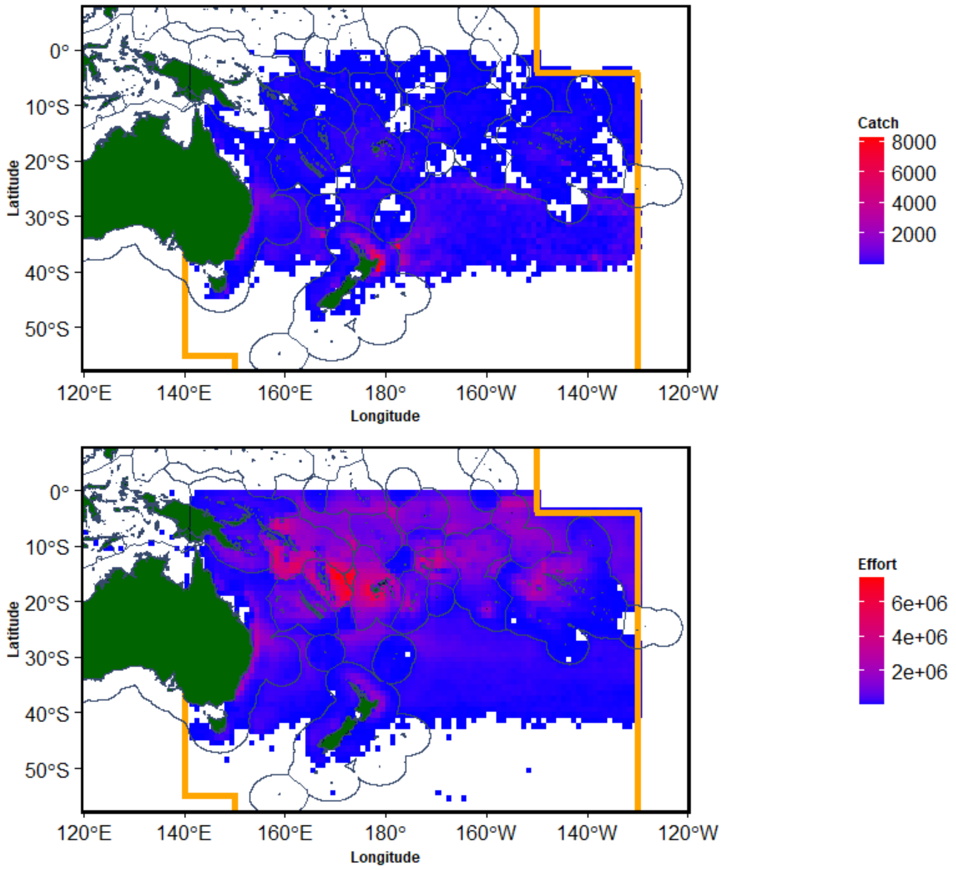

Figure 1: Longline shortfin mako shark catch in tonnes (top) fishing effort in hooks set (bottom) as reported on the available logsheets in the WCPFC Convention area 1995 - 2020.

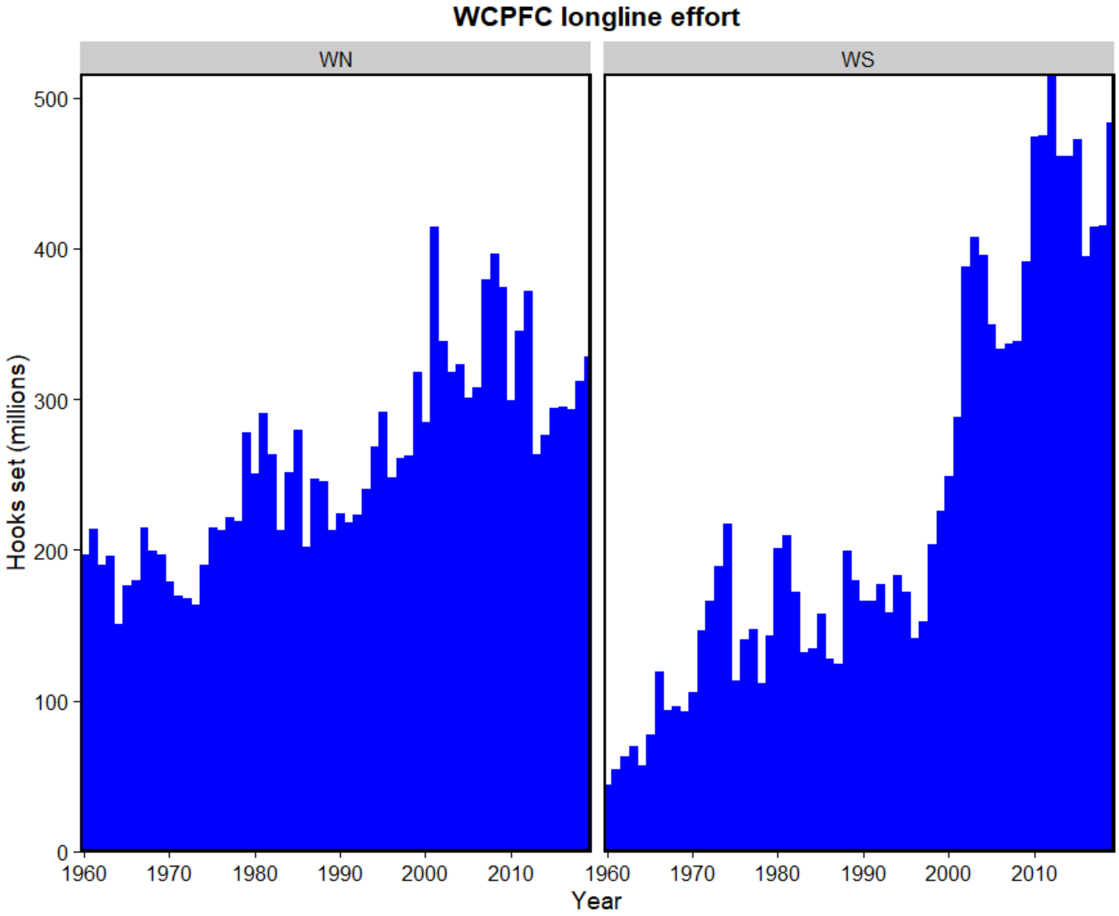

Figure 2: Longline fishing effort in the North (WN) and South (WS) WCPO south of the equator 1960-2020.

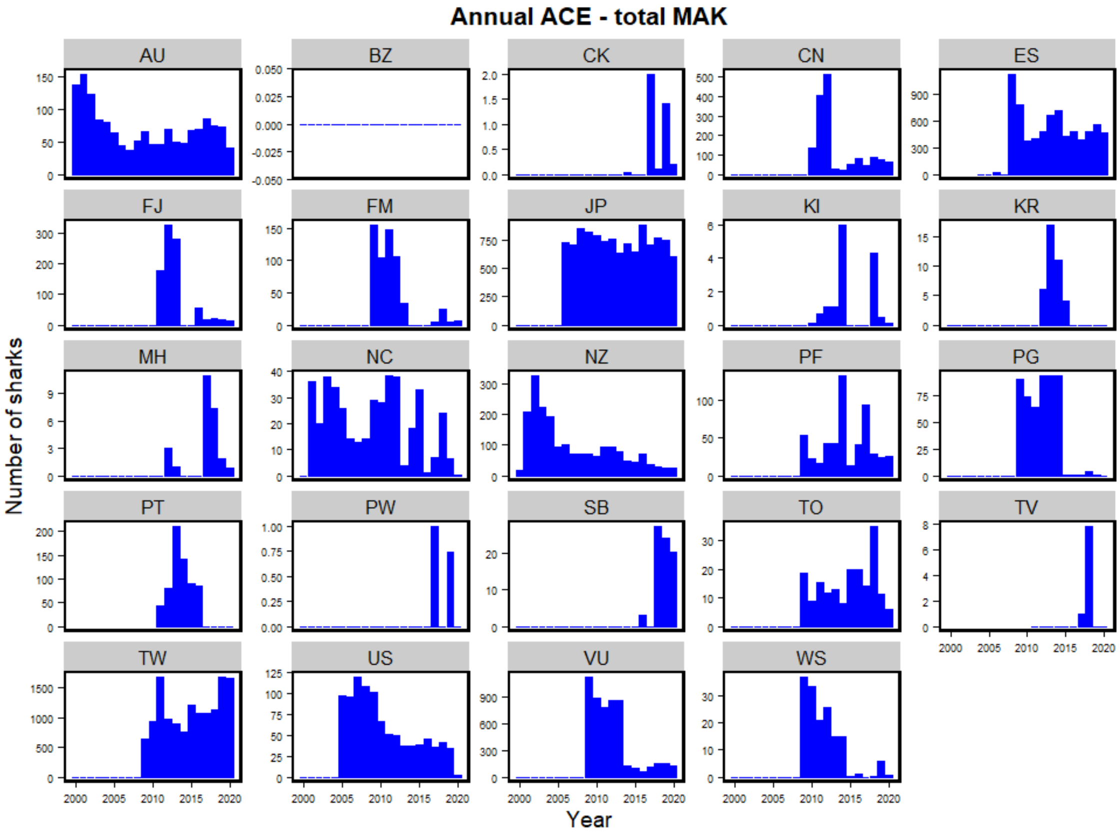

Figure 3: Longline shortfin mako shark annual catch estimates reported by flag states in WCPFC the WCPFC Convention area 2000 - 2021.

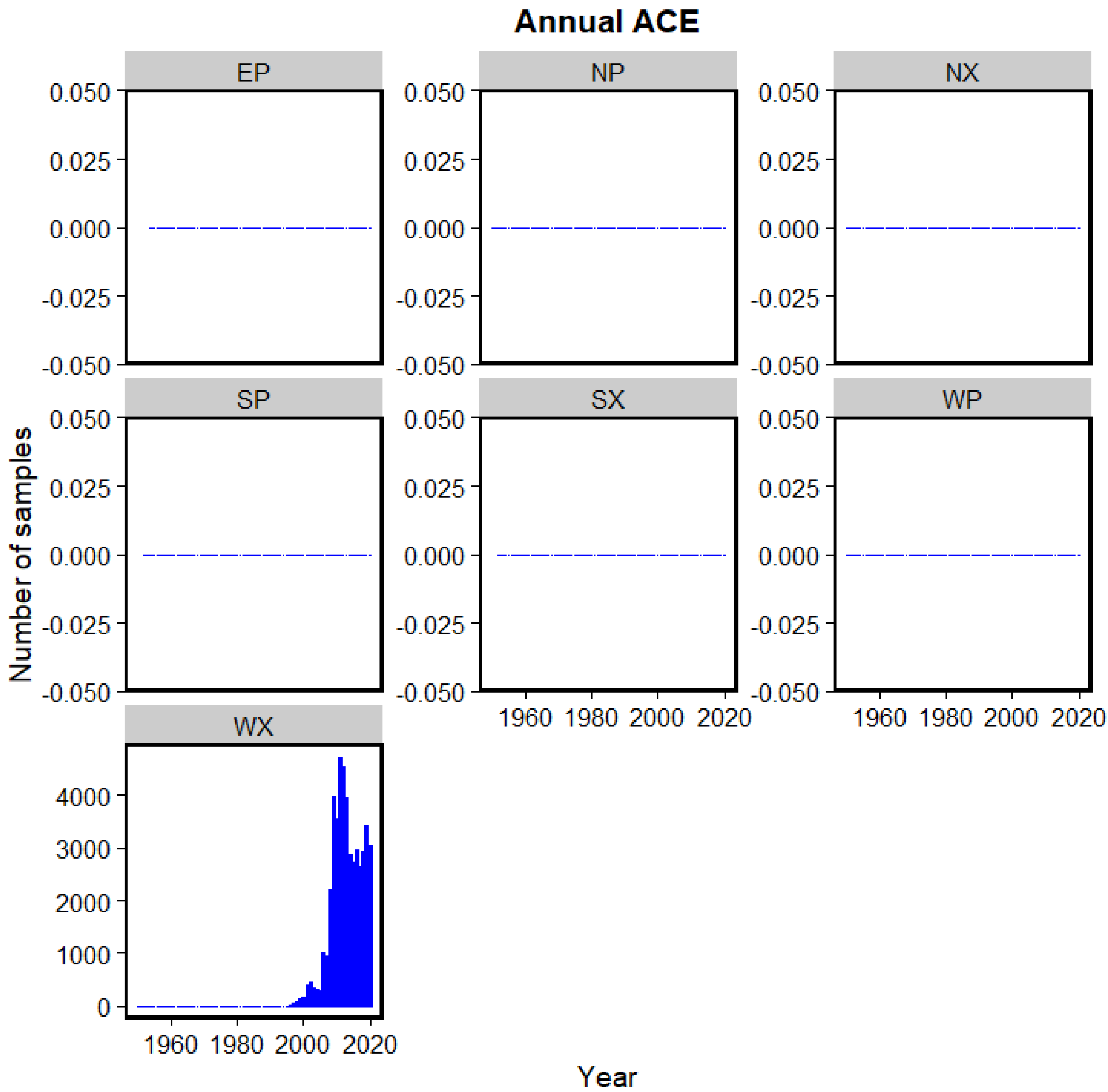

Figure 4: Longline shortfin mako shark annual catch estimates by ocean area reported to the WCPFC 2000 - 2021. EP = Eastern Pacific; NP = North Pacific; NX = North Pacific within the WCPFC Convention area; SP = South Pacific; SX = South Pacific within the WCPFC Convention area; WP = western Pacific Ocean; WX = western Pacific within the WCPFC Convention area.

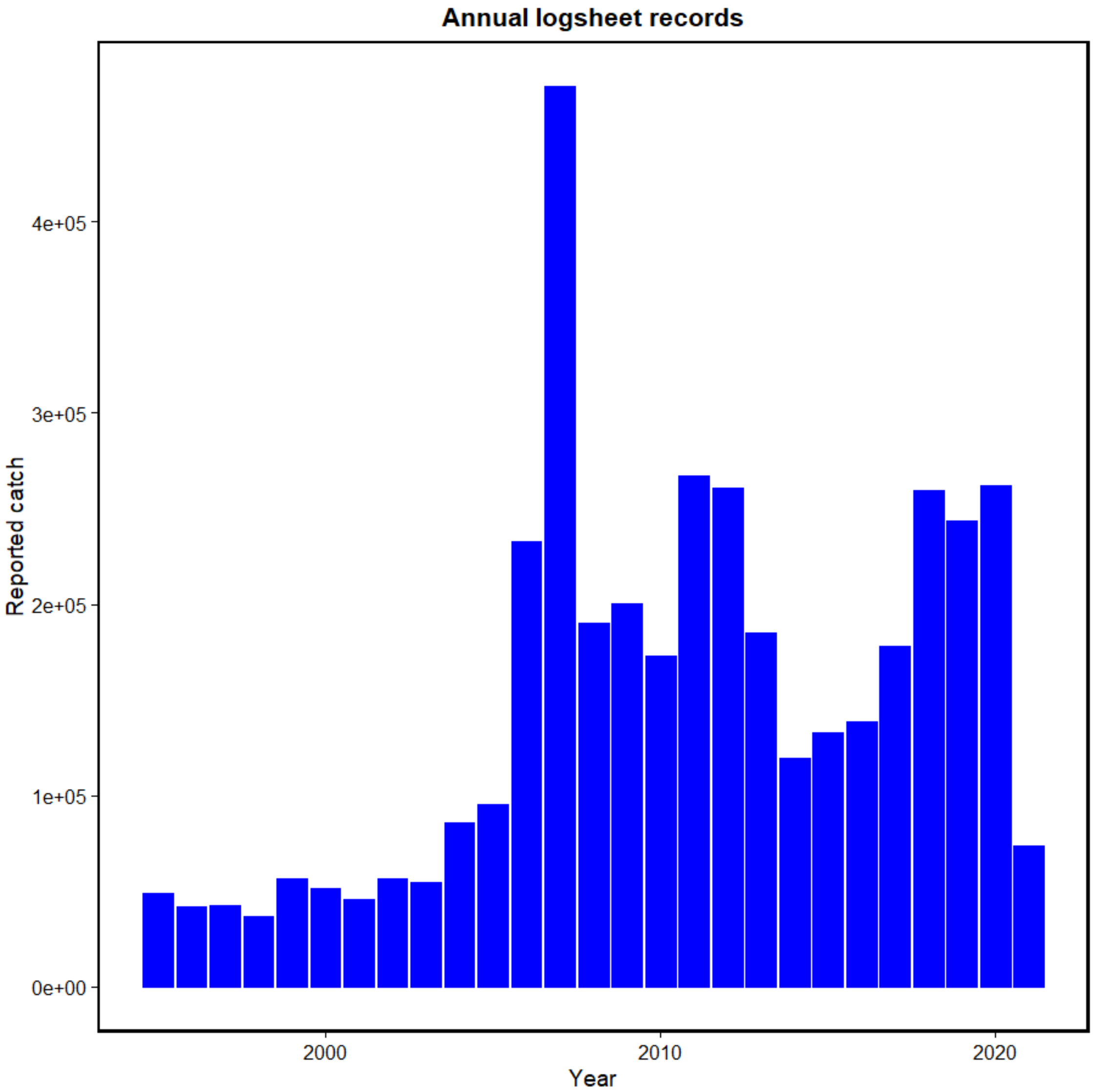

Figure 5: Longline south Pacific shortfin mako shark catch reported annually south of the Equator to the WCPFC 1995 - 2021.

