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# Characterisation of the fisheries catching South Pacific blue sharks (*Prionace glauca*) in the Western and Central Pacific Ocean

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Report prepared for WCPFC SC17

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# EXECUTIVE SUMMARY

South Pacific blue sharks (*Prionace glauca*) are thought to consist of a single stock separated from blue sharks in the north Pacific at the Equator. This paper describes the fisheries catching blue 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. The proportion of blue sharks in logsheets increased, and the proportion of logsheets with zero blue sharks has declined in recent years from around 80% prior to 2010 to around 35% currently. 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 blue shark is not consistently representative through time.

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 propensity 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 blue sharks. Smaller blue sharks are found in the more southerly latitudes.

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.

Blue sharks are wide ranging across the South Pacific Ocean, and display weak size and seasonal movement patterns which do not seem to cross the Equator into the north Pacific. Overall, there appears to be a reasonable amount of data from 1990-2019, 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, 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 following recommendations are proposed for the Scientific Committee to consider:

1. The length data should only be used as fleet specific selectivity data and not used to interpret changes in length over time.
2. Aggregated data are submitted as annual totals for the WCPFC area only, making them uninformative for a stock specific assessment. Therefore, blue shark (and probably other Key Sharks) aggregated data should be reported by ocean area not simply as WCPO and, where possible, these data should be retrospectively corrected.
3. Observers (or the vessel) should record number of shark lines deployed or the

number of floats with shark lines.

# 1. INTRODUCTION

South Pacific blue sharks (*Prionace glauca*) are thought to consist of a single stock separated from blue sharks in the north Pacific at the Equator. This premise is largely based on extensive tagging work in Japan, the USA, and New Zealand (Sippel et al. 2016; Kai and Fujinami 2020). These studies have shown that blue sharks move extensively across the North and South Pacific Ocean but have not been observed crossing the Equator. While some trans-equatorial movement has been observed in the Atlantic Ocean (Vandeperre et al. 2014), this has not been observed in the Pacific. Blue sharks are relatively productive compared to other elasmobranchs, they are relatively fast growing, have a high fecundity, and pup annually (Clarke 2015; Joung et al. 2018; Chin and Simpfendorfer 2019; Brouwer and Hamer 2020).

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. 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, much of the catch is made as bycatch in tuna and swordfish target fisheries.

Historically, bycatch went unreported or were poorly reported on vessel logsheets, particularly for sharks that were finned and discarded. 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 estimated rather than relying on reported or observed catch (Peatman et al. 2018).

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 conservation 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 of WCPFC Key Sharks (which includes blue 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 blue sharks which therefore fall under the general provisions. Blue sharks in the North and South Pacific are both scheduled for periodic (5-yearly) assessments under the SRP (Brouwer and Hamer 2020).

This paper describes the fisheries catching blue sharks in the Southwestern Pacific Ocean as well as the reported and observed data potentially available for use in a stock assessment. Note that 2020 data are provisional, as longline data are reported with a 1-year delay due to the long length of the trips. While blue sharks are predominantly caught in longline fisheries, and these are the focus of this report, there are some purse seine catch which are also reported and these data are included here for completeness. The South Pacific blue shark stock assessment is reported in Neubauer et al. 2021b.

## 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$^o$ 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$^o$ 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 and purse seine 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, and these analyses are presented in Neubauer et al. 2021b.

[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 blue shark stock assessment and related analyses.

The total blue 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.

Blue 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 (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 blue 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 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, $5x5^o$ 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 blue shark catch comes from the areas south of 30$^o$ south, while fishing effort is concentrated north of 30$^o$ south (Figure 1). Most of the reported blue shark catch comes from the New Zealand EEZ and the south central and south eastern high seas areas to the east of New Zealand, with lower levels of reported catch elsewhere. Reported blue shark catch on logsheets is highest in the EEZs, and are highest in the Vanuatu, Fiji, the Solomon Islands and the Samoan EEZs. Some high seas areas, such as the high seas pocket between Fiji, Vanuatu and the Solomon Islands, have high levels of reported effort.

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 and Australia have beed reporting catch contunuously since the early 2000s, most of the other CCMs began reporting blue shark catch in the mid- to late-2000s (Figure 3). For a number of CCMs, such as the USA, Papua New Guinea and New Zealand, there is a marked decline in reported blue shark catch since 2015. For other CCMs, such as the Solomon Islands, blue shark catch reporting began after 2015. Unfortunately, the annual catch estimates submitted to the WCPFC are all reported as blue shark in the Convention Area and not separated north and south of the Equator (Figure 4).

Since 2006, the longline catch of South Pacific blue sharks has increased markedly. The catch levels have fluctuated without trend at this elevated level, with the exception of a strong peak in 2007. The low catch in 2020 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 blue sharks was low with around 87% of logsheets from the WCPFC Convention area south of the Equator not recording any blue shark catch (Figure 6). However, since 2010 catch reporting has shown a marked improvement, and in 2019 only about 37% of longline logsheets did not report any blue shark catch.

Catch reporting of blue sharks in the south Pacific has been inconsistent through time. In the 1990s a small amount of catch was reported, mostly within the New Zealand and Australian EEZs (Figure 7 top). Through the 2000s catch reporting improved and blue sharks were reported from some fisheries on the high seas south of 25$^o$ south. Reporting also improved within some Pacific Island State EEZs such as the Cook Islands, Papua New Guinea and Fiji (Figure 7 middle). In the 2010s South Pacific blue 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 blue 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 blue sharks are being discarded, and since 2017 most of the discards are fish that are cut free, with only a small proportion currently being retained. For many CCMs prior to 2015 a high proportion of the blue shark catch was retained, with discarding (including fish being cut free) strongly apparent in the last five years (Figure 9). There are some exceptions to these trends, French Polynesia and New Caledonia began discarding blue sharks about a decade before most other countries, as did the USA, while some CCMs such as Japan and Chinese Taipei still retain a high proportion of their blue shark catch.

Observer reporting on blue shark condition at capture shows that most blue 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 record code A0 ("Alive but not categorized") frequently. New Zealand 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 (Figure 11).

Comparing the fate, condition at capture, and condition at release across fleets overall, in the most recent years most blue 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 blue 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 2009 and currently a high proportion of blue 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 blue sharks are caught on the shallowest hooks most frequently and, while they can get caught on the deepest hooks, this happens in low numbers. Generally speaking, blue sharks are caught on the hook numbers 1-6 in a basket, that is, the hooks closest to the float (Figure 13). Blue 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 in a set and, as a result, we could not calculate relative frequencies.

### 3.4 Length data

South Pacific blue 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 blue sharks in the South Pacific increased, after which it fluctuated without trend until around 2012 when it increased and remained stable at that new level. A small increase in the latest year is likely a result of low sample size (Figure 14 top left). Most blue sharks are measured to UF (Figure 14 top right). Overall, the number of samples has increased through time (Figure 14 bottom left) and the length frequency seems to be bimodal with no difference between male and females (Figure 14 bottom right).

Most length samples come from New Zealand, Australia, Japan and Chinese Taipei (Figure 15). Australia, Japan and New Zealand all have a high number of small fish in their catch while fish are larger in the Chinese Taipei, China and Fiji samples. 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 blue shark size in the Australian and Japanese catch 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 blue shark size was relatively consistent through time but for New Zealand, Fiji, Tonga and French Polynesia the median fish size had declined in the most recent period.

Blue shark size does not seem to change with depth, where the catch by hook number analysis showed relatively consistent size at catch with changes in 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). While blue sharks are more frequently landed on the shallowest hooks, the larger number of deep sets results in a higher number of sharks landed in the deeper sets and, therefore, a higher number of samples.

There are relatively strong trends in blue shark size with latitude (Figure 19). Blue sharks in the higher latitudes are smaller (mostly just below the size-at-maturity $\sim$ 195cm) than those in the mid-latitudes (mostly at or above the size-at-maturity) and the equatorial regions (mostly below or around the size-at-maturity). The largest mature fish seem to reside in the mid-latitudes between 20 and $35^o$ South, with medium sized fish in the Tropics and juveniles in the higher latitudes.

Assessing the blue shark catch relative to the target tuna and swordfish stocks 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 blue sharks are caught in higher proportions in the shallow sets compared to deep sets (Figure 20). In addition, the shallow set data, while more variable than the deep set data, show that in the 1990s blue sharks constituted more than 50% of the catch, but have declined since then. The deep set data indicate that blue sharks catch proportions were high (around 30%) prior to 2000, but since then blue shark make up less than 10% of the catch.

For most CCMs, the catch ratios are relatively consistent through time, with Australia and Japan being the only CCMs with distinctive changes (Figure 21). These data will however be confounded by where the data come from with sets in the higher latitues being shallower than those in the tropics. Prior to 2000, both Australia and Japan had high catch proportions of blue sharks, and these declined from 2000 onwards. New Zealand has had consistently high proportions of blue sharks compared to the other CCMs, and the remaining CCMs have very low blue shark catch proportions. Some of the trends in catch ratios may be linked to management regulations. As noted above, in recent years blue shark discarding rates have increased substantially, resulting in lower blue shark catch proportions. New Zealand is the exception, possibly due to the higher rates of observed discards included in the catch data.

The depth of the fishing gear is also likely to influence blue shark catch. New Zealand vessels have consistently set shallower sets than other CCMs. Australia and Tonga have switched from deep to shallow sets, with most other CCMs having relatively consistent estimated gear depth being used through time (Figure 22). 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, 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 is evenly distributed with most vessels setting between 9 and 30 hooks between floats and setting 2000-3000 hooks (Figure 23). 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 fish bait (Figure 23).

There is a distinctive switch in gear over time (Figure 24). Since the mid-2000s there has been a change for vessels to use more hooks between floats (Figure 24 top left), and to set fewer baskets per line (Figure 24 bottom left). There has also been a decline in the numbers of hooks set, although this trend is less marked (Figure 24 top right). Vessels use less squid bait in the more recent years (Figure 24, bottom right). Prior to the mid-2000s just under half of the sets used squid or a mix of squid and fish, thereafter most sets use fish as bait.