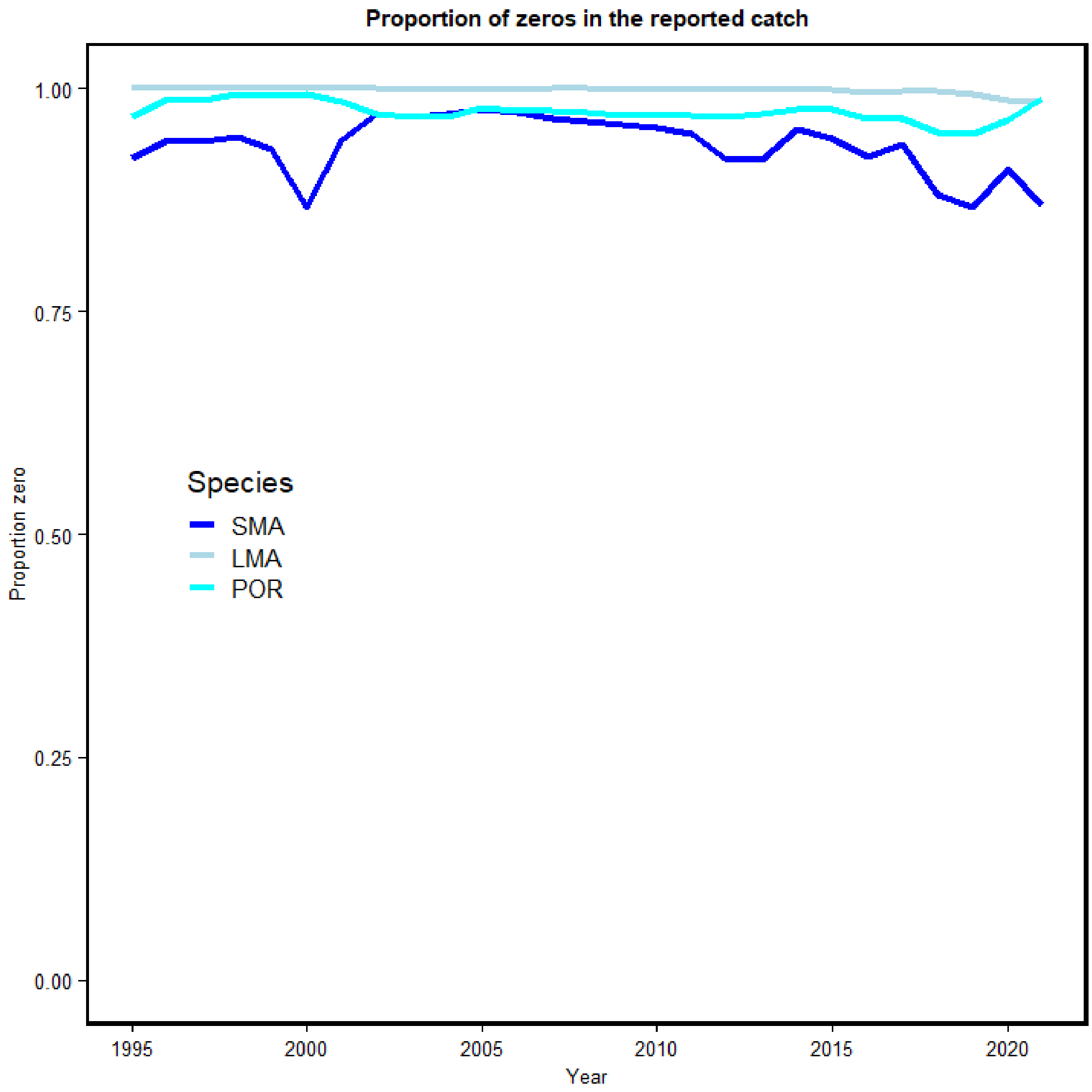

Figure 6: Longline logsheet reporting trends of south Pacific shortfin mako shark reported annually south of the Equator to the WCPFC 1995 - 2021 showing the proportion of logsheet records with zero catch reported. SMA = shortfin mako; LMA = longfin mako; POR = porbeagle sharks.

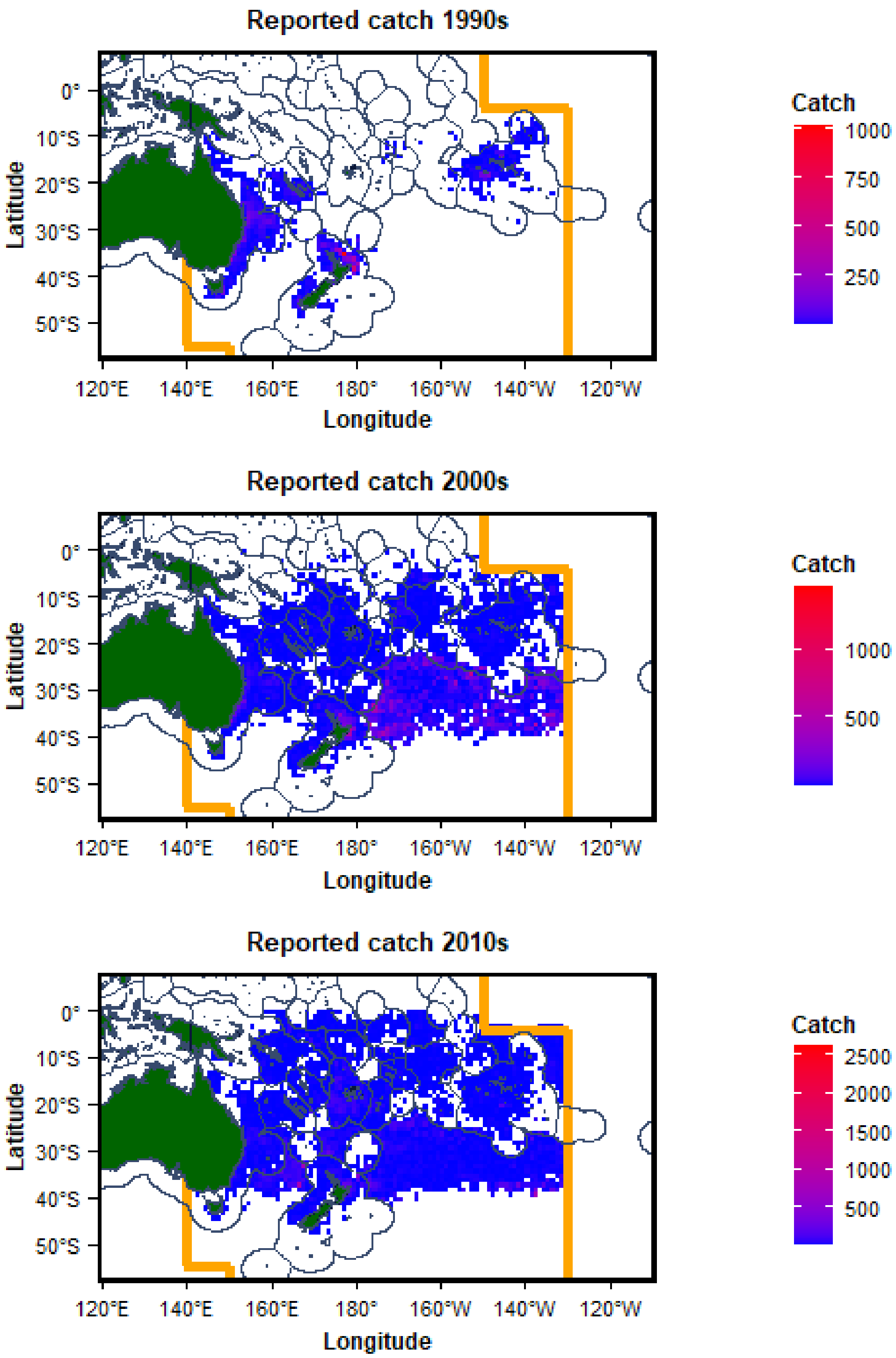

Figure 7: Reported logsheet catch by decade of shortfin mako sharks in the WCPFC south of the Equator from 1990 - 2021 aggregated to 1x1 degree squares across all fleets and months of the year.

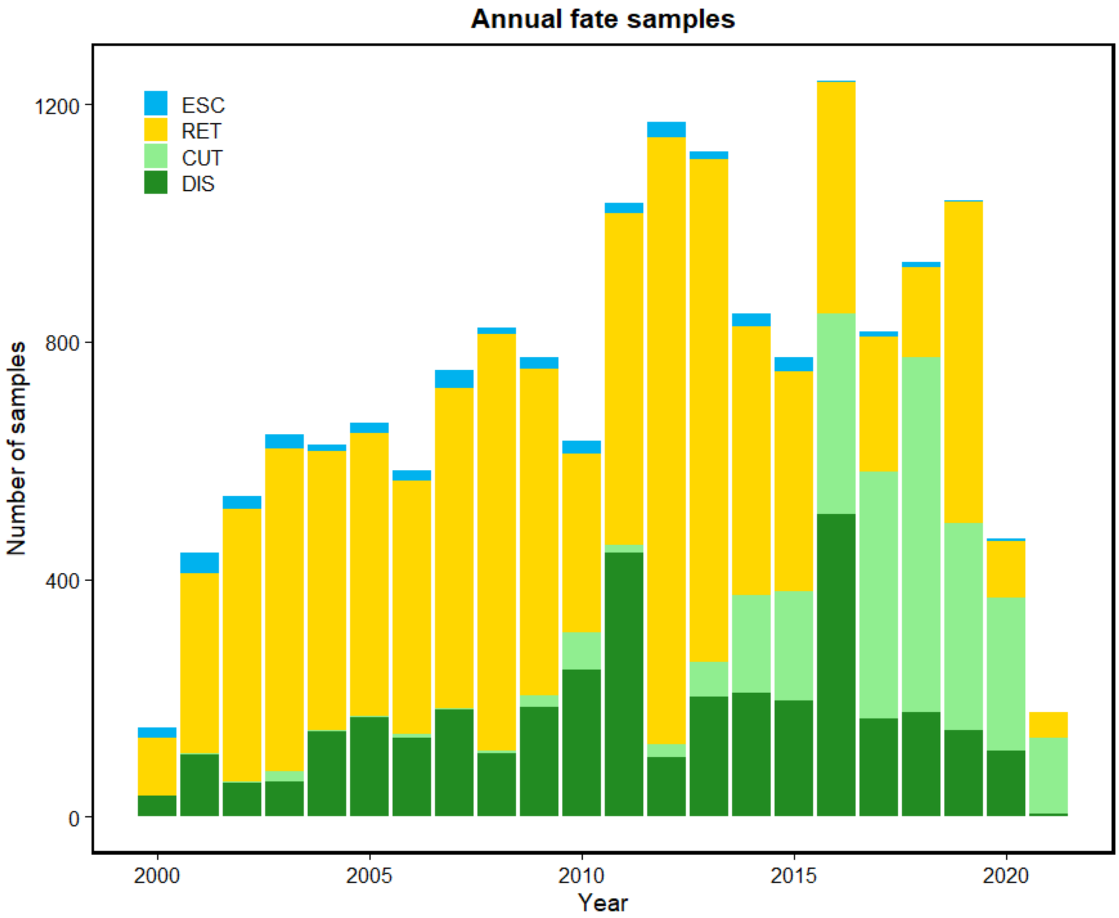

Figure 8: Fate of longline caught south Pacific shortfin mako shark observed by flag 2000 - 2021. ESC = Escaped, RET = Retained, DIS = Discarded, CUT = Cut free.

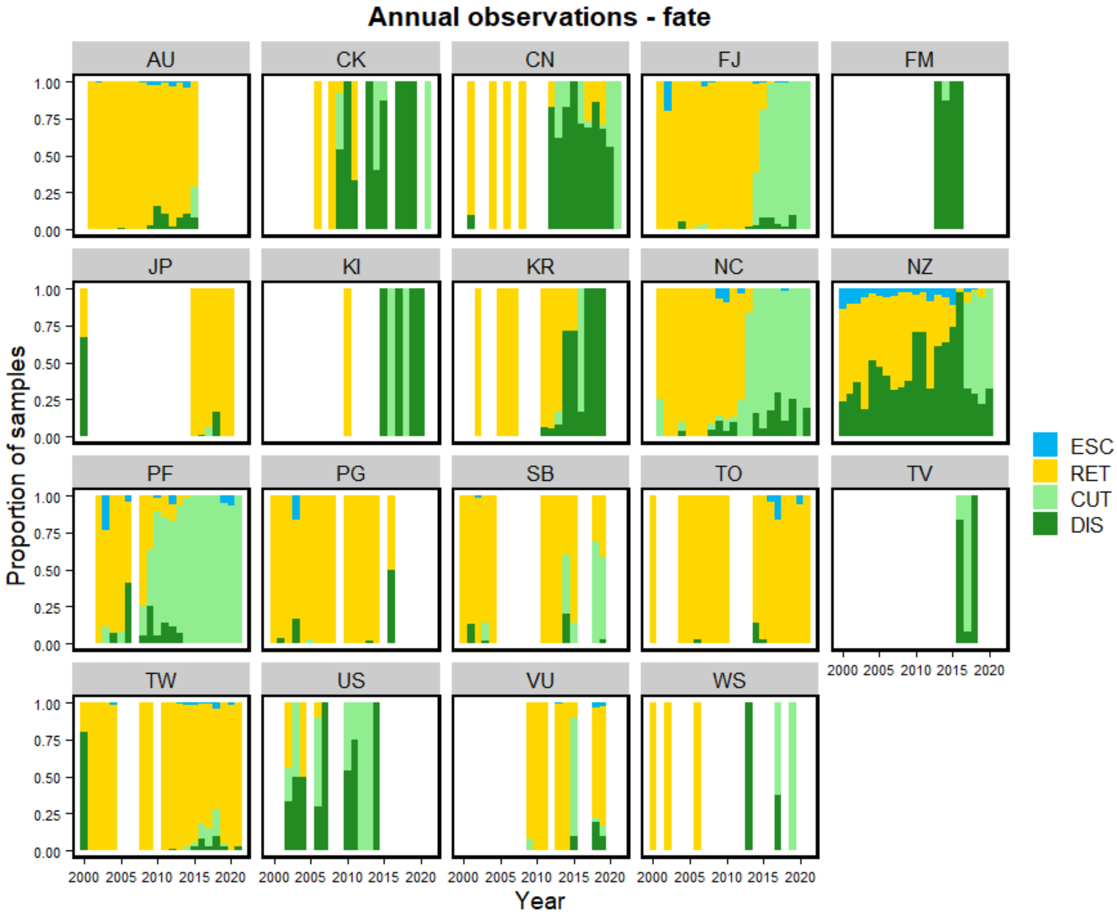

Figure 9: Fate proportions by flag of longline caught south Pacific shortfin mako shark observed by flag 2000 - 2021. ESC = Escaped, RET = Retained, DIS = Discarded, CUT = Cut free.

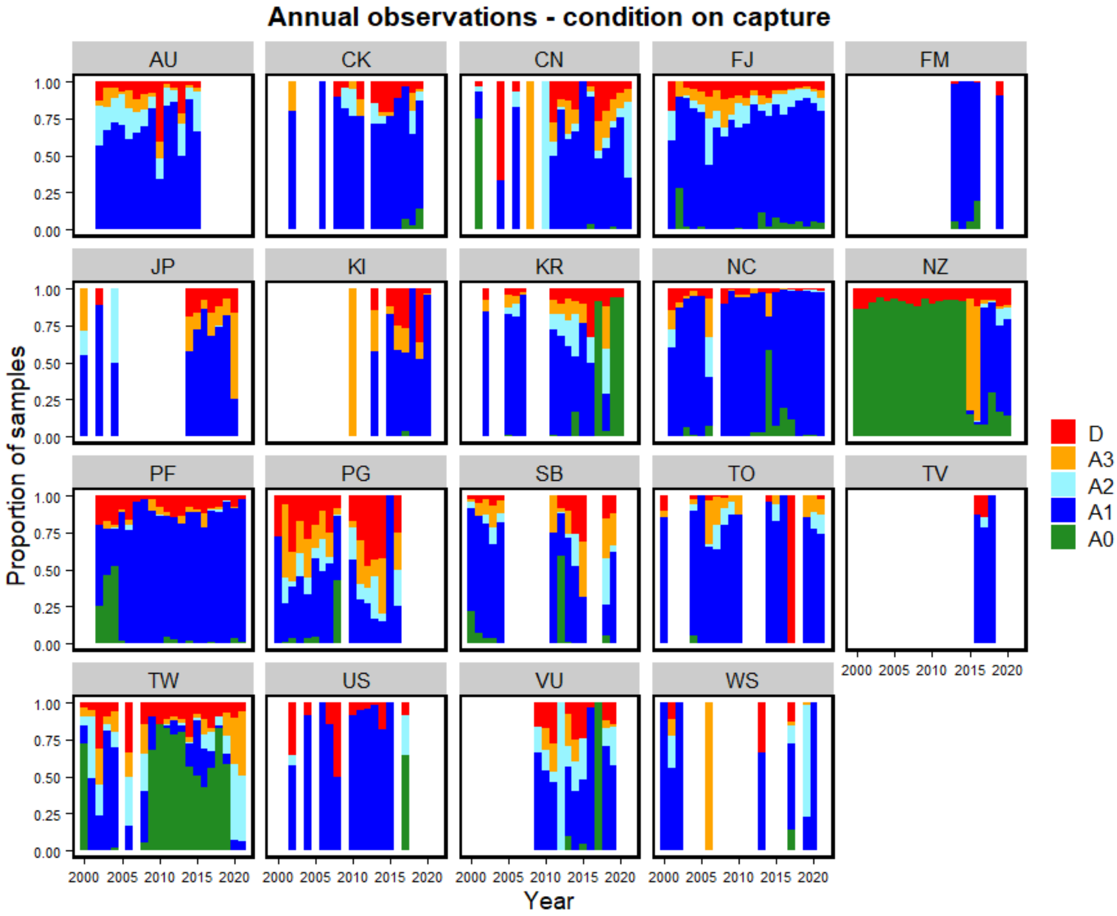

Figure 10: Condition at capture of longline caught south Pacific shortfin mako shark observed by flag in the WCPFC between 2000 - 2021. D = Dead, A0 - A3 are various life states as defined in Table 2.

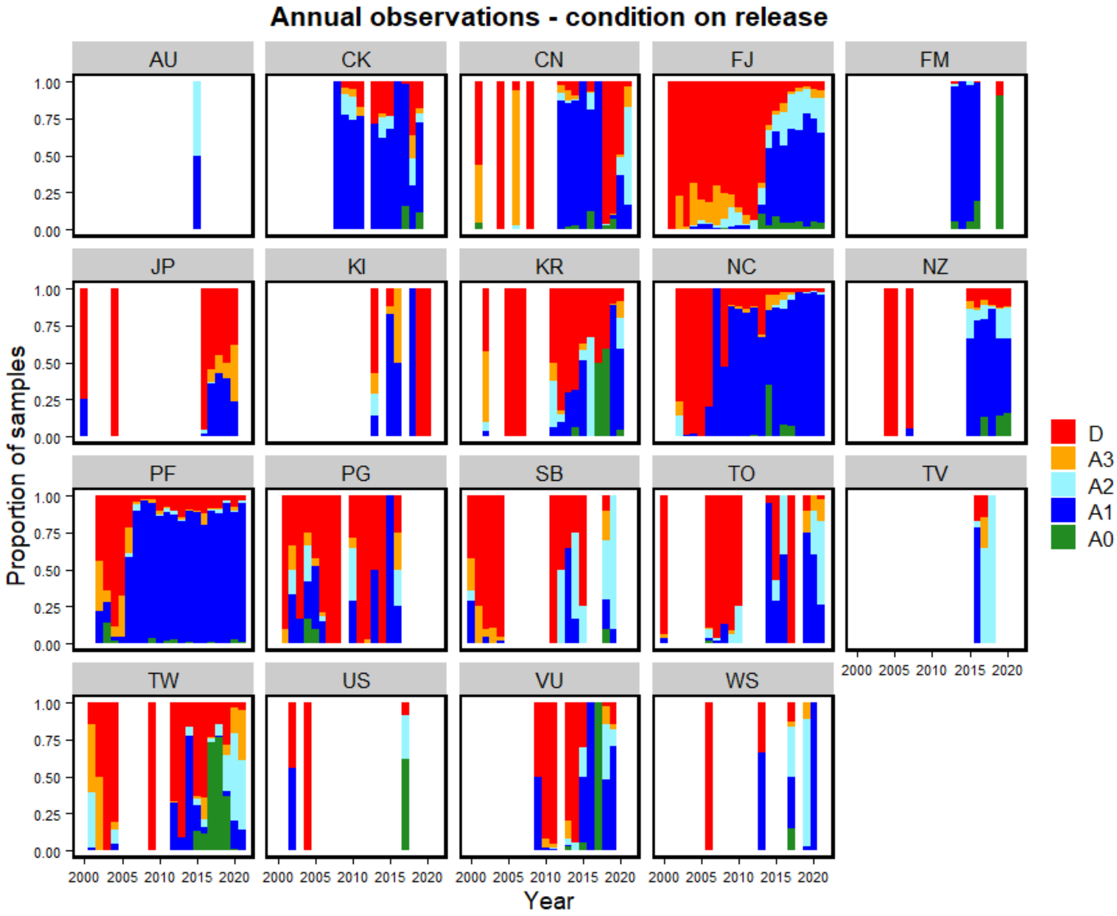

Figure 11: Condition at release of longline caught south Pacific shortfin mako shark observed by flag in the WCPFC between 2000 - 2021. D = Dead, A0 - A3 are various life states as defined in Table 2.

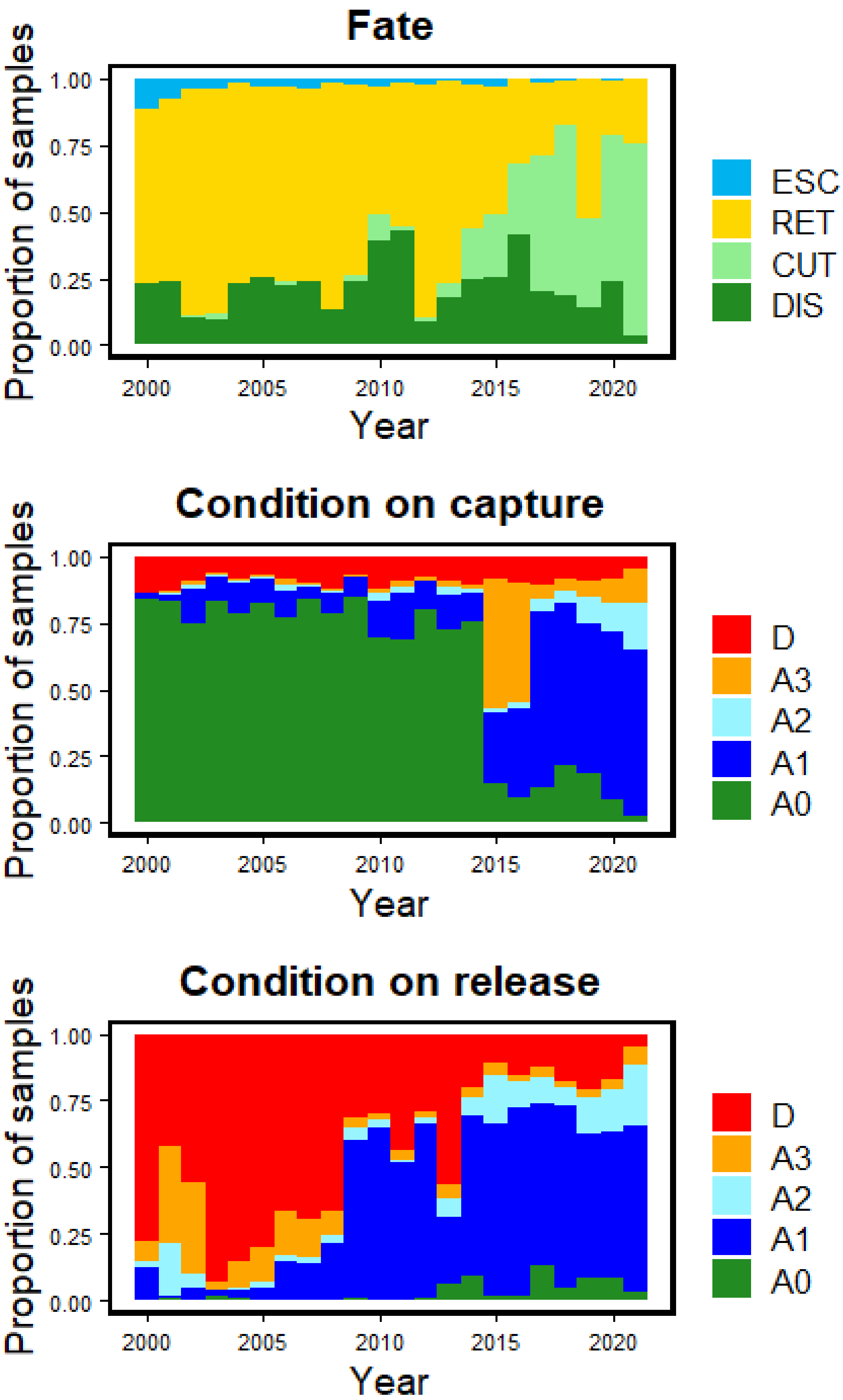

Figure 12: Fate of fish (top), condition at capture (middle) and release (bottom) of all longline caught south Pacific shortfin mako shark observed in the WCPFC between 2000-2021. ESC = Escaped, RET = Retained, DIS = Discarded, CUT = Cut free, D = Dead, A0-A3 are various life states as defined in Table 2.

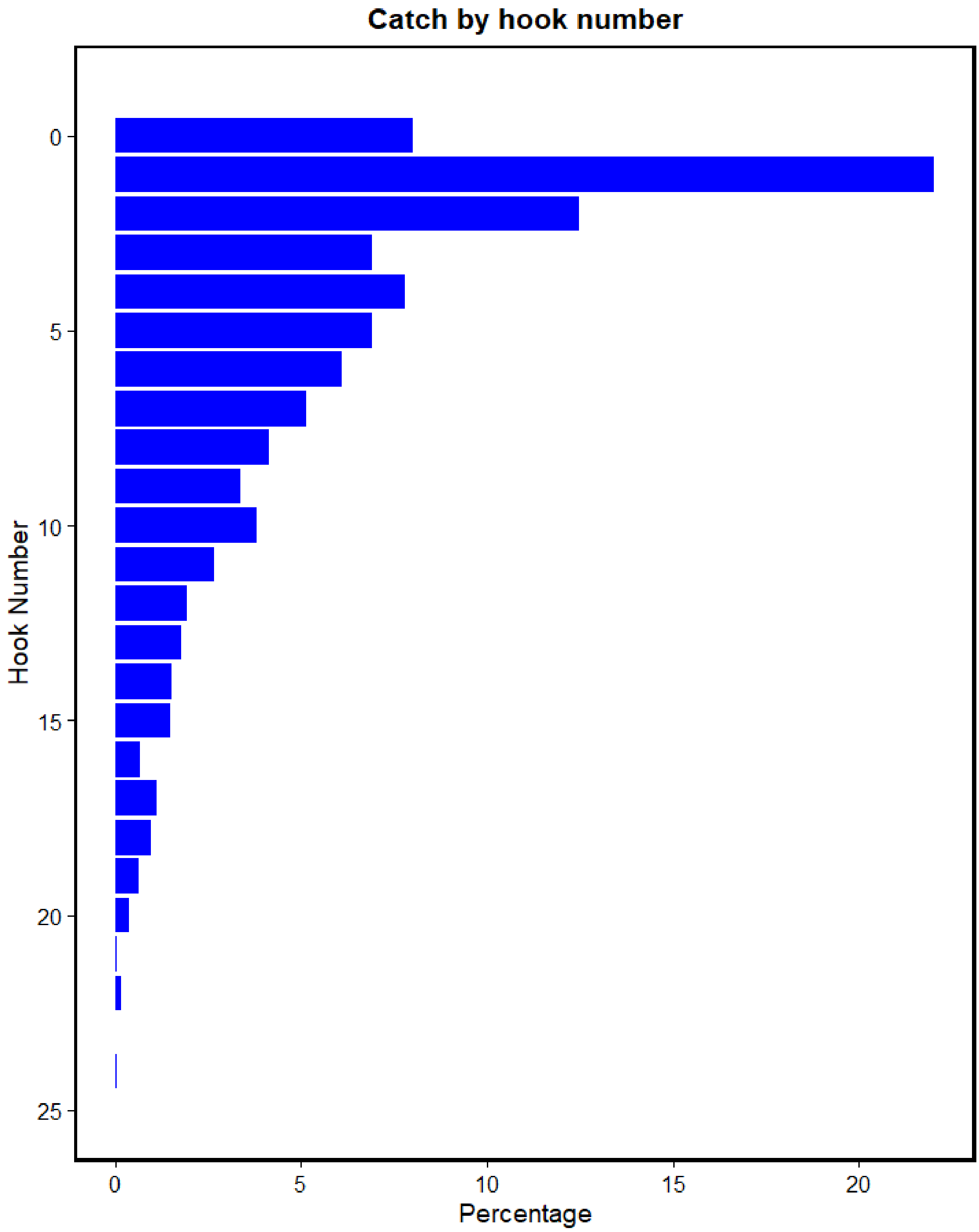

Figure 13: Catch of south Pacific shortfin mako shark by hook number relative to the closest float observed in the WCPFC between 2000 - 2021. Hooks were numbered from 1 to the middle of the basket and then back to 1 hook number 0 refers to fish caught on shark lines that are attached to the float.

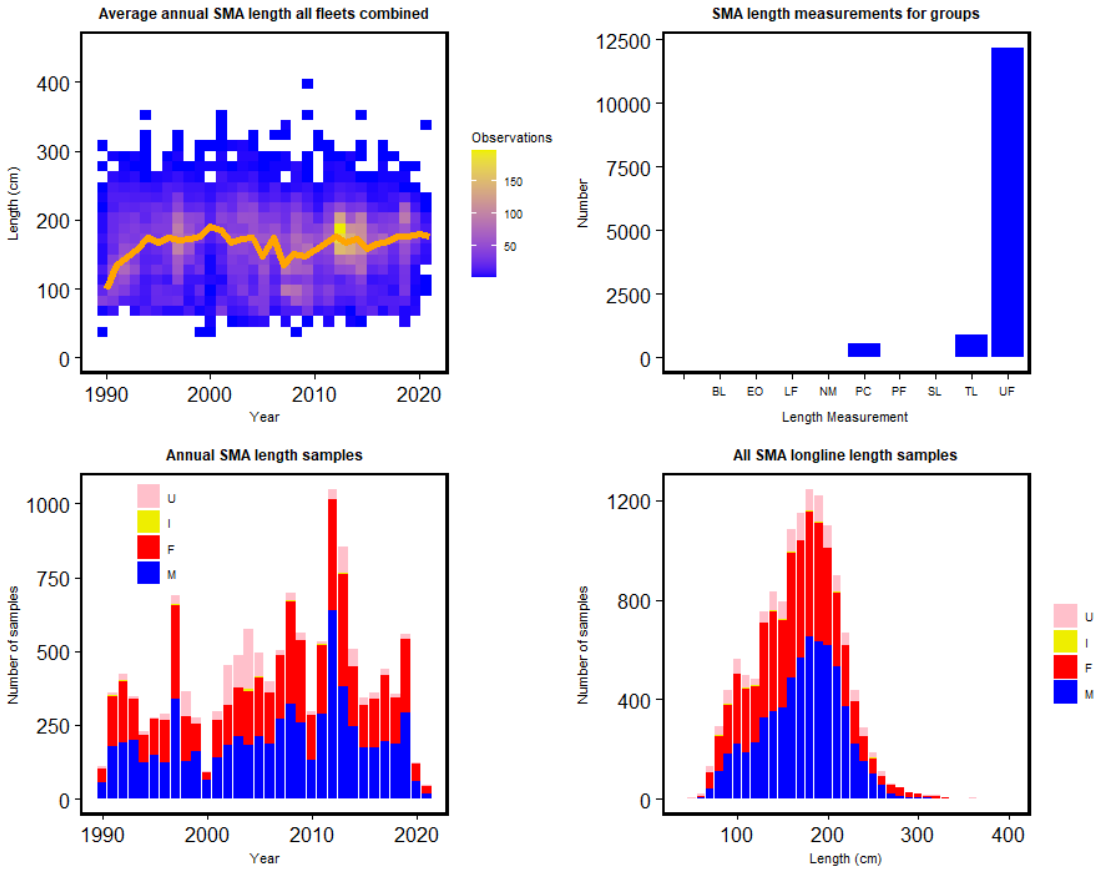

Figure 14: Length data availability of south Pacific shortfin mako sharks observed in the WCPFC between 1990 - 2021, showing the average annual length (top left), the units of length measurements (top right), the number of samples collected by sex (bottom left) and the overall length frequency (bottom right). UL = Upper-jaw fork length; TL = Total Length; PC = Pre-caudal length; U = Sex unknown; I = Immature; F = Female; and M = Male.

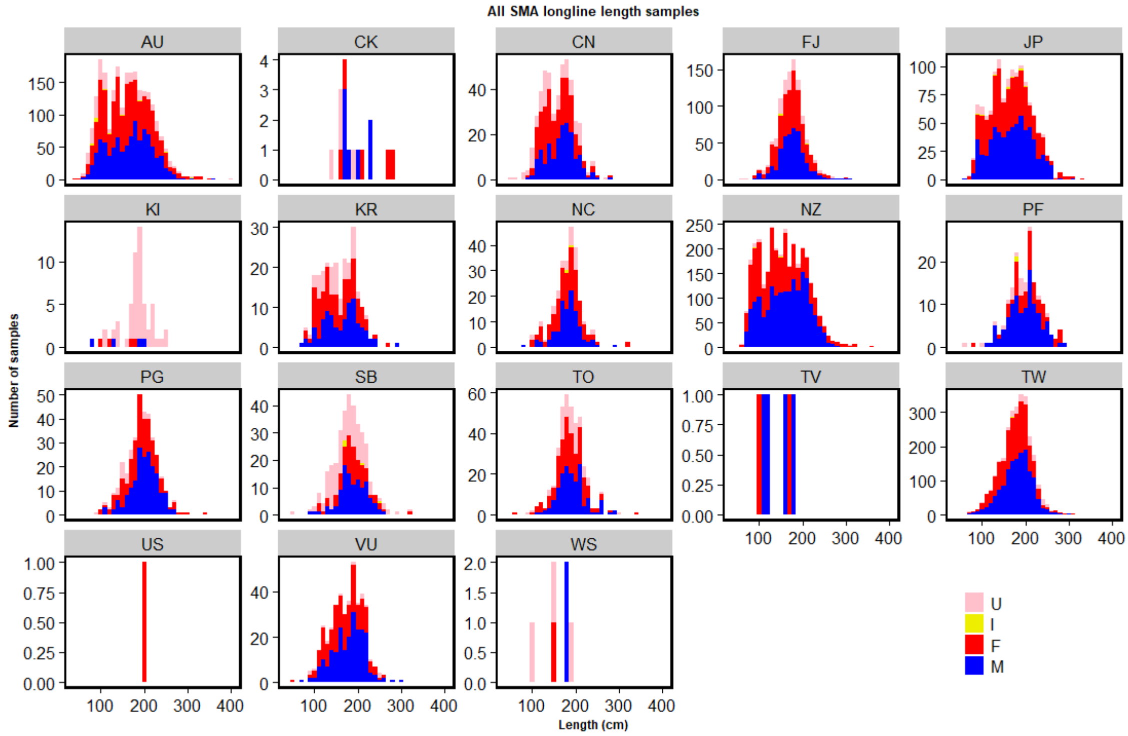

Figure 15: Length frequency distributions, of south Pacific shortfin mako sharks observed in the WCPFC between 1990 - 2021 by flag. U = Sex unknown, I = Immature, F = Female and M = Male. Note: the y - axis scales are not the same between plots.