The combined fleet data are likely influenced by data availability by fleet. 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 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 25). Australia, Papua New Guinea, New Caledonia, New Zealand and Tonga have all moved to setting fewer hooks, while Fiji, China, Chinese Taipei, Japan the Solomon Islands and Vanuatu vessels all set more hooks in the more recent period (Figure 26). Australia, the Cook Islands, China, Korea, Chinese Taipei, the USA and Vanuatu all have fewer baskets per line in the more recent years, while Fiji and Tongan vessels set more baskets per set (Figure 27). Bait use across fleets is variable, but the data for many fleets are sparse (Figure 28). 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 29 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 in recent years (Figure 30). 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 31). Floatline length for most fleets has been relatively consistent through the 2000s but is increasing in Fiji and Chinese Taipei since 2010 (Figure 32). It is difficult to assess the fleet specific lightstick use trends, the only vessels showing and strong trends is that if the Chinese Taipei vessels who are increasing their use of lightsticks in the most recent two years (Figure 33).

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 34). While most vessels (94%) used no lightsticks, a number of vessels (0.6%) used 100% lightsticks (here 100% lightsticks referrs 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 10.5% have 100% lightsticks, and 14% had 50% or more (Figure 35).

The use of different hook types revealed that circle and "Japanese hooks" are most frequently used and there has been an increase in the use of circle hooks and a decline in "Japanese hooks" (Figure 36). 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 37).

### 3.6 Purse seine gear attributes

There were few blue shark records in the purse seine catch and, as a result, all the trends are reported for all fleets combined only (Figure 38). These data show that there has been an increasing propensity to discard blue sharks (Figure 38 top left), although actual observed catch is low. Condition at landing and release data are too infrequently recorded to be meaningful (Figure 38 top right and middle left). Only a few length measurements are available and these are also uninformative (Figure 38 middle right). Blue 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 schools with no bait fish, and never in sets associated with whales or whalesharks[2] (Figure 38 bottom left). The catch and CPUE are both variable with no distinct trends (Figure 38 bottom right).

### 3.7 Nominal CPUE map

Blue shark catch rates were higher in the south-easterly portion of the WCPFC convention area between 30$^o$S and 40$^o$S and to the east of the New Zealand EEZ (Figure 39). However, the catch rates change seasonally (Figure 40) and blue shark catch rates are highest in the first quarter in the southeast, reducing through the Austral winter, and are lowest in the last quarter of the year.

## 4. DISCUSSION

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. 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 blue sharks. There are good biological data for blue sharks (e.g. Clarke 2015; Chin and Simpfendorfer 2019; and Joung et al. 2018). There are a number of 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.

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

The WCPFC does not hold any new age and growth samples for analyses. The two main sources of information about age and growth of blue shark in the South Pacific have limitations, and age and growth data are still required. The Joung et al. 2018 investigation covered a wide area of the South Pacific but had few samples and did not have samples from very large individuals, whereas Manning and Francis 2005 assessed blue 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 these two studies should be included in the assessment to assess the impact of growth on the assessment results.

The SRP information sheet summarises the known biological parameters and fishery data for South Pacific blue sharks (Brouwer and Hamer 2020). The WCPFC recognise that South Pacific blue sharks comprise a single stock separated from blue sharks in the north Pacific at the Equator. They are relatively productive compared to other elasmobranchs, relatively fast growing, and with a high fecundity.

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 Neubauer et al. 2021a and Neubauer et al. 2021b. The report card notes that gaps in the observer data may inhibit catch history estimation, and this issue will be dealt with below. 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. Notably 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 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. Ocean area specific data will be more useful 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 blue sharks increased substantially. However, there were still a lot of logsheets where no blue sharks were reported. CMM2009-04 included specific reference to WCPFC Key Sharks which were defined and included blue sharks. As a result of that (and probably the development of new logsheets that specifically included blue sharks), the proportion of blue sharks in the logsheets increased, and the proportion of logsheets with zero blue sharks has declined in recent years from around 80% prior to 2010 to around 35% currently. 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 blue 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 they are not.

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 propensity 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 blue sharks currently being released alive and healthy.

South Pacific blue 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.

Both depth of the gear and latitude will likely impact the ability of the gear to catch blue 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 blue sharks to target tuna and swordfish catch which, in turn, will influence catch reconstructions that use catch ratios.

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 blue 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 baring 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 float line 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 float lines. 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 blue shark catch rates, although the effect for blue sharks was less obvious than other 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 blue shark catch when vessels changed from fish to squid bait rather than changing from "Japanese hooks" and J-hooks to circle hooks (Howard 2015). While some studies show increased catch rates of blue sharks on circle hooks (Andraka et al. 2013), 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 do not have a major effect on shark catch rates, but do 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 blue 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 blue 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 their abundance.

Purse seine catch rates of blue sharks are low and as a result the data are uninformative. It is recommended that the purse seine data be excluded from further analysis.

Blue shark catch rates were higher in the southeast between 30$^{o}$S and 40$^{o}$S and to the east of the New Zealand EEZ. However, the catch rates vary seasonally and are highest in the first quarter in the southeast reducing through the Austral winter, and lowest in the last quarter of the year. While these trends imply that some seasonal movement patterns are prevalent, they are not absolute, and both the catch data presented here and tagging data (Sippel et al. 2016) show that deliberate seasonal movements of the whole population do not seem to occur.

In conclusion, blue sharks are wide ranging across the South Pacific Ocean, and display weak size and seasonal movement patterns which do not seem to cross the Equator into the north Pacific. Overall, there appears to be a reasonable amount of data from 1990-2019, 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 blue 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. As a result, length data can be used to assess selectivity, but probably not used as indicators of trends in biomass or other temporal trends for most fleets. Blue sharks are landed in both shallow and deep sets, most frequently caught on the shallow hooks and comprise a higher proportion of the catch in shallow sets. However, the number of deep sets is much larger and therefore contains most of the catch data, an observation also noted by Peatman et al. 2018. Relative to tuna, the catch proportion of blue 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, or targeting could be inferred through cluster analysis of the target tuna and swordfish catch.

## 5. RECOMMENDATIONS

The following recommendations are proposed for the SC to consider:

1. The length data should only be used as fleet specific selectivity data and not used to interpret changes in length over time.

2. Aggregated data are submitted as annual totals for the WCPFC area only, making them uninformative for a stock specific assessment. Therefore, blue shark (and probably other Key Sharks) aggregated data should be reported by ocean area not simply as WCPO and, where possible, these data should be retrospectively corrected.

3. Observers (or the vessel) should record number of shark lines deployed or the number of floats with shark lines.

## 6. ACKNOWLEDGMENTS

The authors would like to thank SPC, particularly Peter Williams for providing the WCPFC Members data for these analyses. We would also like to thank Paul Hamer and Sam McKechnie for constructive comments on earlier drafts of this report, and the SPC Pre-Assessment Workshop Members for their helpful feedback on the initial data characterisation and CPUE proposals. The authors would also like to thank the SPC for providing the funding for this work through the WCPFC project 107.

## 7. REFERENCES

Andraka, S.; Mug, M.; Hall, M.; Pons, M.; Pacheco, L.; Parrales, M.; Rendon, L.; Parga, M.; Mituhasi, T.; Segura, A.; Ortega, D.; Villagran, E.; Perez, S.; de Paz, C.; Siu, S.; Gadea, V.; Caicedom, J.; Zapatam, L.; Martinez, J.; Guerrero, P.; Valqui, M., & Vogel, N. (2013). Circle hooks: Developing better fishing practices in the artisanal longlinefisheries of the Eastern Pacific Ocean. *Biological Conservation*, *160*, 214–223.

Brouwer, S. & Hamer, P. (2020). *2021-2025 Shark Research Plan* (tech. rep. No. EB-IP-01 Rev1). WCPFC.

Chin, A. & Simpfendorfer, C. (2019). *Operational planning for shark biological data improvement* (tech. rep. No. SC15-EB-IP-04). WCPFC.

Clarke, S. (2015). *Understanding and mitigating impacts to whale sharks in purse seine fisheries of the Western and Central Pacific Ocean* (tech. rep. No. SC11-EB-WP-03). WCPFC.

Francis, M. P. & Duffy, C. (2005). Length at maturity in three pelagic sharks (*Lamna nasus*, *Isurus oxyrinchus*, and *Prionace glauca*) from New Zealand. *Fish. Bull*, (103), 489–500.

Godin, A.; Carlson, J. K., & Burgener, V. (2012). The effect of circle hooks on shark catchability and at-sea vessel mortality rates in longline fisheries. *Bulliten of Marine Science*, *88*(3), 469–483.

Howard, S. (2015). *Mitigation options for shark bycatch in longline fisheries* (tech. rep. No. New Zealand Aquatic Environment and Biodiversity Report No. 148). New Zealand, Ministry for Primary Industries.

Joung, S. J.; Lyu, T., G; Hsu, H. H.; Liu, K. M., & Wang, S. B. (2018). Age and growth estimates of the blue shark *Prionace glauca* in the central South Pacific Ocean. *Marine and Freshwater Research*. doi:10.1071/MF17098

Kai, M. & Fujinami, Y. (2020). stimation of mean movement rates for blue sharks in the northwestern Pacific Ocean. *Animal Biotelemetry*, *8*(35). doi:https://doi.org/10.1186/s40317-020-00223-x

Kaplan, I. C. & Cox, J. F., S. P. Kitchell (2007). Circle hooks for Pacific longliners: not a panacea for marlin and shark bycatch, but part of the solution. *Transactions of the American Fisheries Society*, *136*, 136–401.

Kim, S. S.; Moon, D. Y.; An, D. H., & Koh, J. R. (2006). *Comparison if corcle hooks and J hooks in the catch rate of target and bycatch species taken in the Korean tuna longline fishery* (tech. rep. No. WCPFC-SC2-2006/EB WP-12). WCPFC.

Manning, M. J. & Francis, M. P. (2005). *Age and growth of blue shark (Prionace glauca) from the New Zealand Economic Exclusive Zome* (tech. rep. No. New Zeland Fisheries Assessment Report 2005/26). New Zealand Ministry of Fisheries.