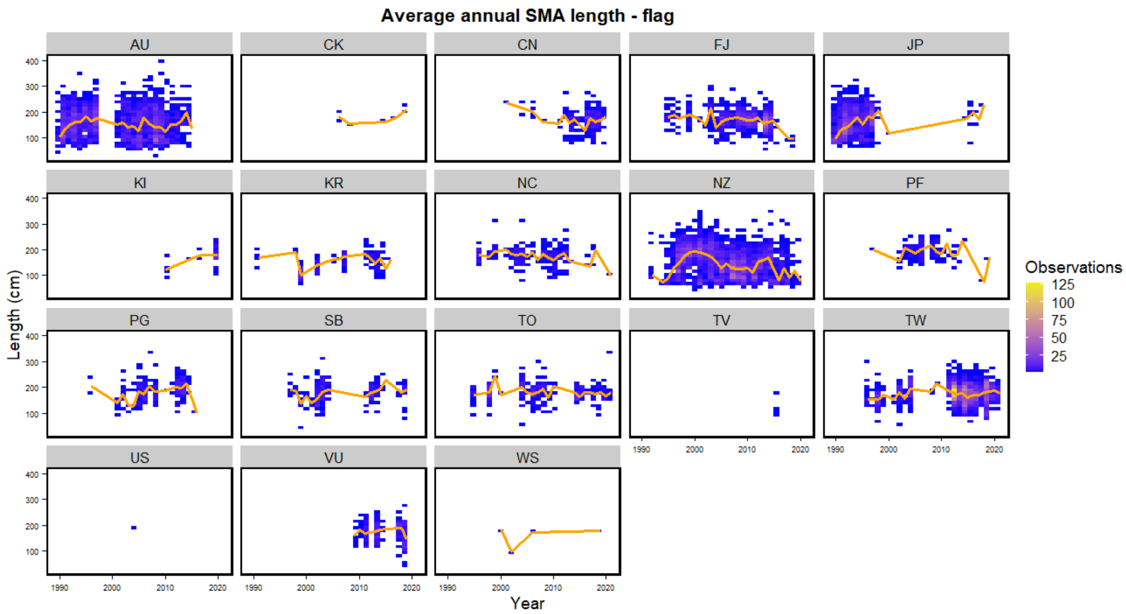

Figure 16: The average annual length distributions, of south Pacific shortfin mako sharks (both sexes combined) observed by flag in the WCPFC between 1990 - 2021 by flag.

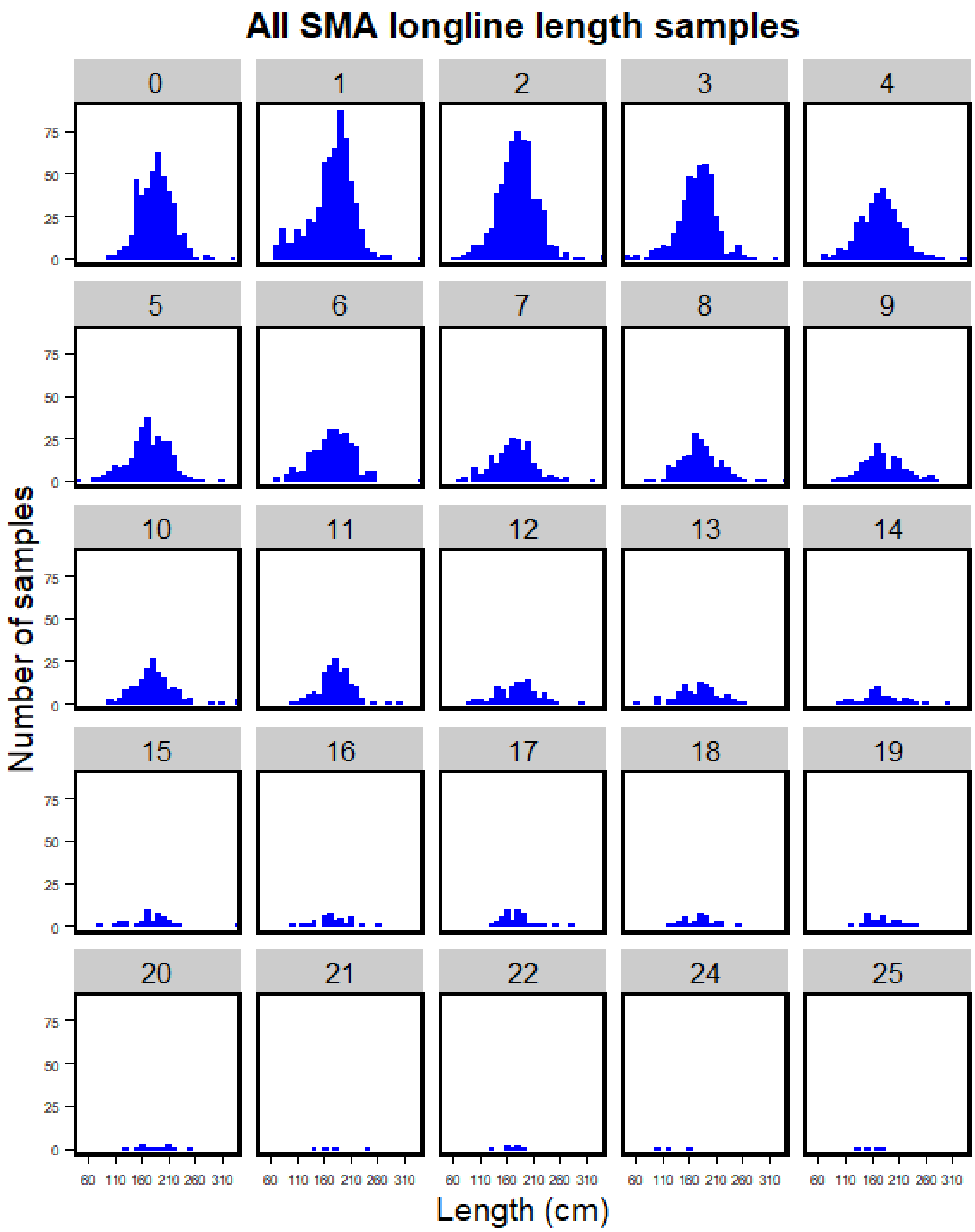

Figure 17: Length frequency distributions, for fish measures to UF only, of south Pacific shortfin mako sharks observed in the WCPFC between 2000 - 2021 caught by hook number.

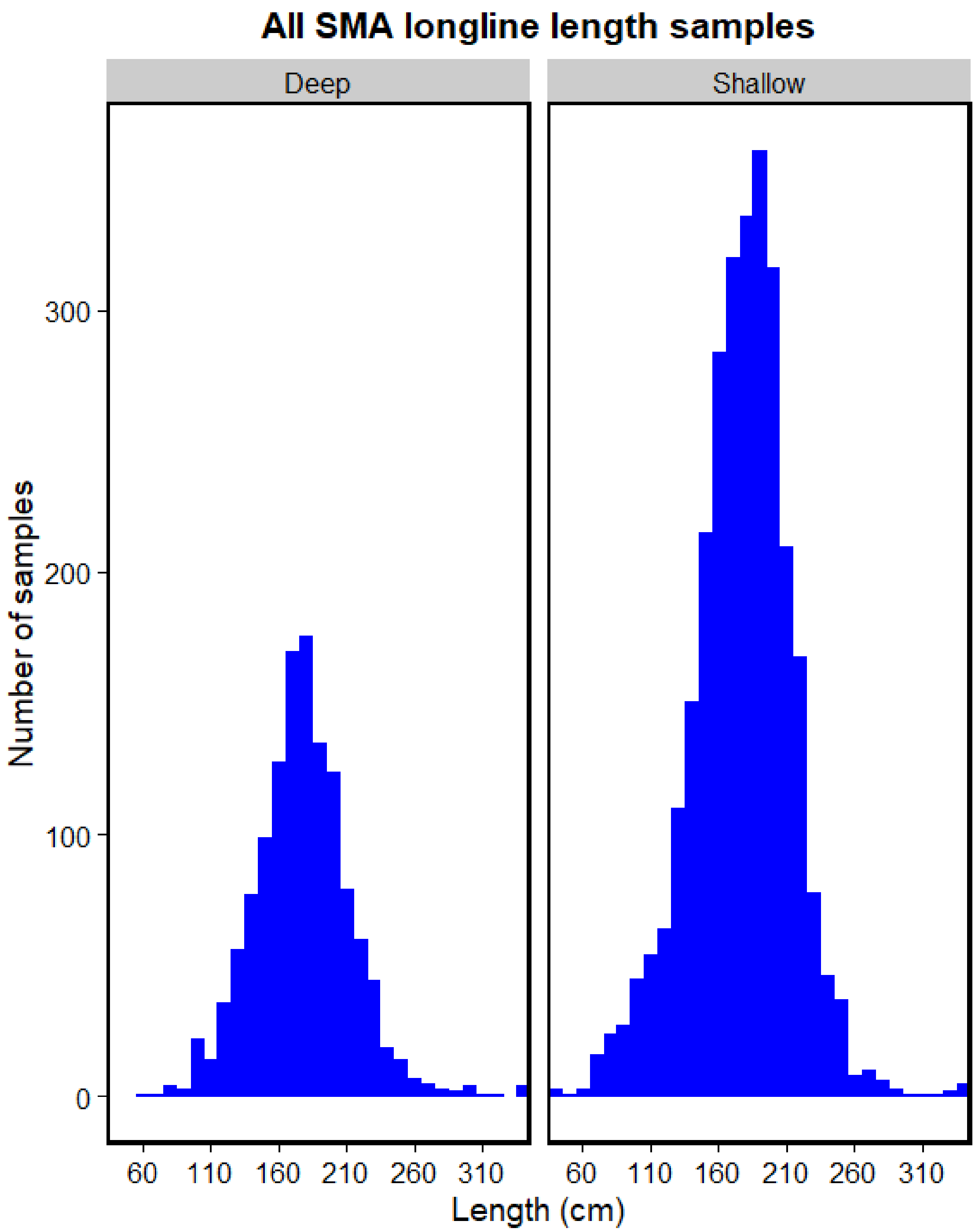

Figure 18: Length frequency distributions, for fish measures to UF only, of south Pacific shortfin mako sharks observed in the WCPFC between 2000 - 2021 caught by depth group where shallow hooks are hook numbers 6 or less and deep are hook numbers 7 and higher.

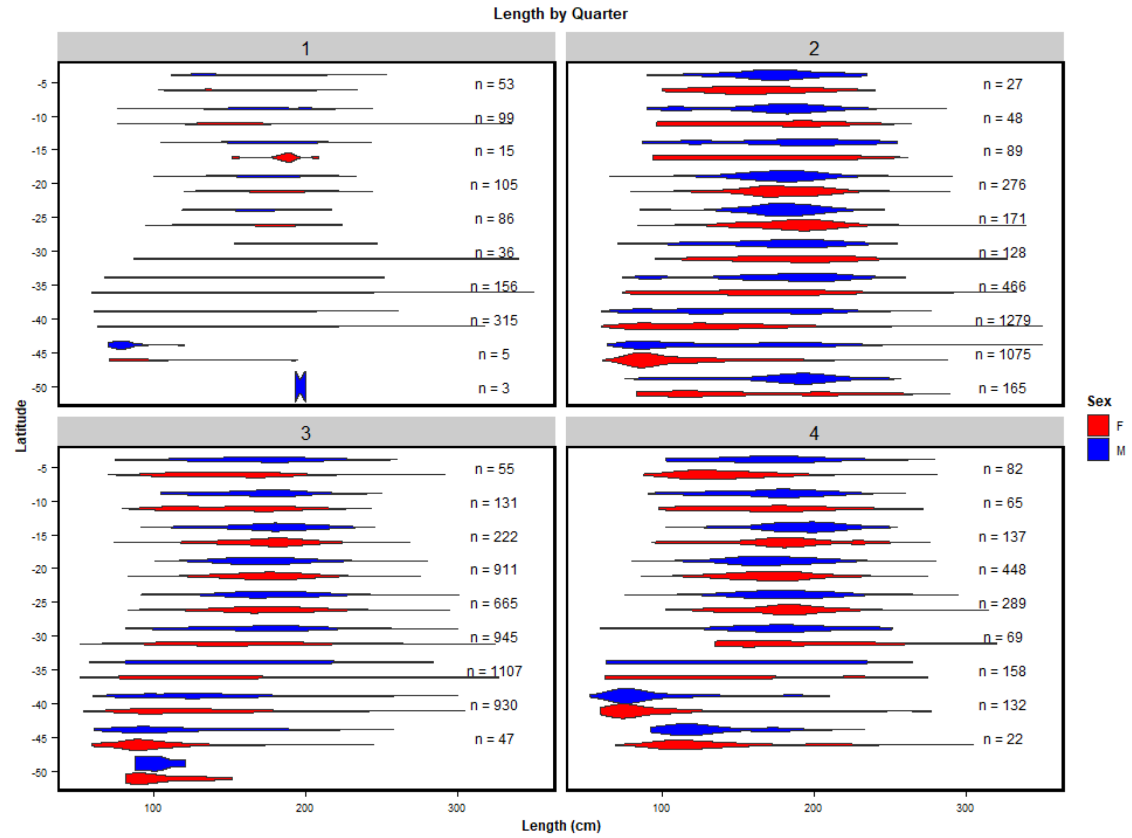

Figure 19: Length distribution by latitude, year quarter and sex, of south Pacific shortfin mako sharks observed in the WCPFC between 2000-2021. n = the total number of samples (male and female combined) by latitude group.

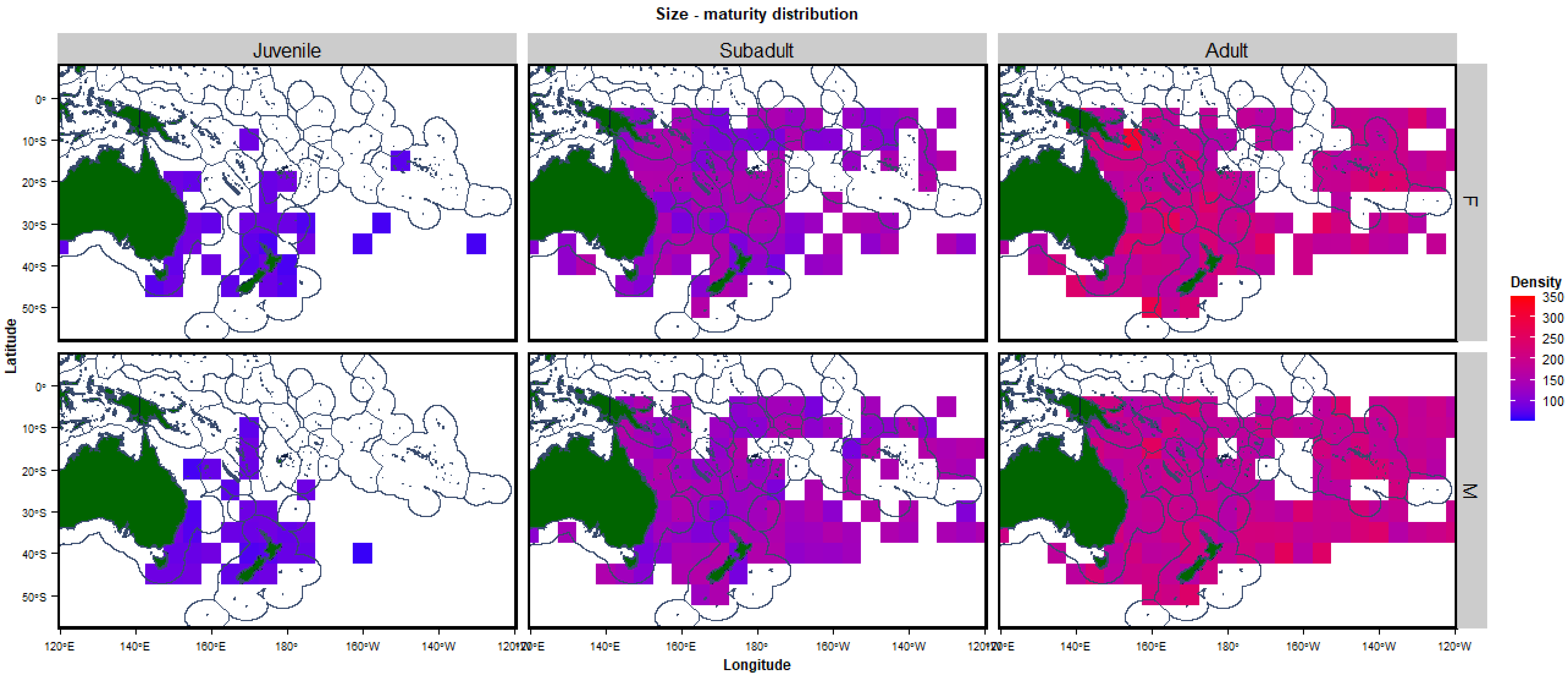

Figure 20: Length distribution by maturity, of south Pacific shortfin mako sharks observed in the WCPFC between 2000-2021. Density = the total number of samples (male and female combined) by latitude group.