Neubauer, P.; Large, K., & Brouwer, S. (2021a). *Stock assessment for south Pacific blue shark in the Western and Central Pacific Ocean* (tech. rep. No. WCPFC-SC17-2021/SA-WP-03). WCPFC.

Neubauer, P.; Large, K.; Team, J. P., & Team, T. W. (2021b). *Blue shark CPUE paper* (tech. rep. No. WCPFC-SC17-2021/SA-IP-XX). WCPFC.

Peatman, T.; Bell, L.; Allain, V.; Caillot, S.; Williams, P.; Tuiloma, I.; Panizza, A.; Tremblay-Boyer, L.; Fukofuka, S., & Smith, N. (2018). *Summary of longline fishery bycatch at a regional scale, 2003-2017*. WCPFC-SC14-2018/ST-WP-03.

R Core Team (2020). *R: A Language and Environment for Statistical Computing*. Vienna, Austria.

Sippel, T.; Wraith, J.; Kohin, S.; Taylor, V.; Holdsworth, J.; Taguchi, M.; Matsunaga, H., & Yokawa, K. (2016). *A summary of blue shark (Prionace glauca) and shortfin mako shark (Isurus oxyrinchus) tagging data available from the North and Southwest Pacific Ocean* (tech. rep. No. SC12-SA-IP-16). WCPFC.

Swimmer, Y.; Suter, J.; Arauz, R.; Bigelow, K.; Lopez, A.; Zanela, I.; Bolanos, A.; Ballestero, J.; Suarez, R.; Wang, J., & Boggs, C. (2011). Sustainable fishing gear: the case of modified circle hooks in a Costa Rican longline fishery. *Marine Biology*, *158*, 757–767.

Vandeperre, F.; Aires-da-Silva, A.; Fontes, J.; Santos, M.; Santos, R., & Afonso, P. (2014). Movements of blue sharks (*Prionace glauca*) across their life history. *PLoS ONE*, *8*(8). doi:10.1371/journal.pone.0103538

WCPFC (2019). *Conservation and Management Measure for Sharks* (tech. rep. No. CMM2019-04). WCPFC.

Williams, p.; Panizza, A.; Falasi, c.; Loganimoce, E., & Schneiter, E. (2020). *Status of Observer Data Management* (tech. rep. No. SC16-2020/ST-IP-02). WCPFC.

## 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

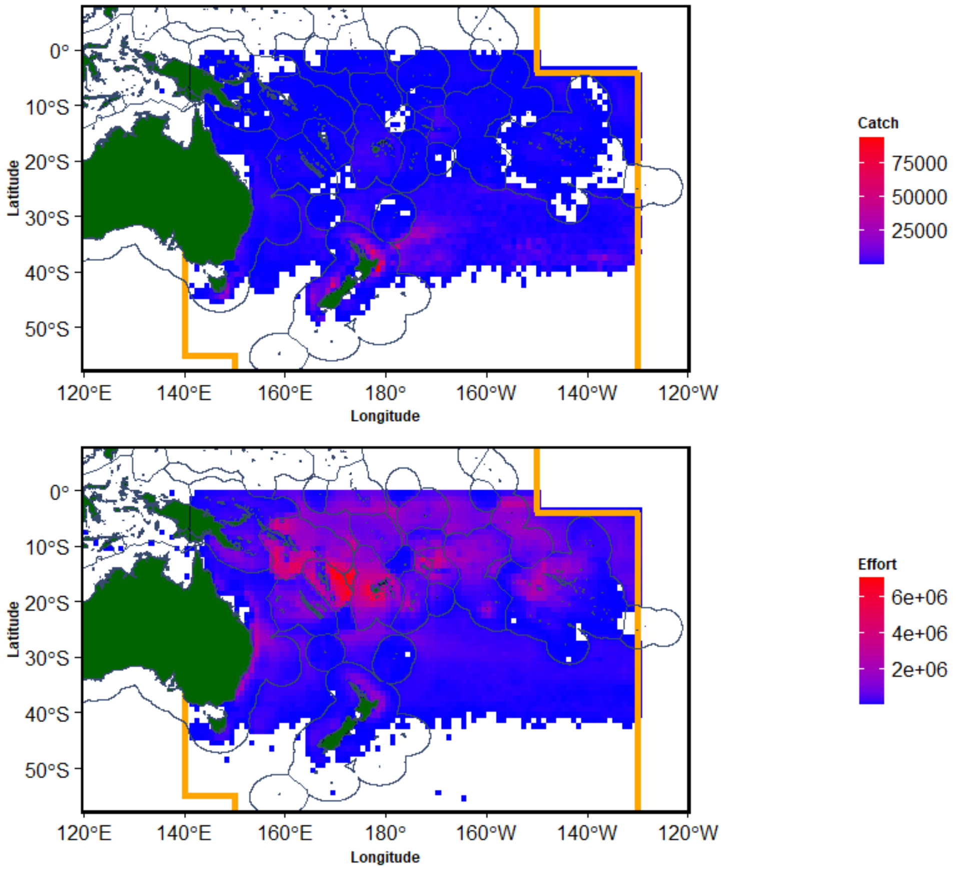


**Figure 1:** Longline bue shark catch in tonnes (top) fishing effort in hooks set (bottom) as reported on the available logsheets in the WCPFC Convention area 1995 - 2019.