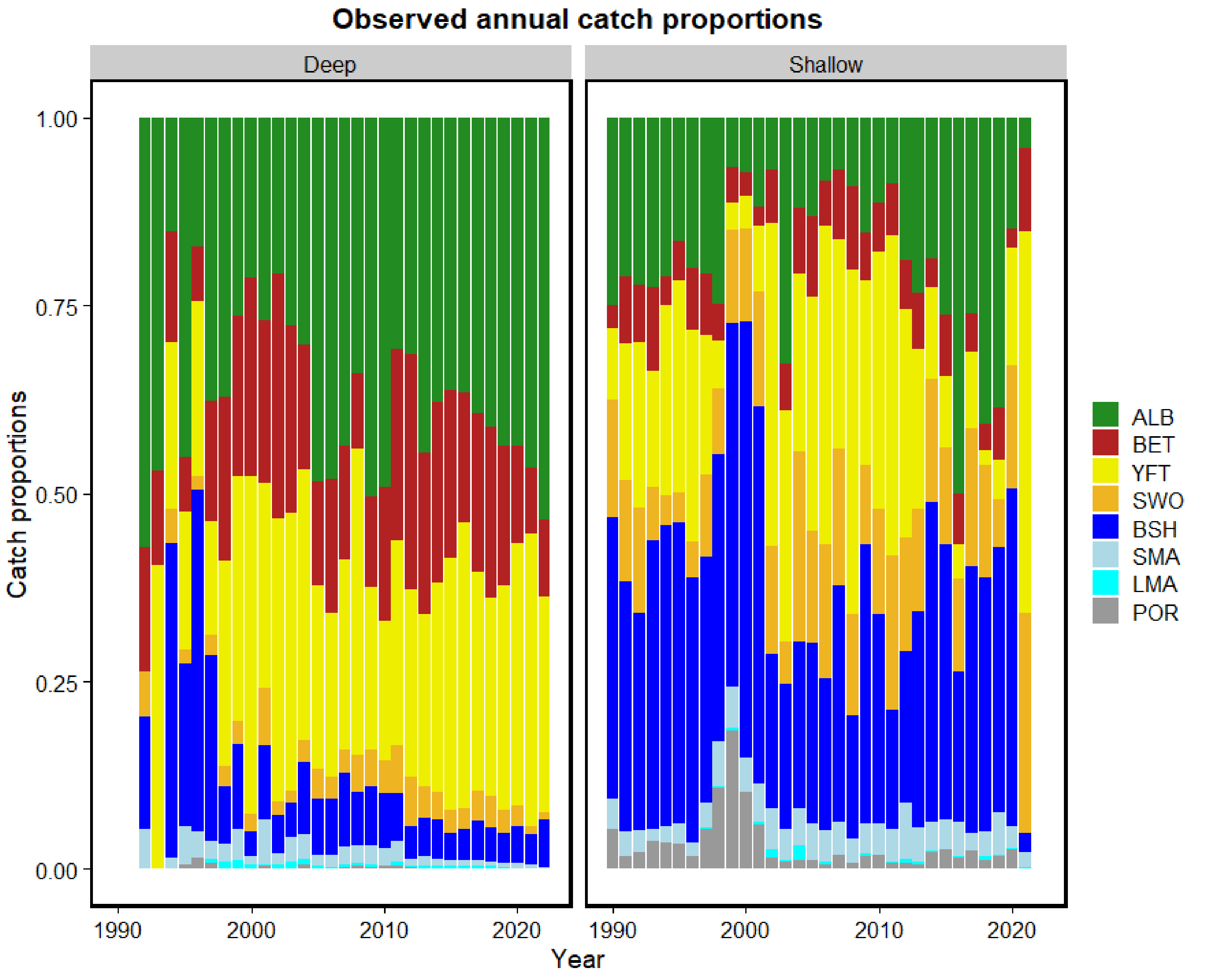

Figure 21: Species proportions of tuna swordfish and south Pacific shortfin mako sharks observed in the WCPFC between 2000 - 2021 and separated into deep (left) and shallow (right) sets.

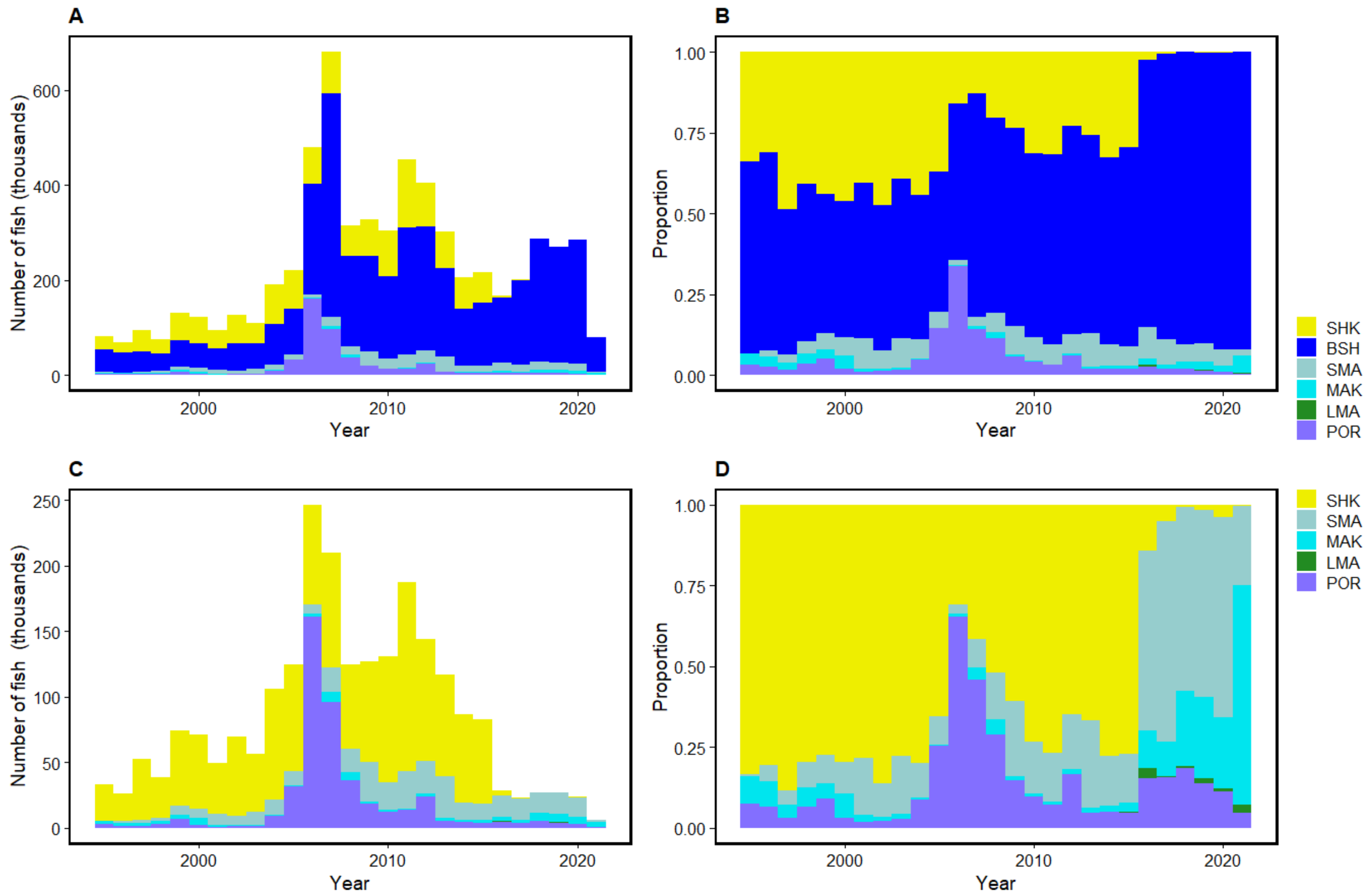

Figure 22: Species proportions of sharks observed in the WCPFC between 1990 - 2021 and separated into all sharks (A) proportion of all sharks (B) the number of mako like sharks (C) and the proportion of mako like sharks (D). SHK = generic shark code; BSH = blue shark; SMA = shortfin mako; MAK = generic mako code; LMA = longfin mako; POR = probeagle.

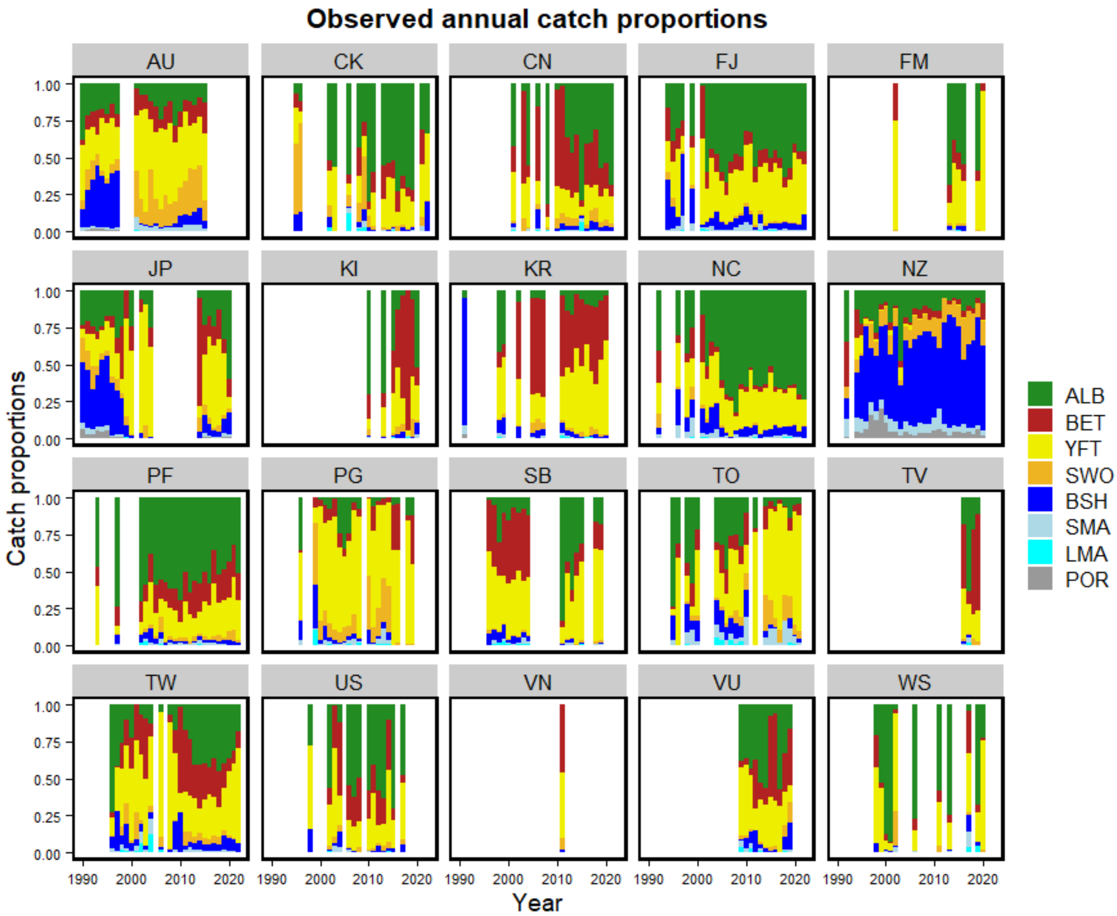

Figure 23: Species proportions of tuna, swordfish and south Pacific shortfin mako sharks observed in the WCPFC between 2000 - 2021 and separated by flag.

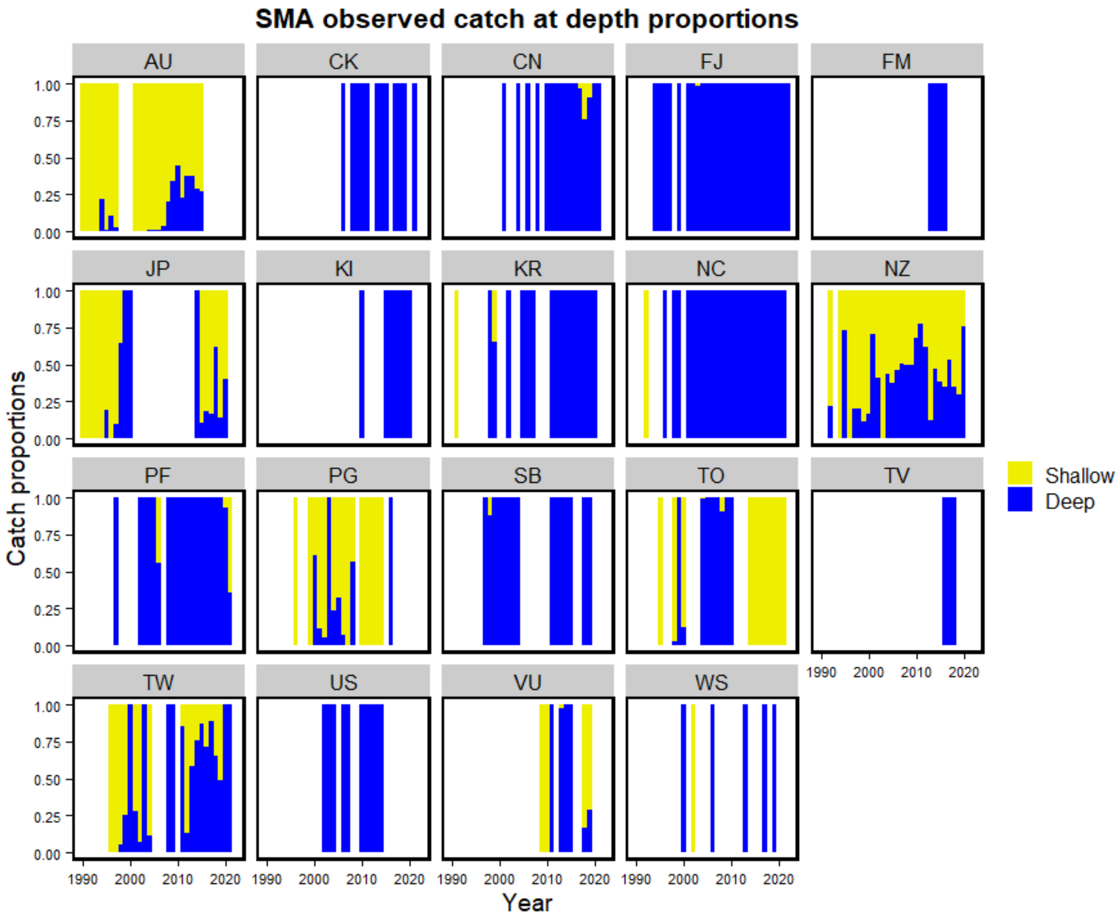

Figure 24: The ratio of shallow to deep sets by flag for sets made in the WCPFC between 2000 - 2021.

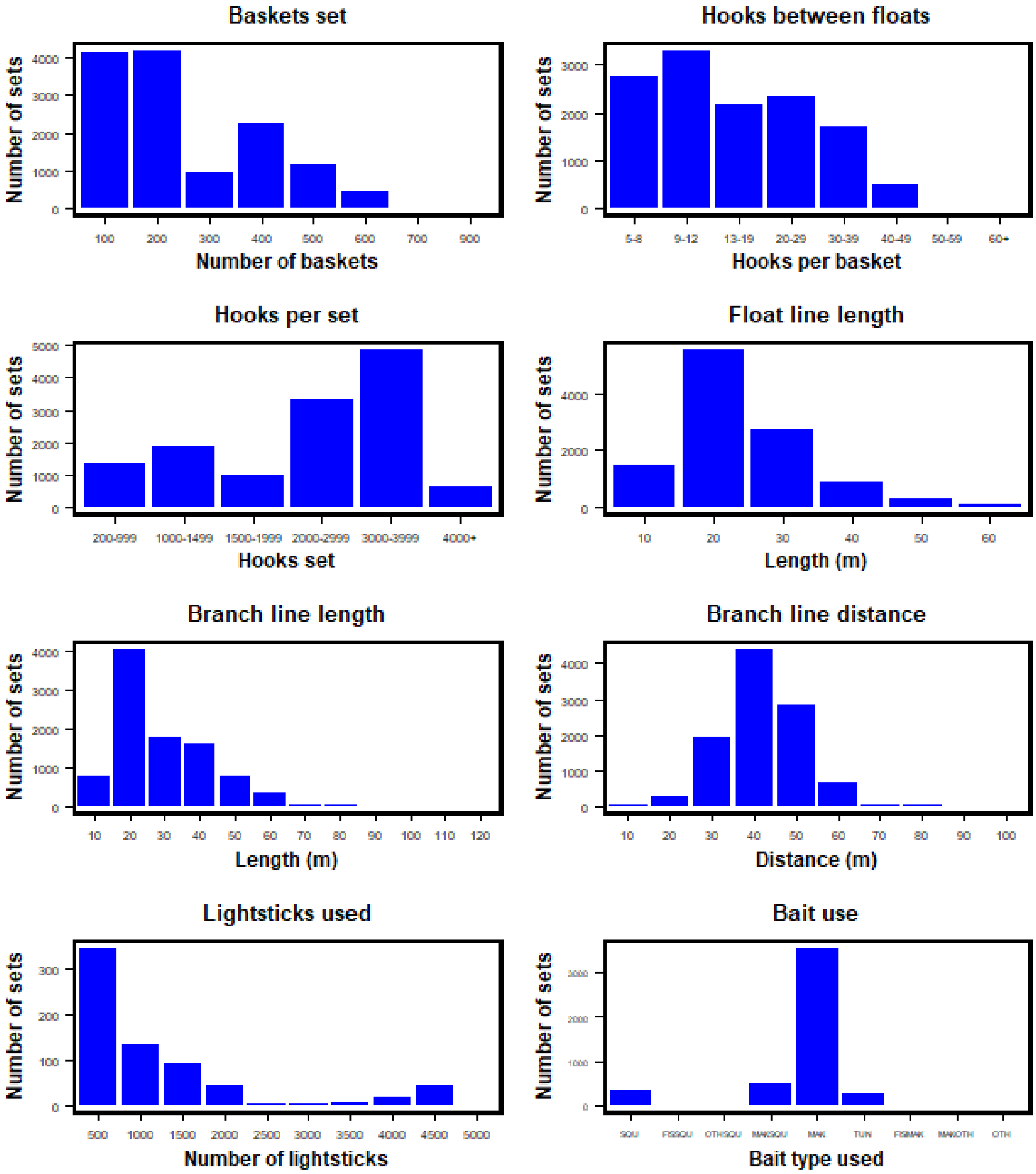

Figure 25: The observed baskets set, hook between floats,hooks set, float line length, branch line length, branch line distance, number of lightsticks used and reported bait use in sets made in the WCPFC between 1990 - 2021 from all fleets.

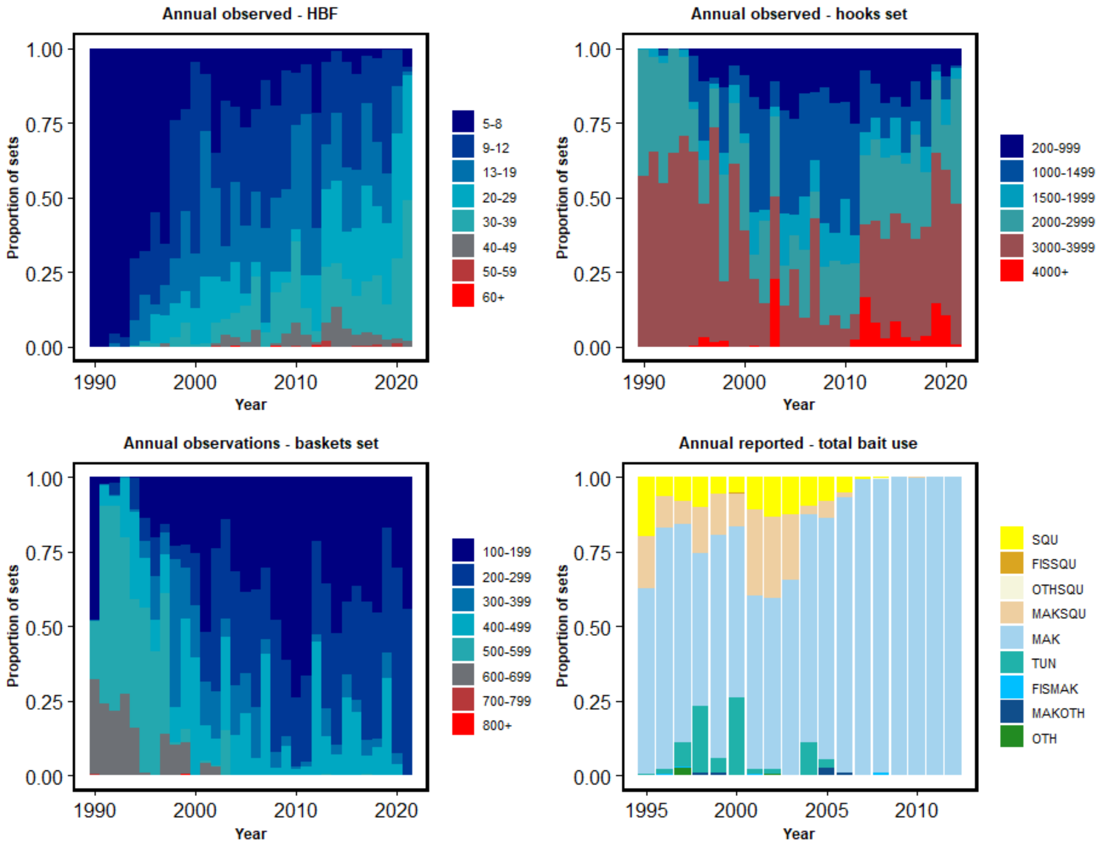

Figure 26: Observed hook between floats (HBF), hooks set, baskets set and reported bait use in sets made in the WCPFC between 1990-2021 from all fleets.

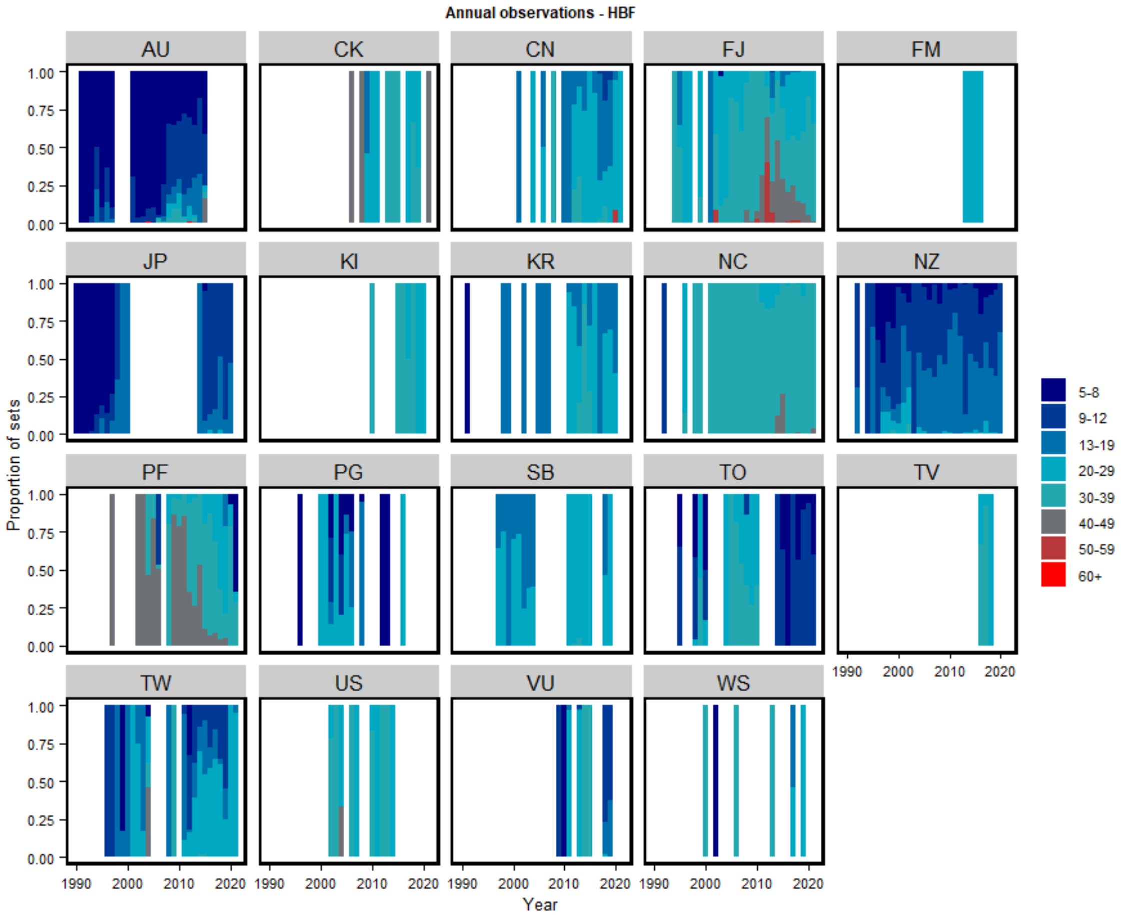

Figure 27: Observed hook between floats (HBF), by flag in the WCPFC between 1990-2021.

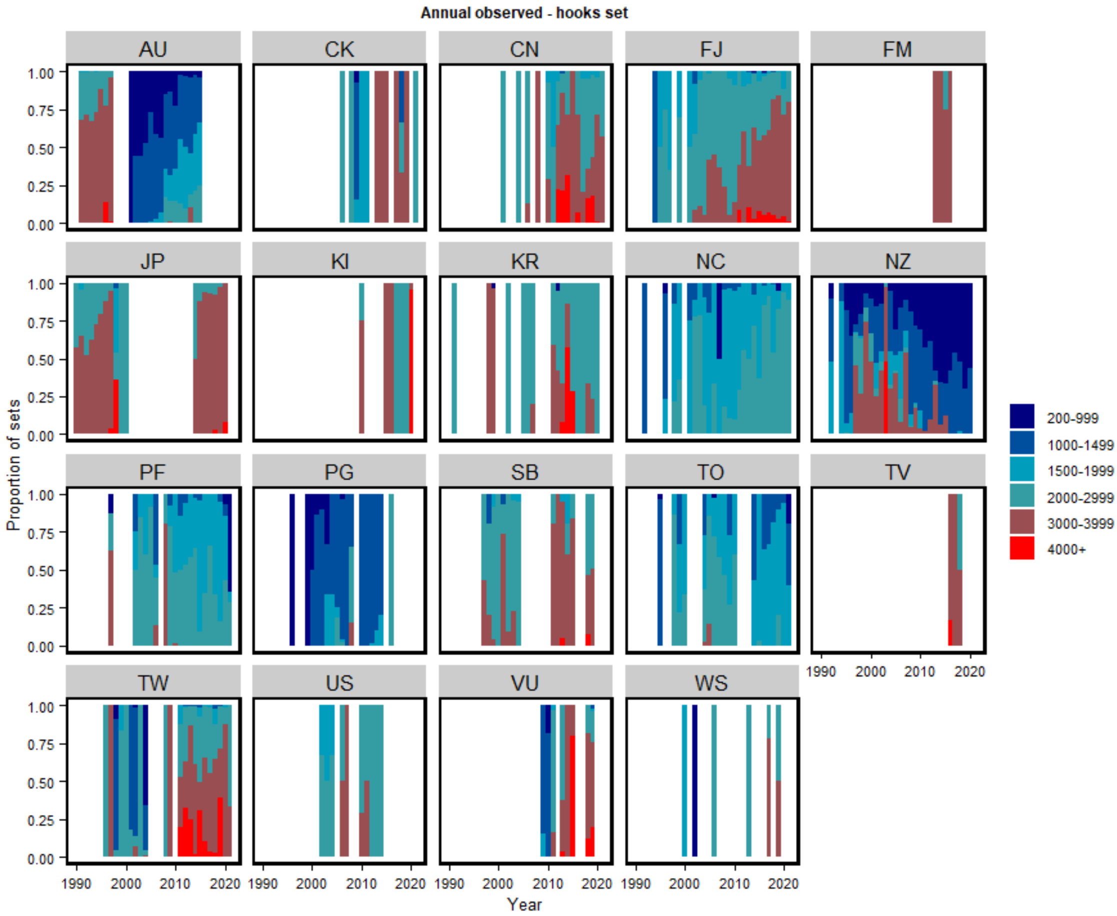

Figure 28: Observed hooks set on longline sets, by flag in the WCPFC between 1990 - 2021.

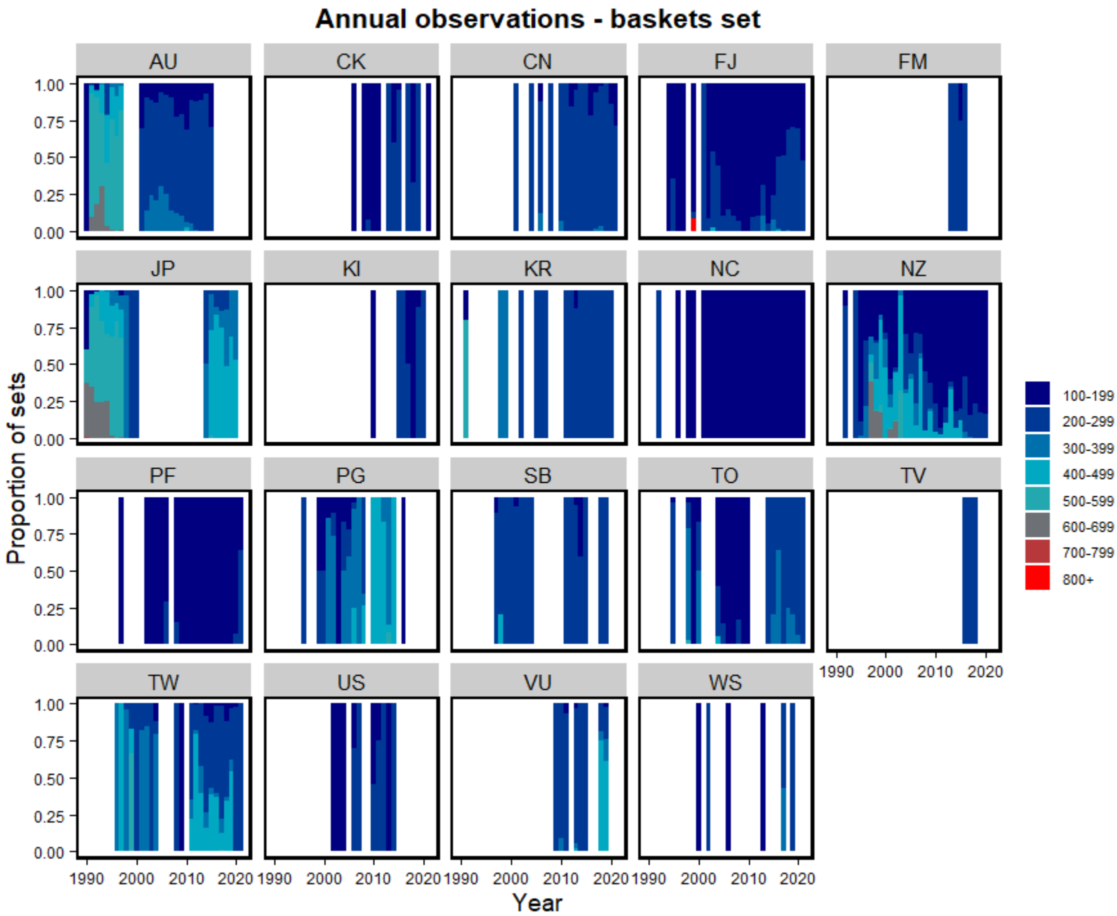

Figure 29: Observed baskets set on longline sets, by flag in the WCPFC between 1990 - 2021.

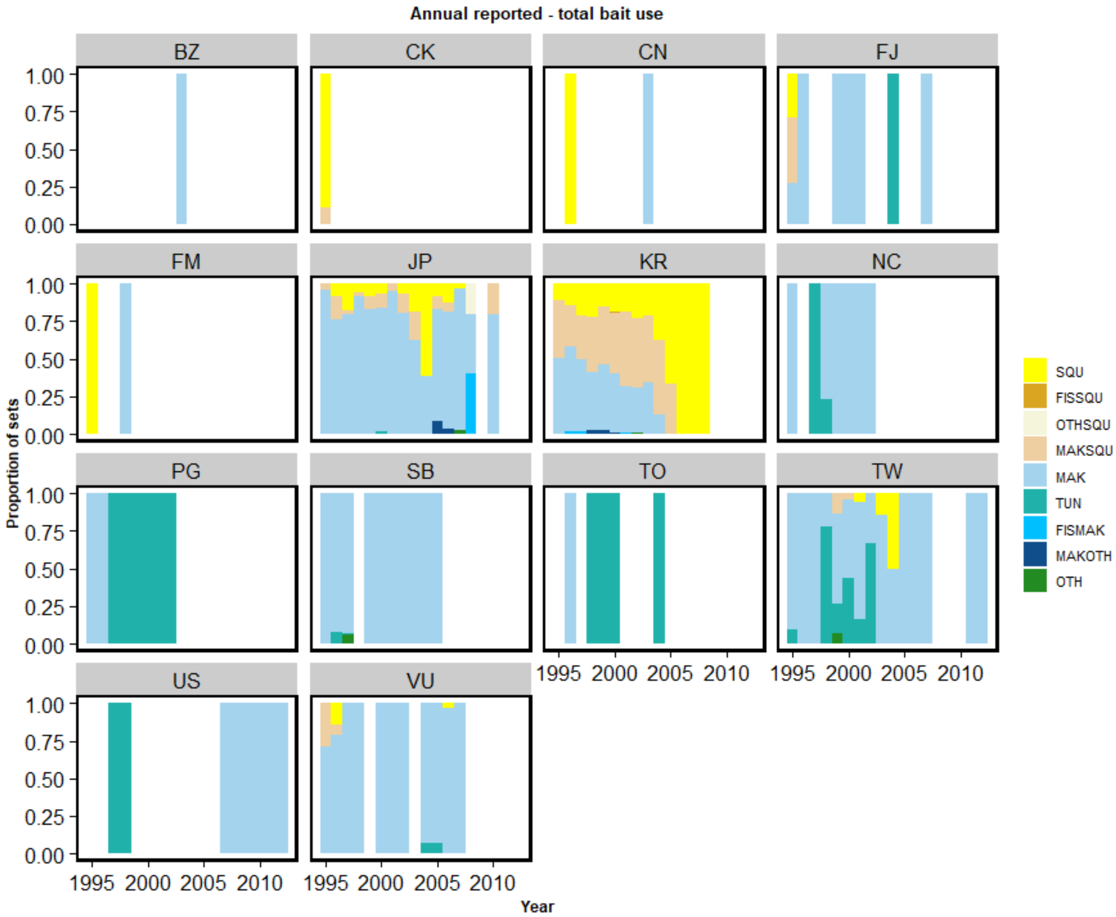

Figure 30: Reported bait use set on longline sets, by flag in the WCPFC between 1990 - 2021.

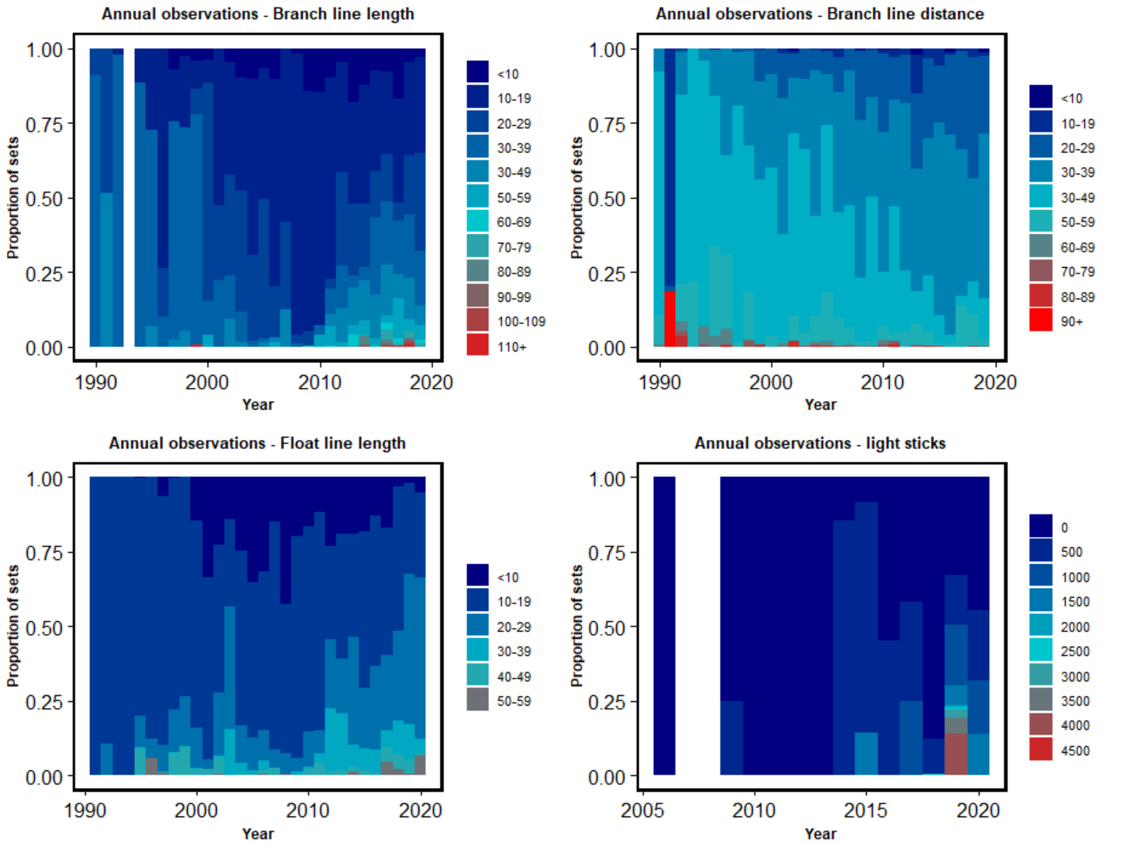

Figure 31: Observed branchline length, branchline distance, float line length and lightstick use on longline sets, in the WCPFC between 1990 - 2021.