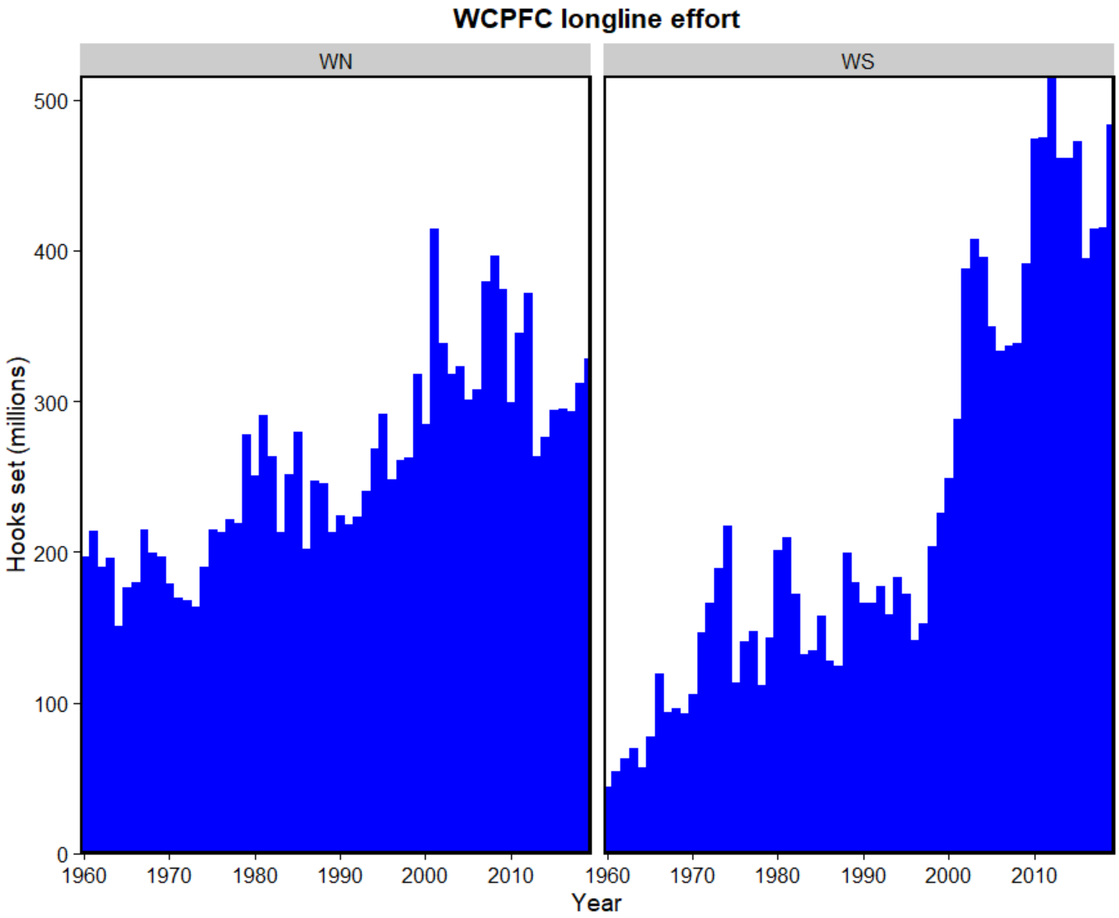


**Figure 2:** Longline fishing effort in the North (WN) and South (WS) WCPO south of the equator 1960-2019.

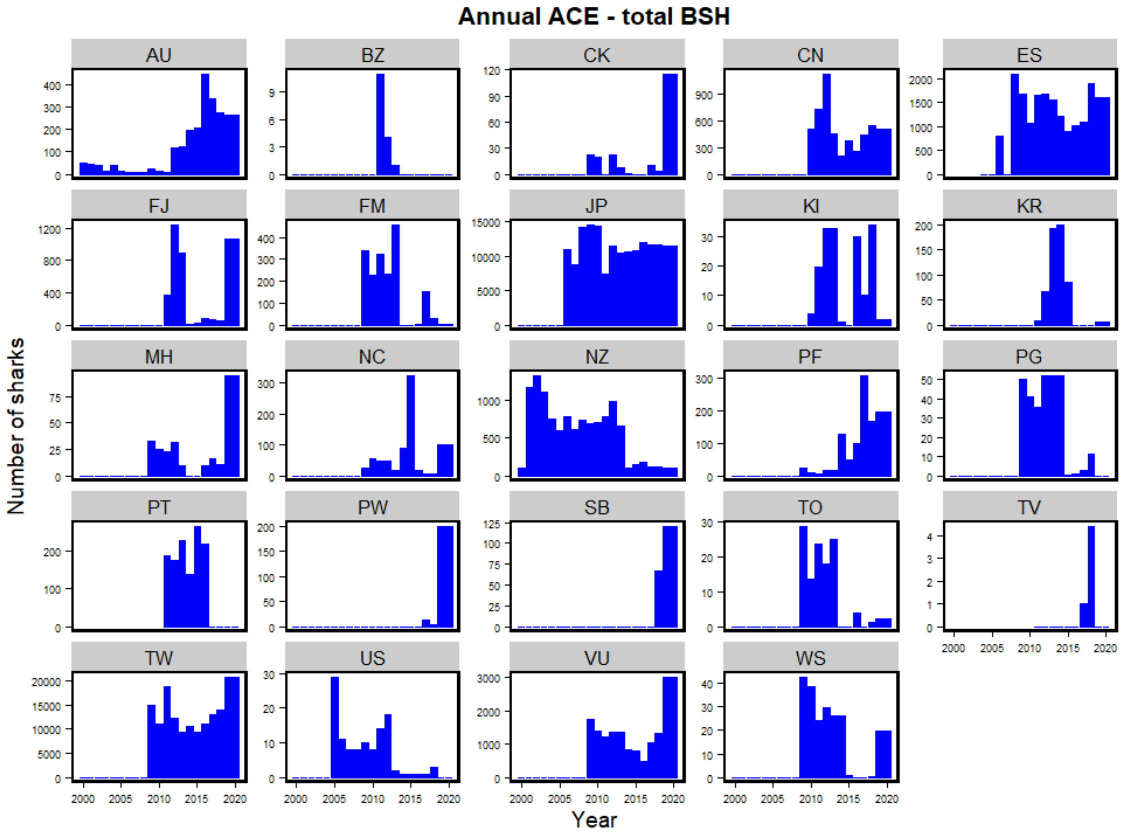


**Figure 3:** Longline blue shark annual catch estimates reported by flag states in WCPFC the WCPFC Convention area 2000-2020.

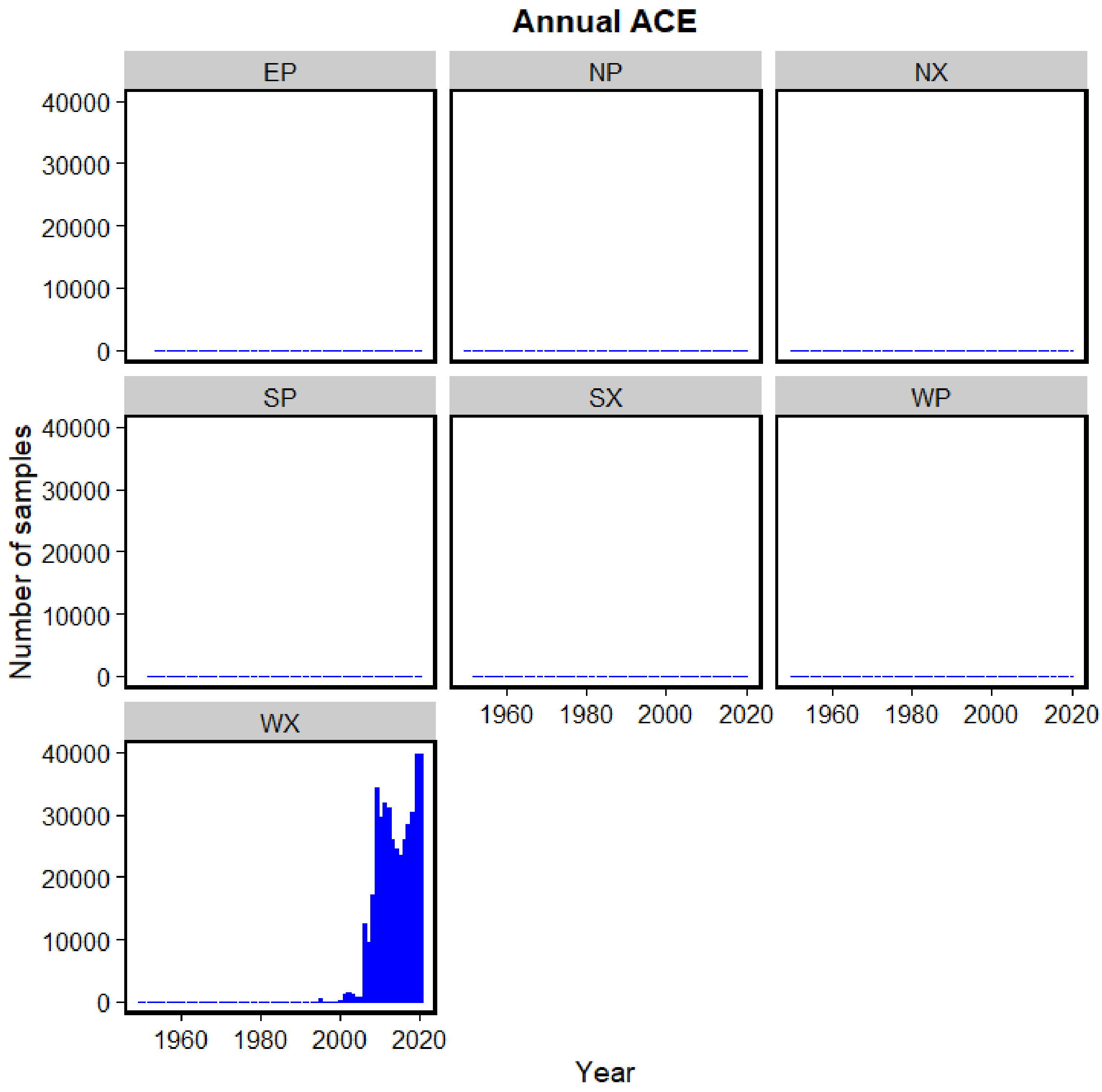


**Figure 4:** Longline blue shark annual catch estimates by ocean area reported to the WCPFC 2000-2020. EP = Eastern Pacific; NP = North Pacific; NX = North Pacific within the WCPFC Convention area; SP = South Pacific; SX = South Pacific within the WCPFC Convention area; WP = western Pacific Ocean; WX = western Pacific within the WCPFC Convention area.

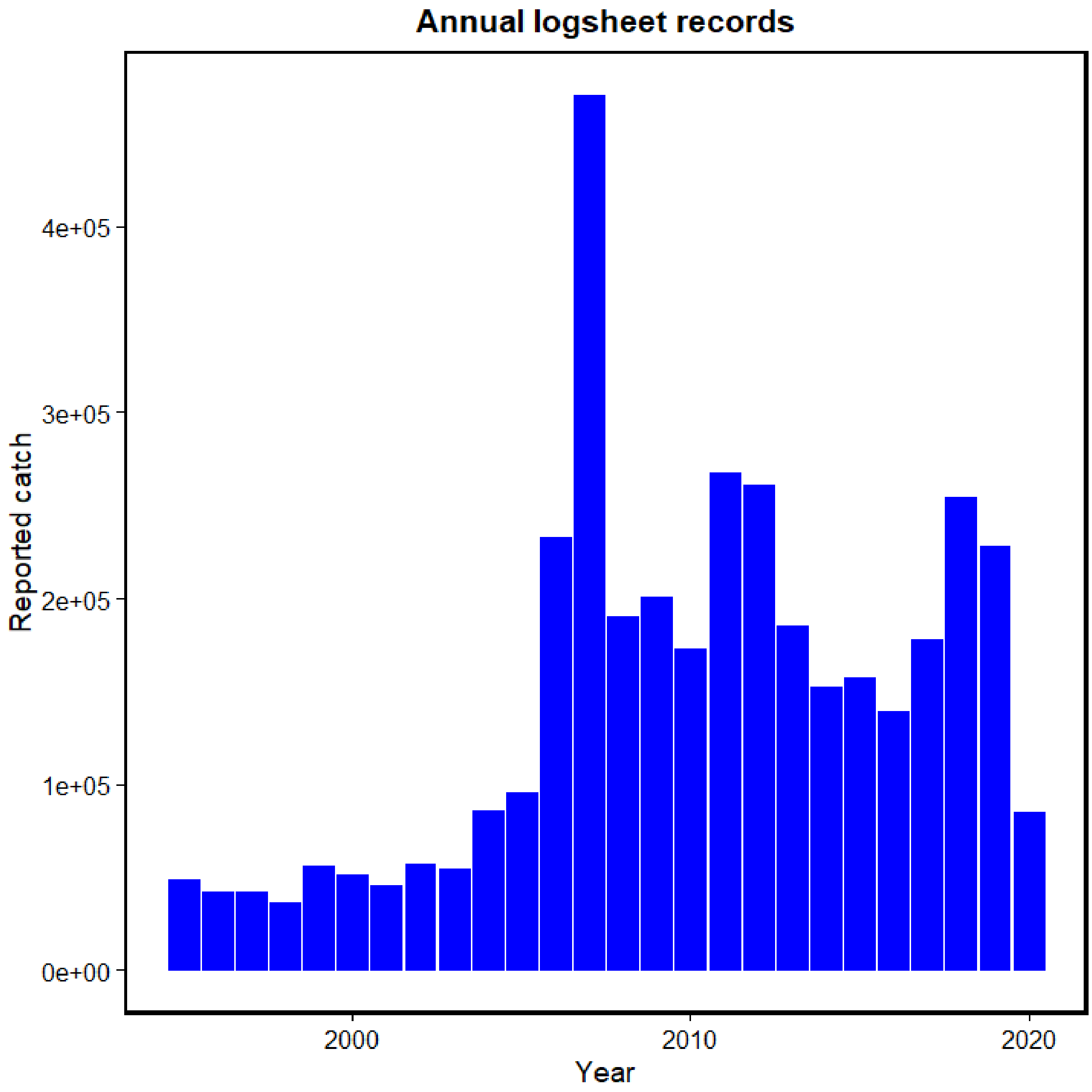


**Figure 5:** Longline south Pacific blue shark catch reported annually south of the Equator to the WCPFC 1995 - 2020.

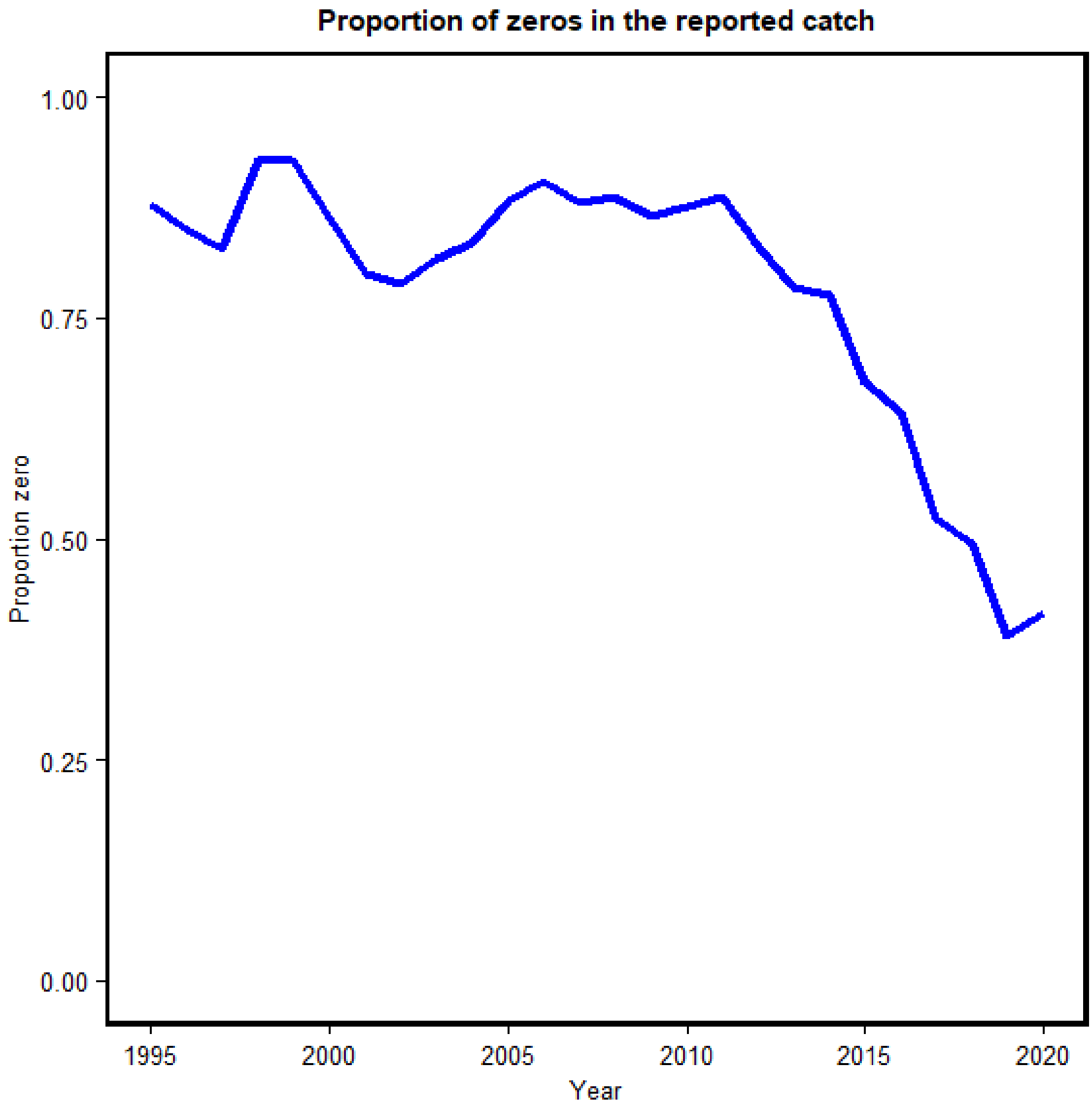


**Figure 6:** Longline logsheet reporting trends of south Pacific blue shark reported annually south of the Equator to the WCPFC 1995 - 2020 showing the proportion of logsheet records with zero catch reported.

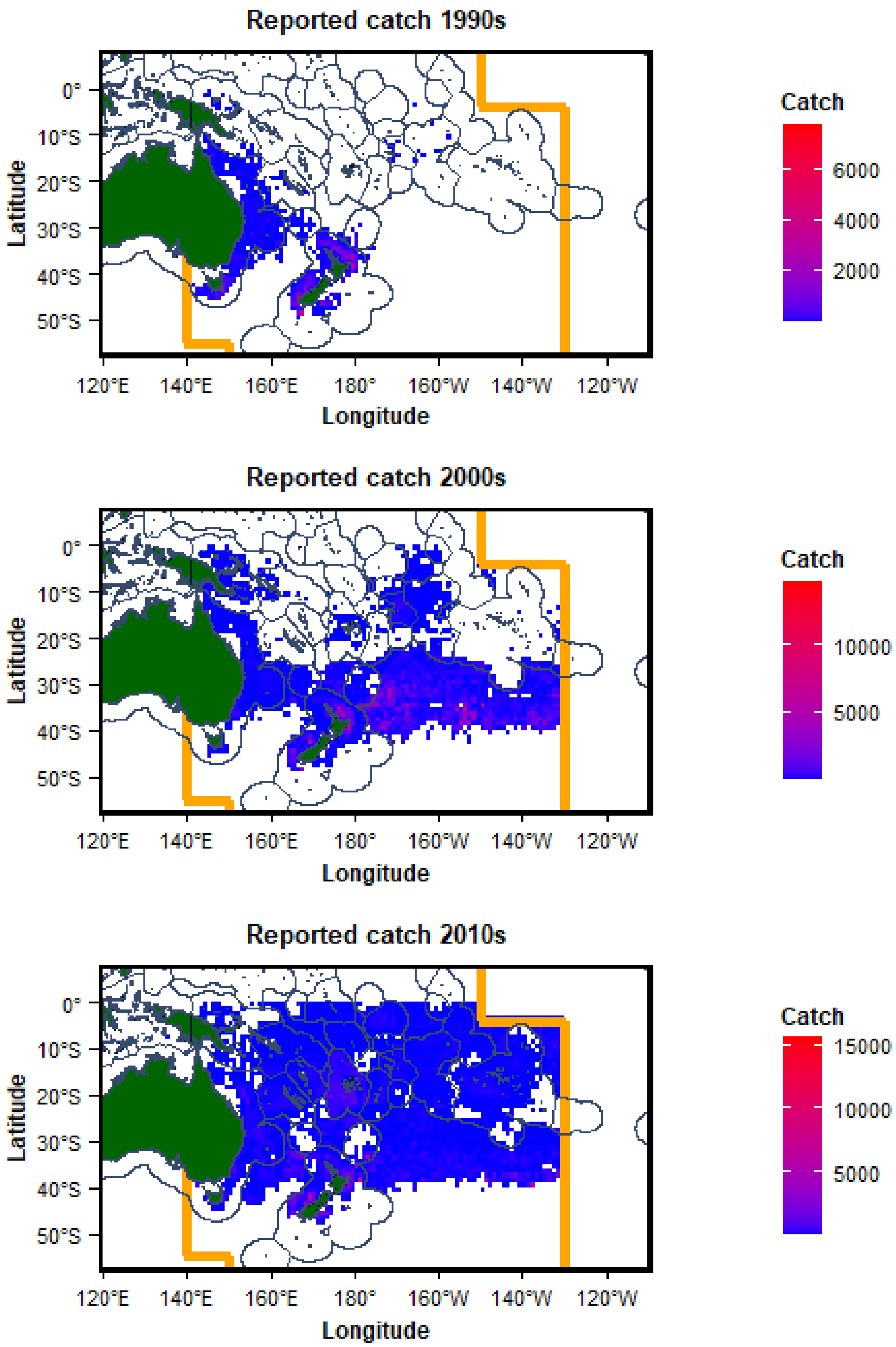


**Figure 7:** Reported logsheet catch by decade of blue sharks in the WCPFC south of the Equator from 1990 - 2020 aggregated to 1x1 degree squares across all fleets and months of the year.

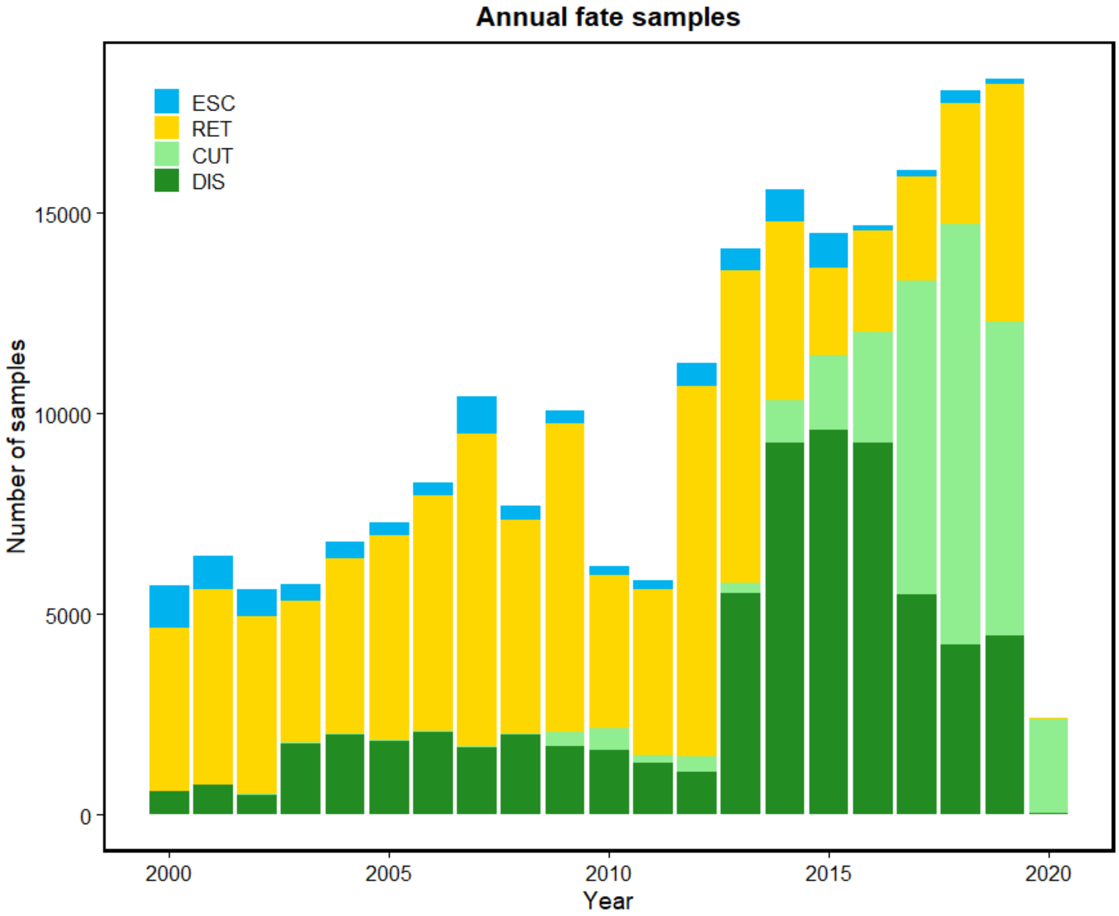


**Figure 8:** Fate of longline caught south Pacific blue shark observed by flag 2000-2020. ESC = Escaped, RET = Retained, DIS = Discarded, CUT = Cut free.