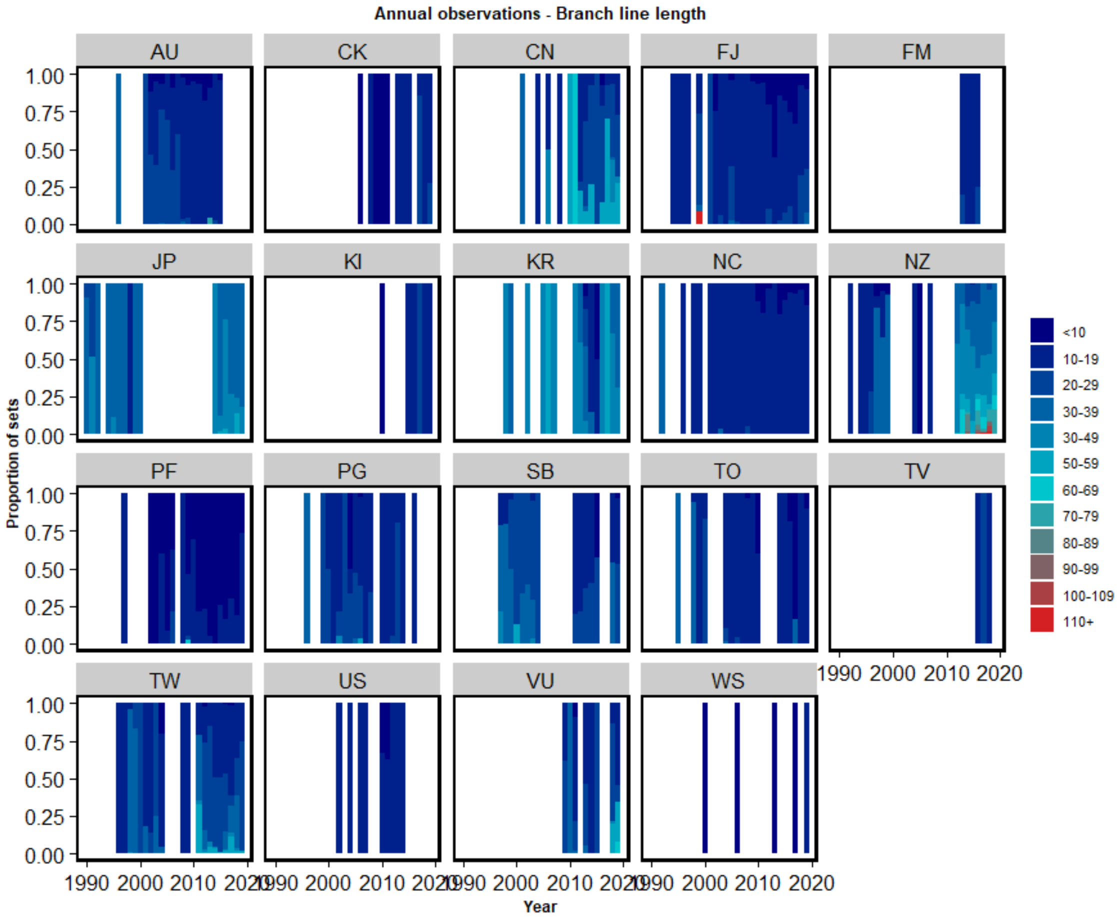

Figure 32: Observed branchline length, used on longline sets, by flag in the WCPFC between 1990-2021.

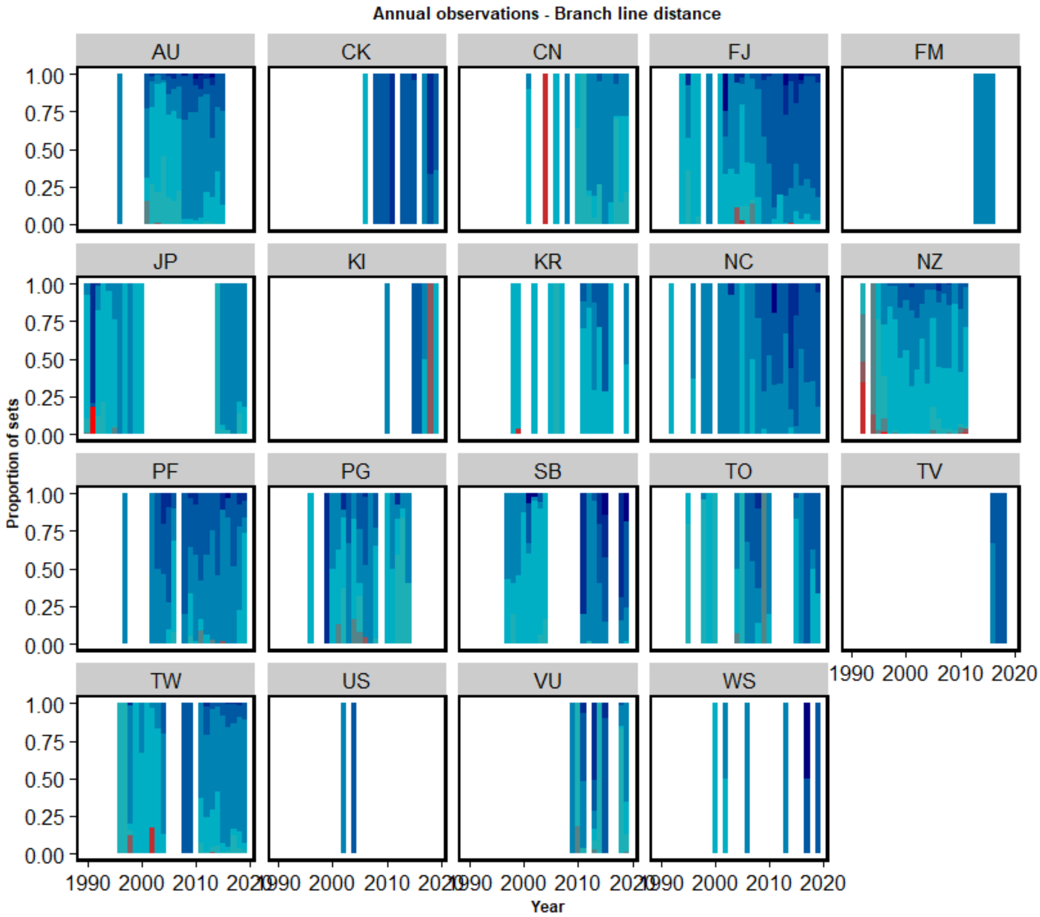

Figure 33: Observed branchline distance, used on longline sets, by flag in the WCPFC between 1990 - 2021.

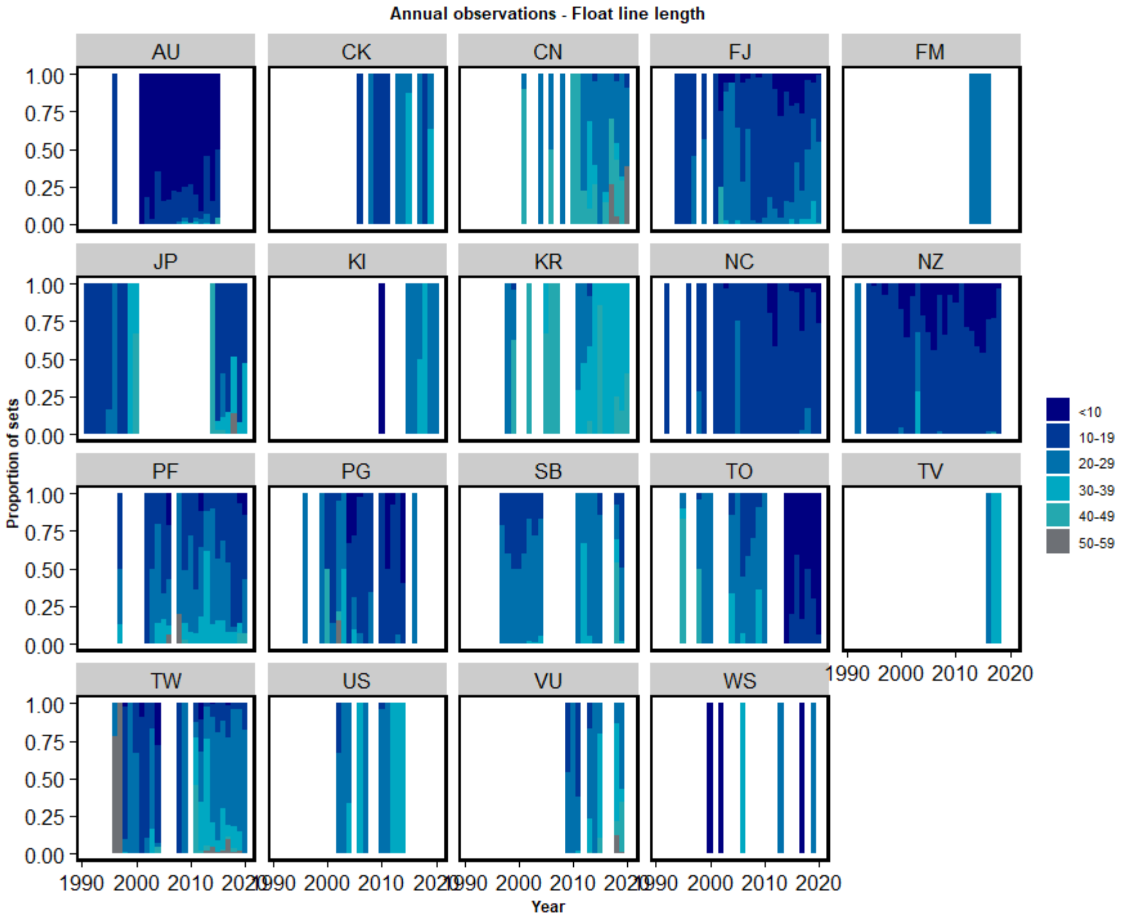

Figure 34: Observed float line length, used on longline sets, by flag in the WCPFC between 1990-2021.

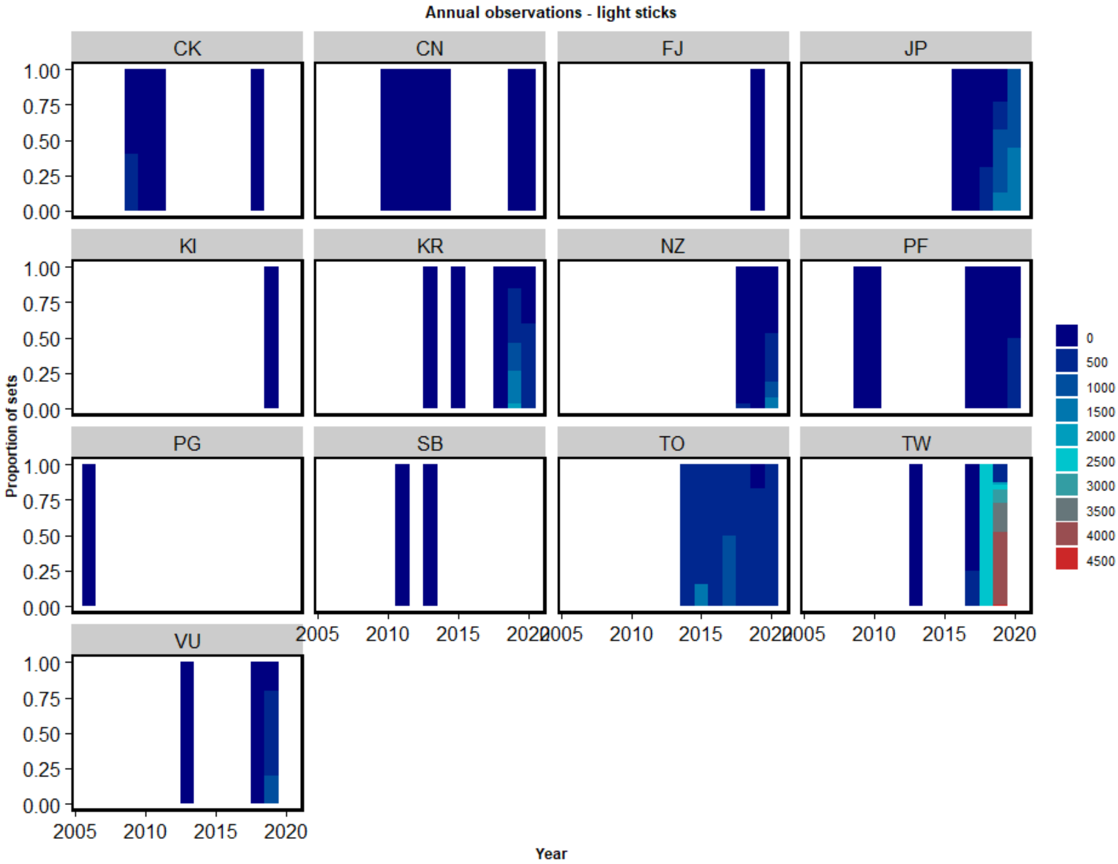

Figure 35: Observed lightstick use on longline sets, by flag in the WCPFC between 1990 - 2021.

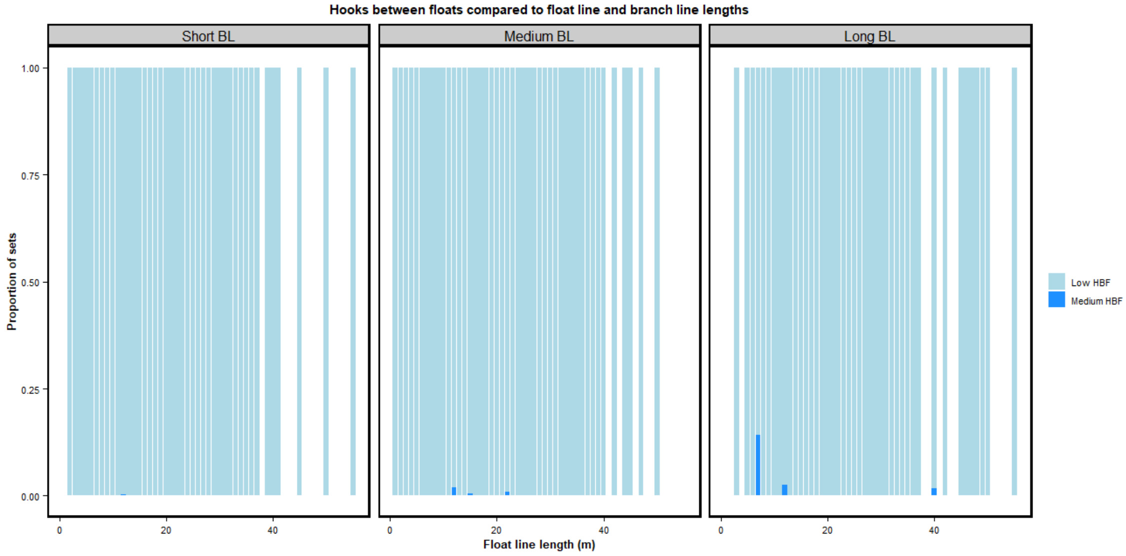

Figure 36: Comparison of the hooks between floats (HBF), branch line length (BL) (as three groups Short Medium and long) and float line length.

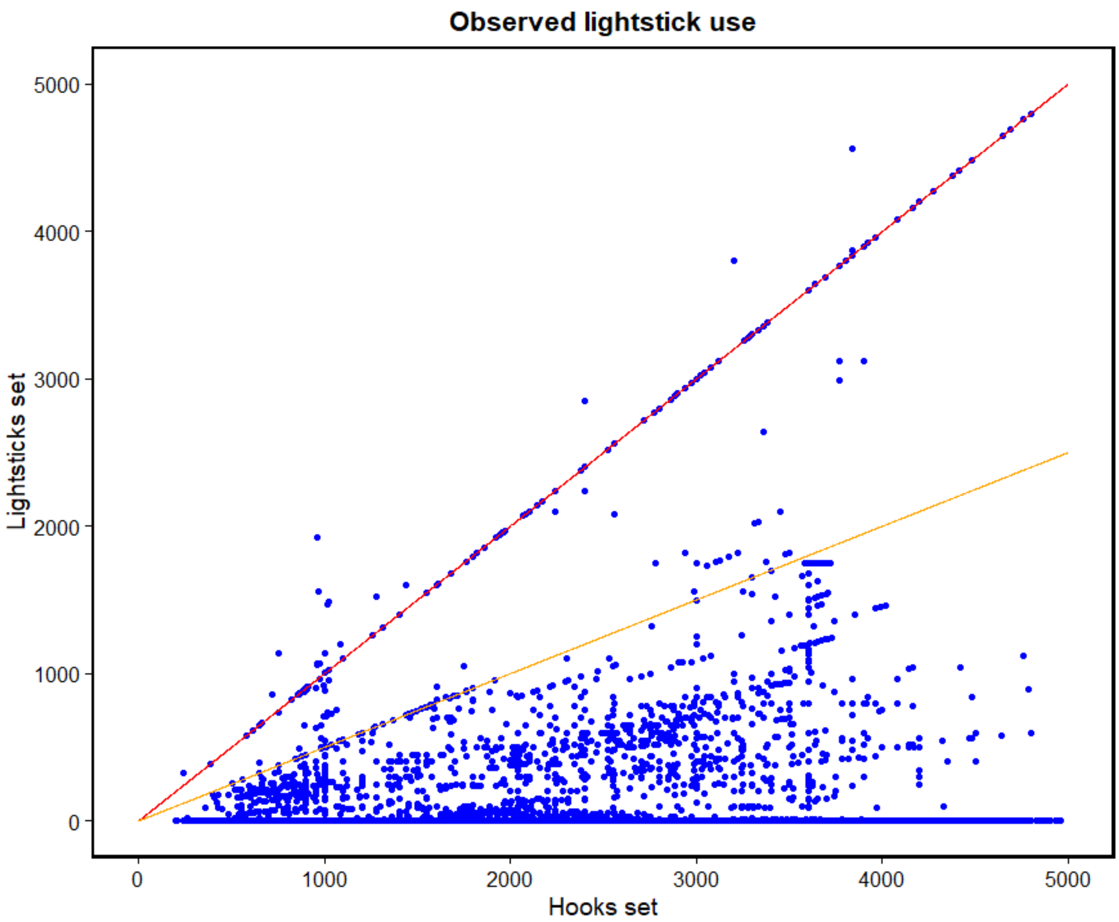

Figure 37: Comparison of the number of lightsticks to the number of hooks set. The red line represents the 1:1 ratio. The orange line represents the 1:0.5 ratio.