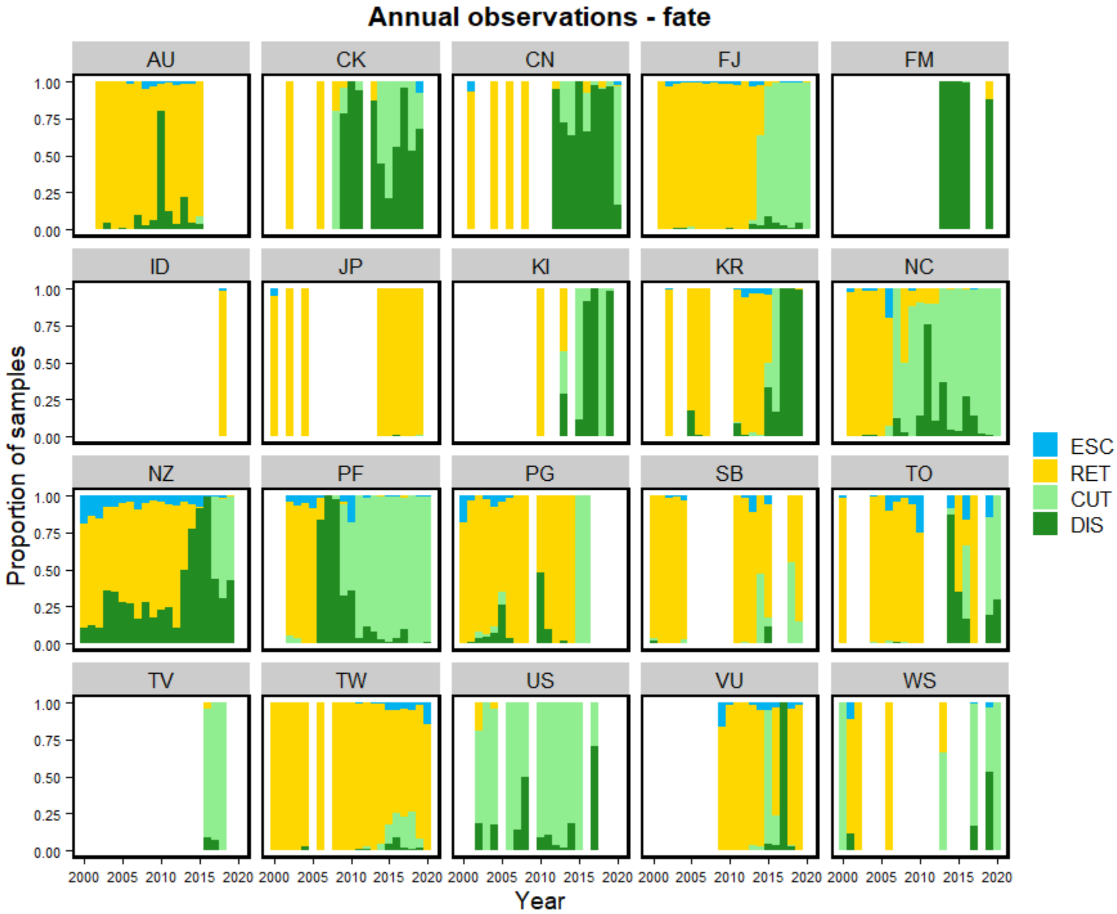


**Figure 9:** Fate proportions by flag of longline caught south Pacific blue shark observed by flag 2000 - 2020. ESC = Escaped, RET = Retained, DIS = Discarded, CUT = Cut free.

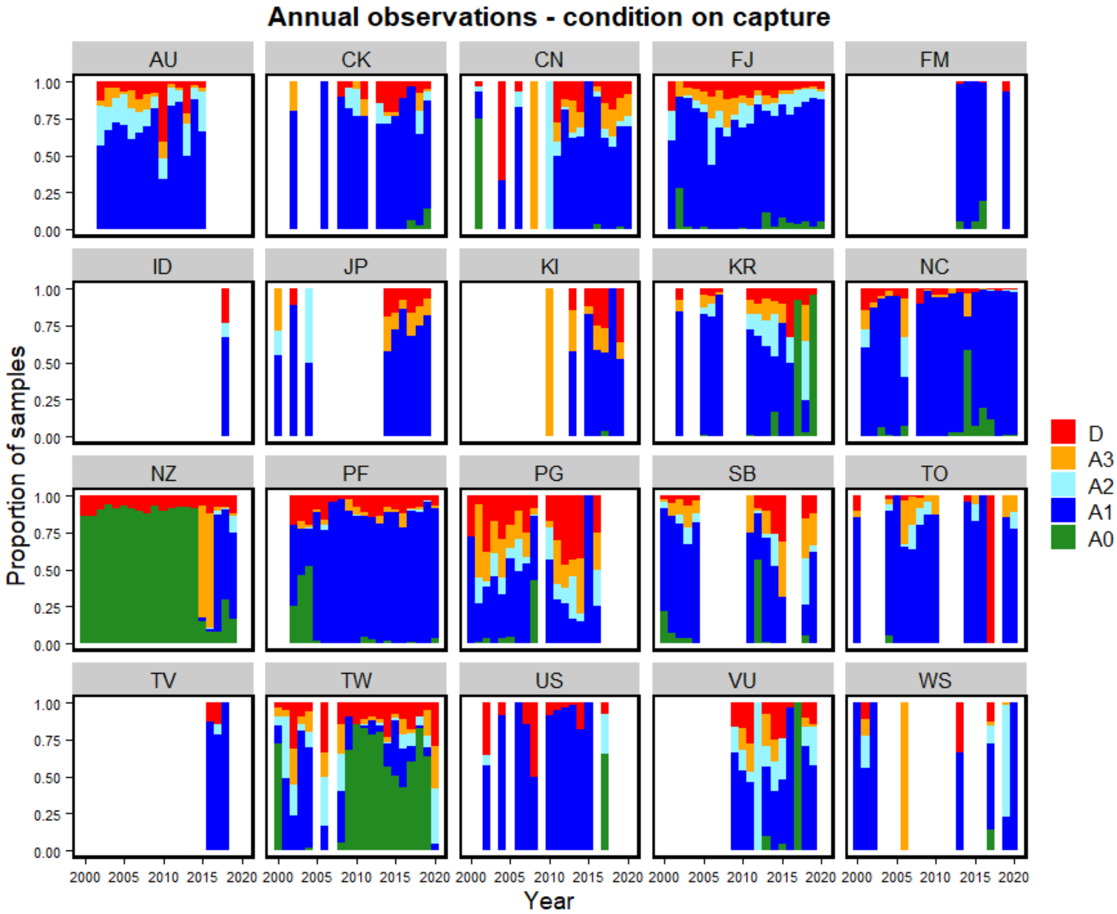


**Figure 10:** Condition at capture of longline caught south Pacific blue shark observed by flag in the WCPFC between 2000 - 2020. D = Dead, A0 - A3 are various life states as defined in Table 2.

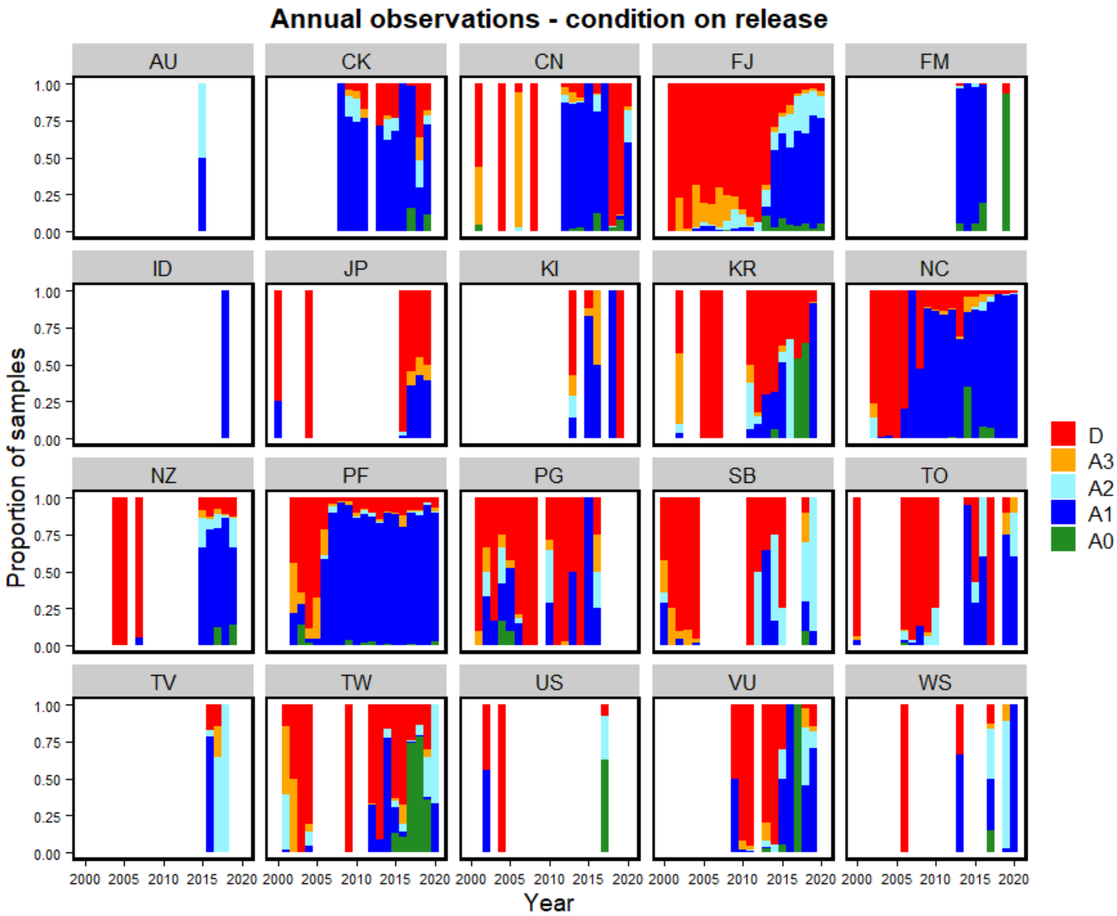


**Figure 11:** Condition at release of longline caught south Pacific blue shark observed by flag in the WCPFC between 2000 - 2020. D = Dead, A0 - A3 are various life states as defined in Table 2.