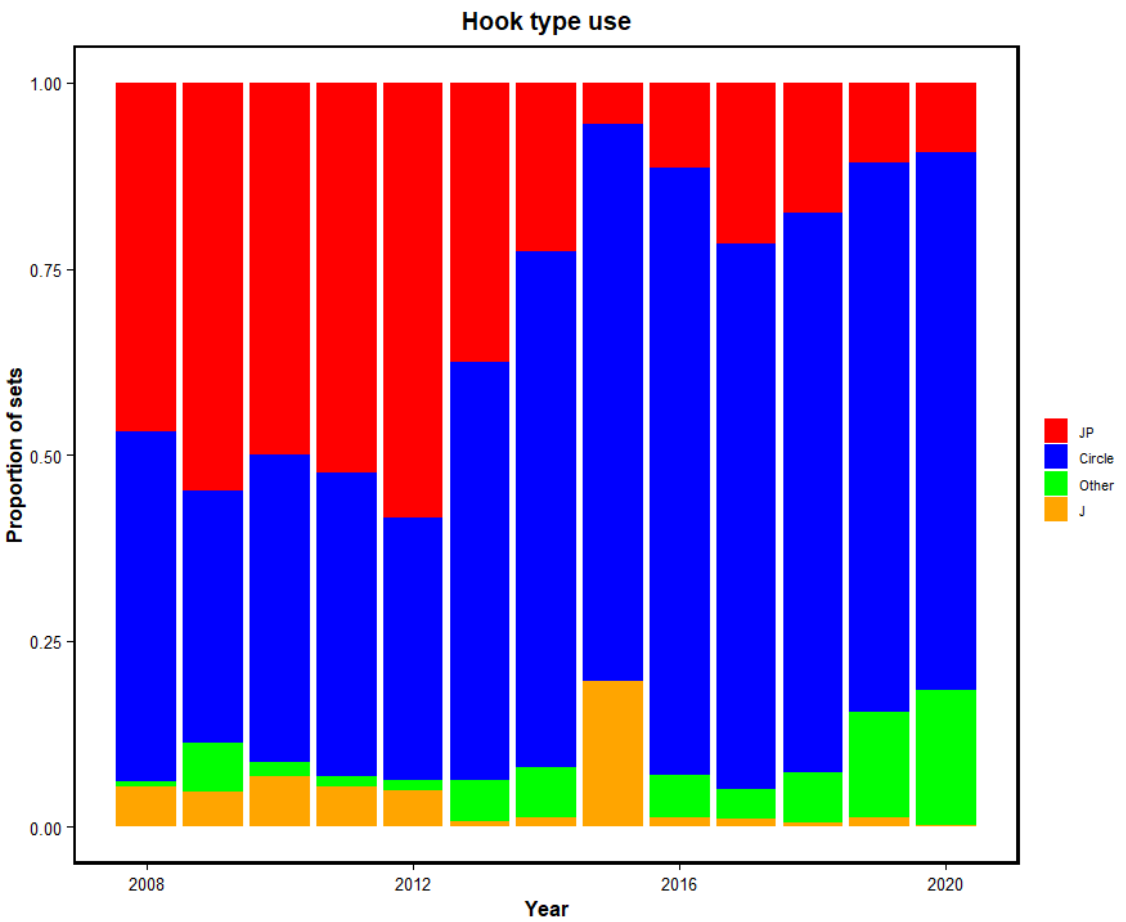

Figure 38: The use of hook types for all fleets combined in the WCPFC between 2008 - 2021.

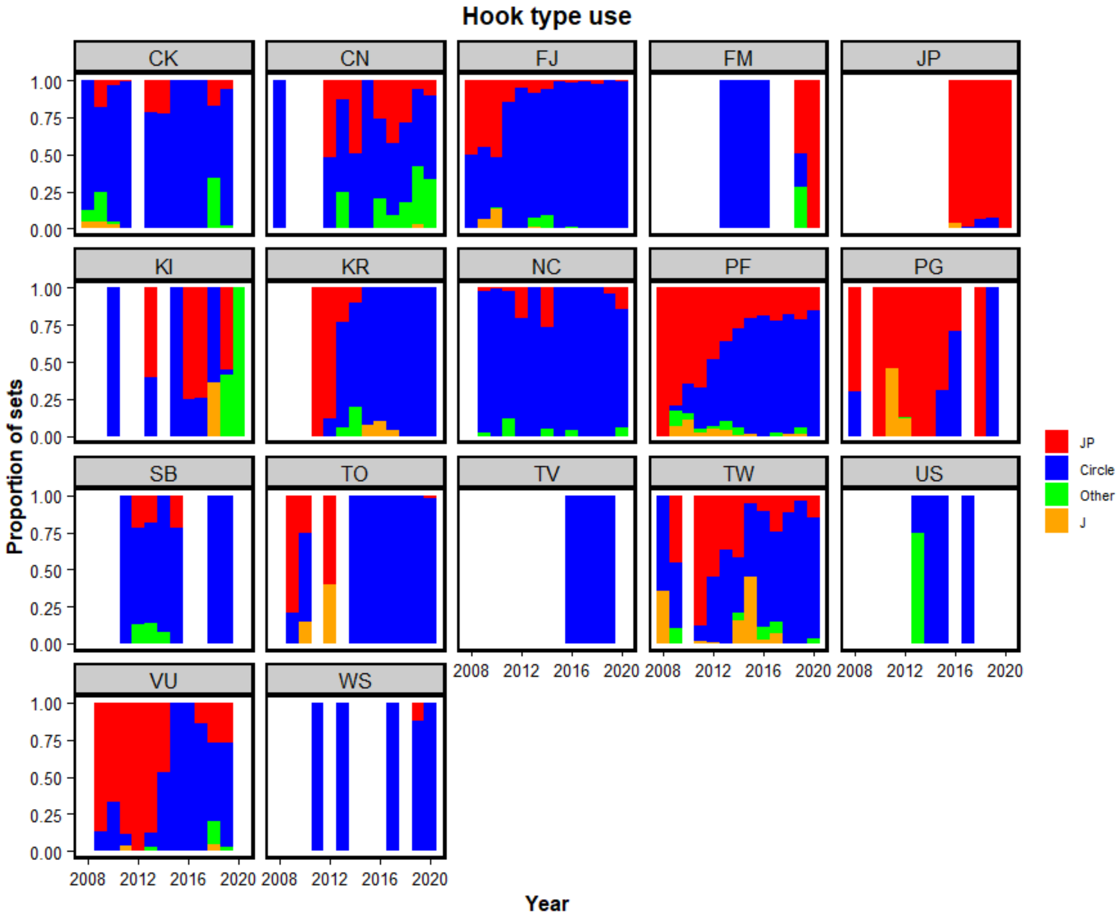

Figure 39: The use of hook types by flag in the WCPFC between 2008 - 2021.

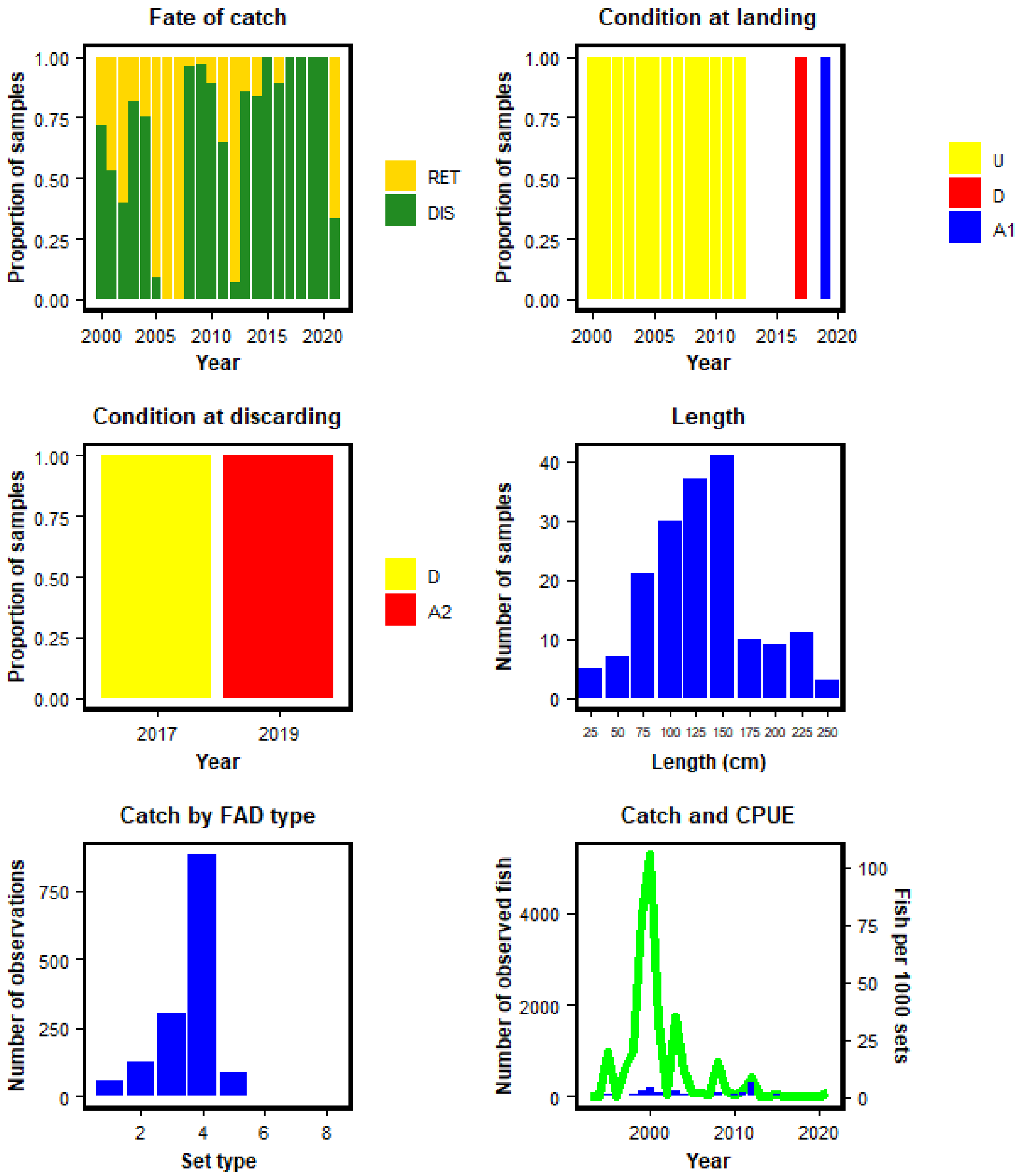

Figure 40: Observed purse seine fate and condition information as well as length catch by set type and catch and CPUE in the WCPFC between 1990 - 2021. RET = Retained, DIS = Discarded, D = Dead, A1 - A2 are various life states as defined in Table 2 and the set type codes are defined in Table 3.

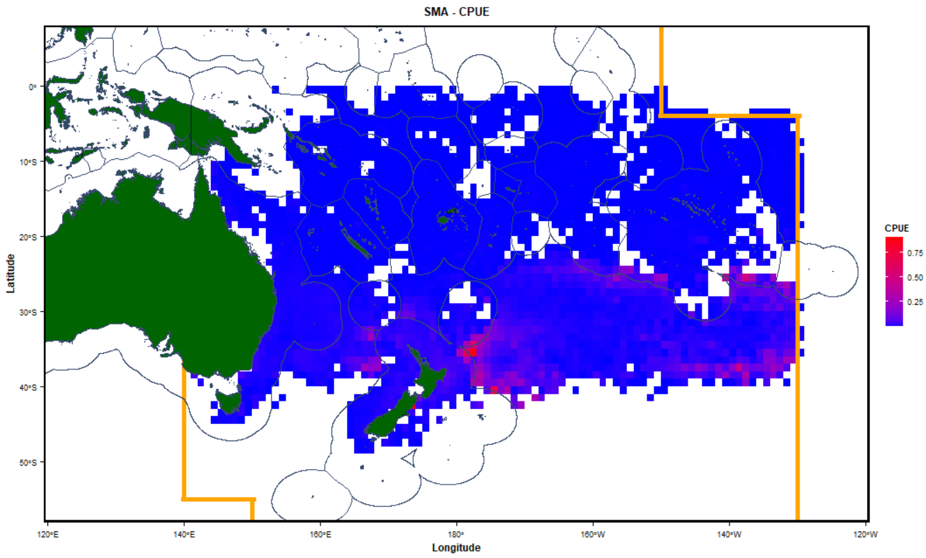

Figure 41: Longline logsheet nominal catch per unit effort (kg / 100 hooks) of south Pacific shortfin mako sharks caught per 1x1 degree square in the WCPFC Convention area between 1990 - 2021.

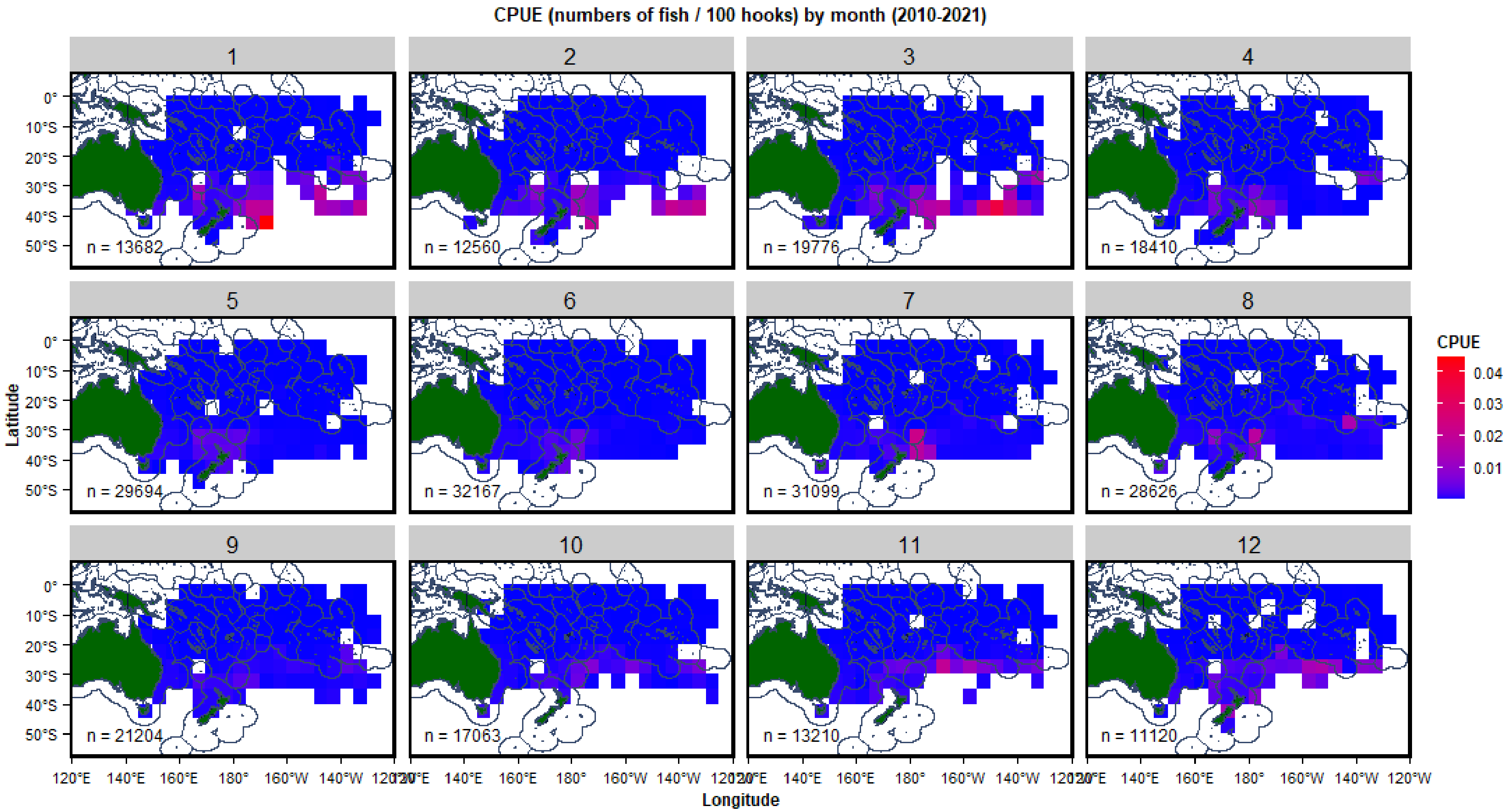

Figure 42: Longline logsheet nominal catch per unit effort (kg / 100 hooks) of south Pacific shortfin mako sharks caught by month and 5x5 degree square in the WCPFC Convention area between 1990 - 2021.