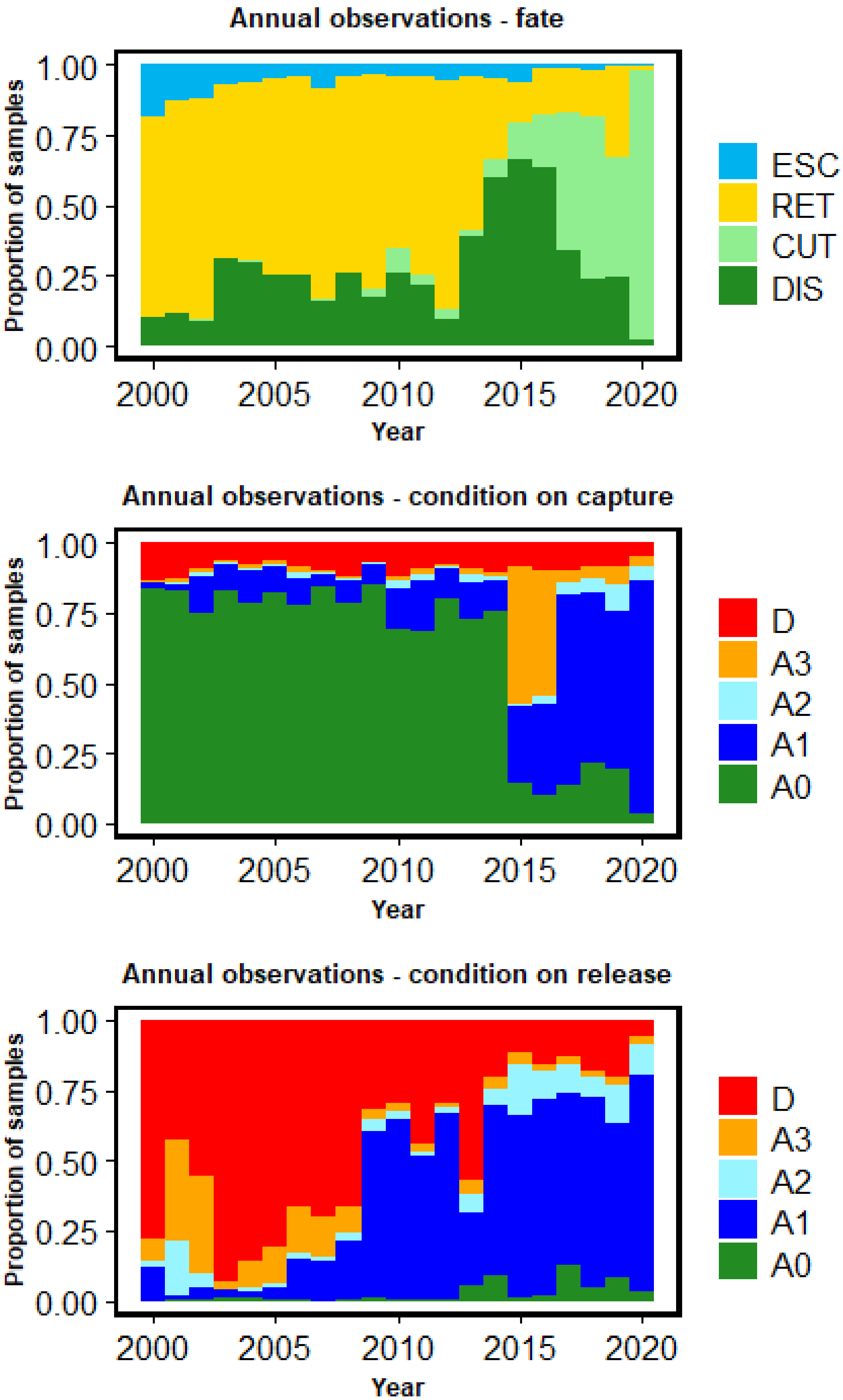




**Figure 12:** Fate of fish (top), condition at capture (middle) and release (bottom) of all longline caught south Pacific blue shark observed in the WCPFC between 2000 - 2020. ESC = Escaped, RET = Retained, DIS = Discarded, CUT = Cut free, D = Dead, A0 - A3 are various life states as defined in Table 2.

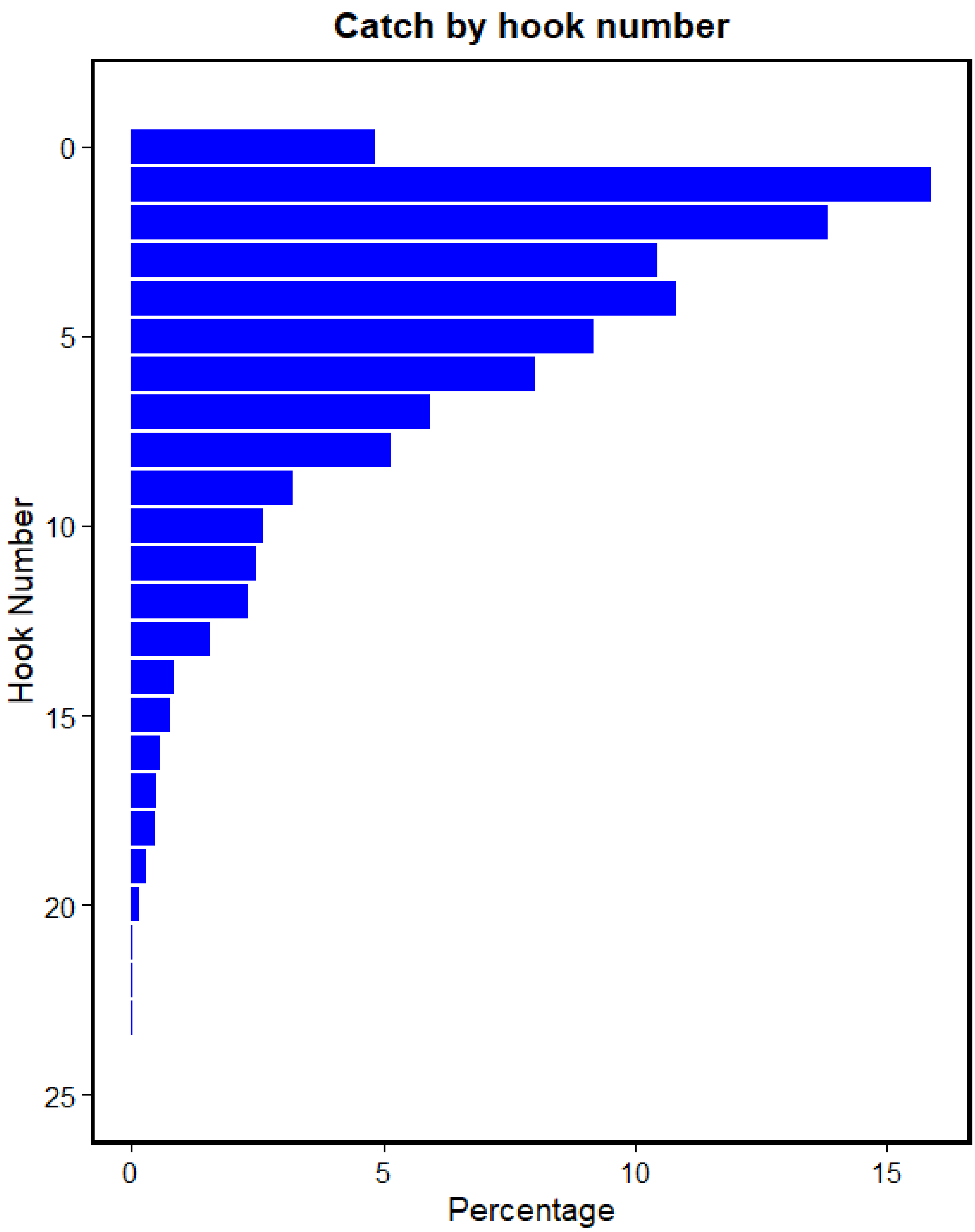


**Figure 13:** Catch of south Pacific blue shark by hook number relative to the closest float observed in the WCPFC between 2000 - 2020. Hooks were numbered from 1 to the middle of the basket and then back to 1 hook number 0 refers to fish caught on shark lines that are attached to the float.

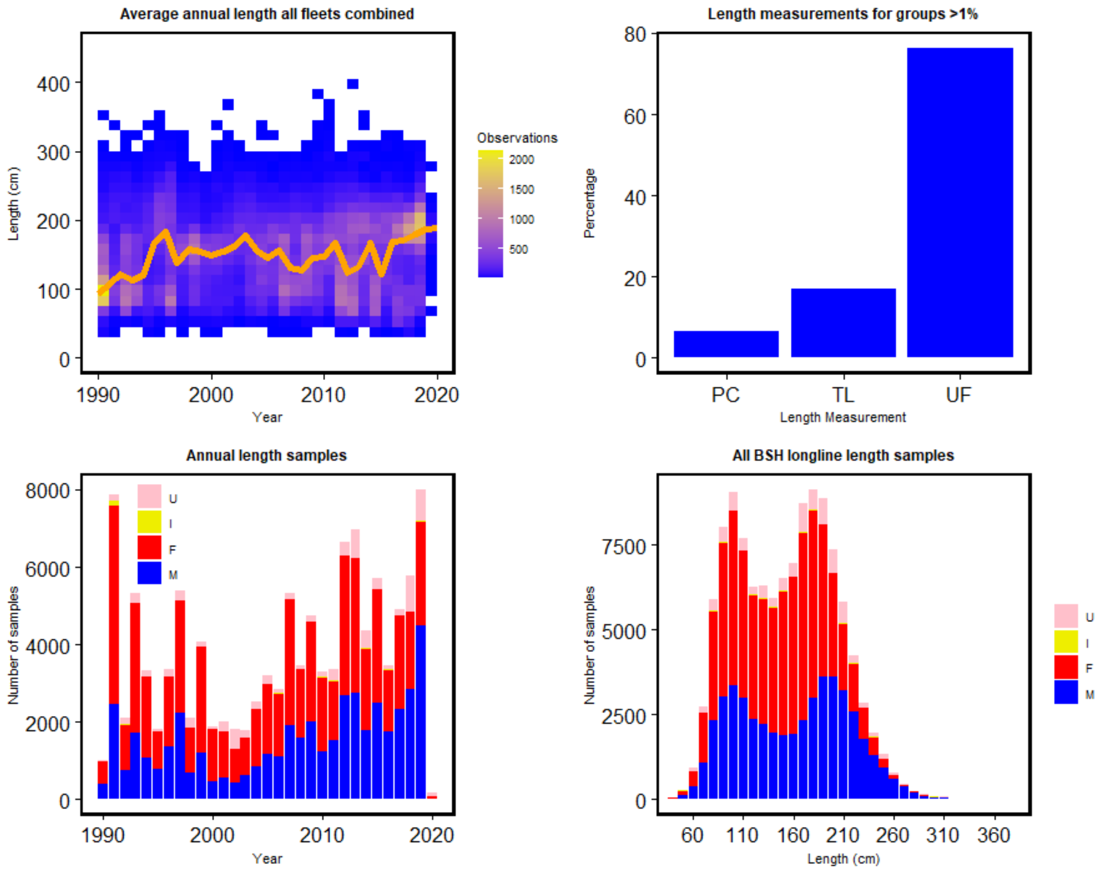


**Figure 14:** Length data availability of south Pacific blue sharks observed in the WCPFC between 1990-2020, showing the average annual length (top left), the units of length measurements (top right), the number of samples collected by sex (bottom left) and the overall length frequency (bottom right). UL = Upper-jaw fork length; TL = Total Length; PC = Pre-caudal length; U = Sex unknown; I = Immature; F = Female; and M = Male.

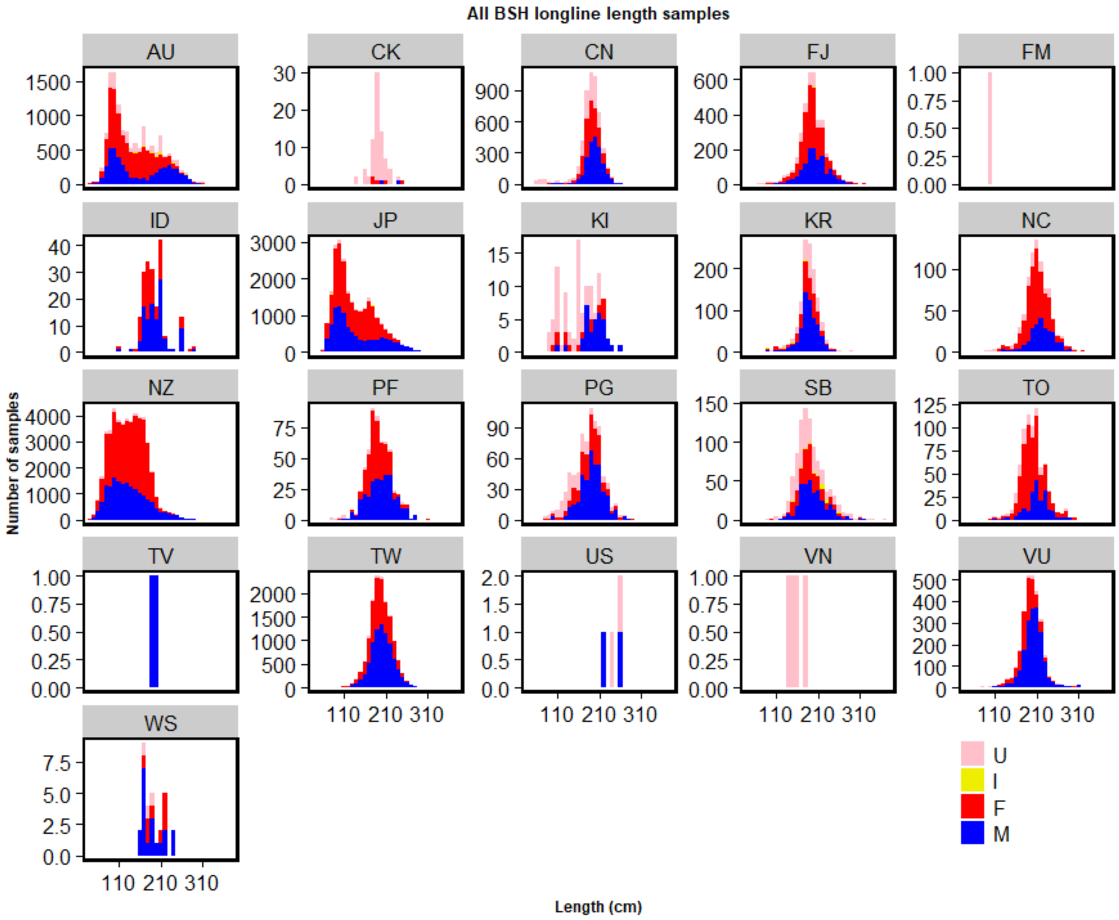


**Figure 15:** Length frequency distributions, of south Pacific blue sharks observed in the WCPFC between 1990-2020 by flag. U = Sex unknown, I = Immature, F = Female and M = Male. Note: the y-axis scales are not the same between plots.

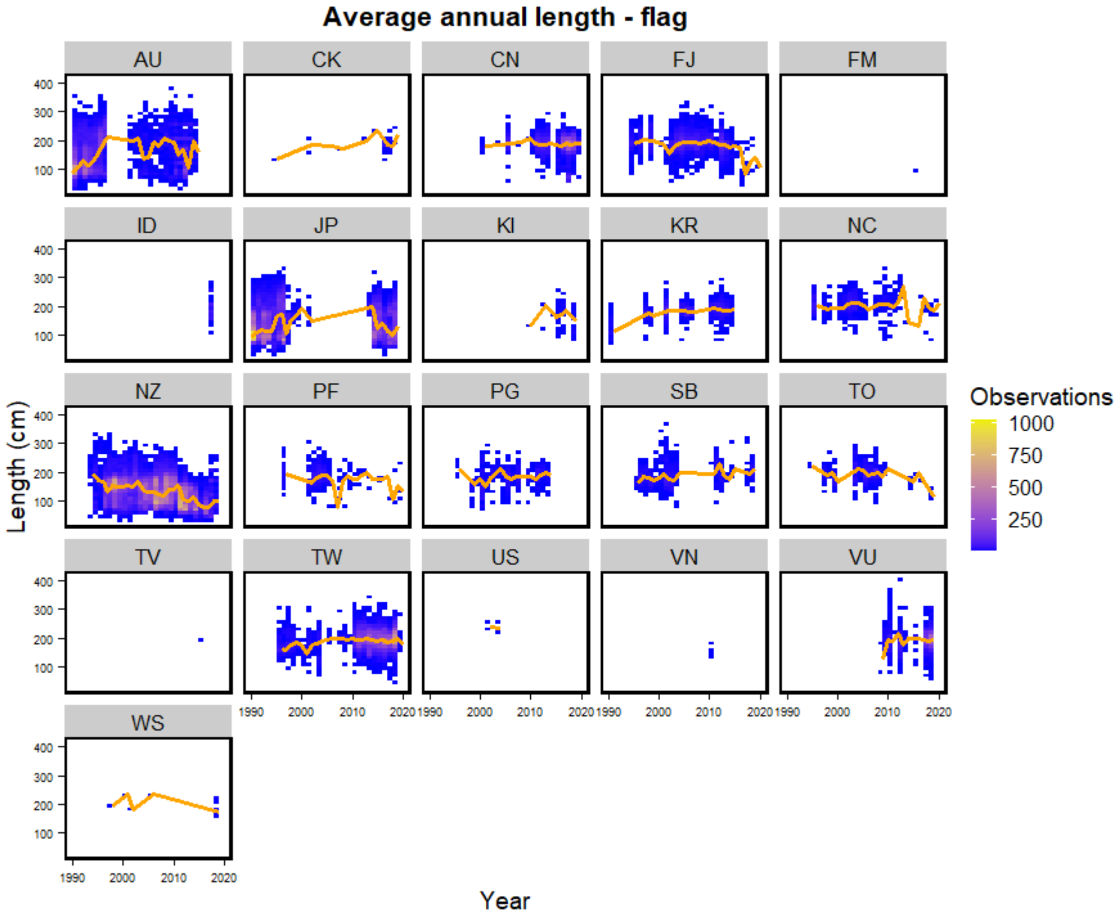


**Figure 16:** The average annual length distributions, of south Pacific blue sharks (both sexes combined) observed by flag in the WCPFC between 1990-2020 by flag.

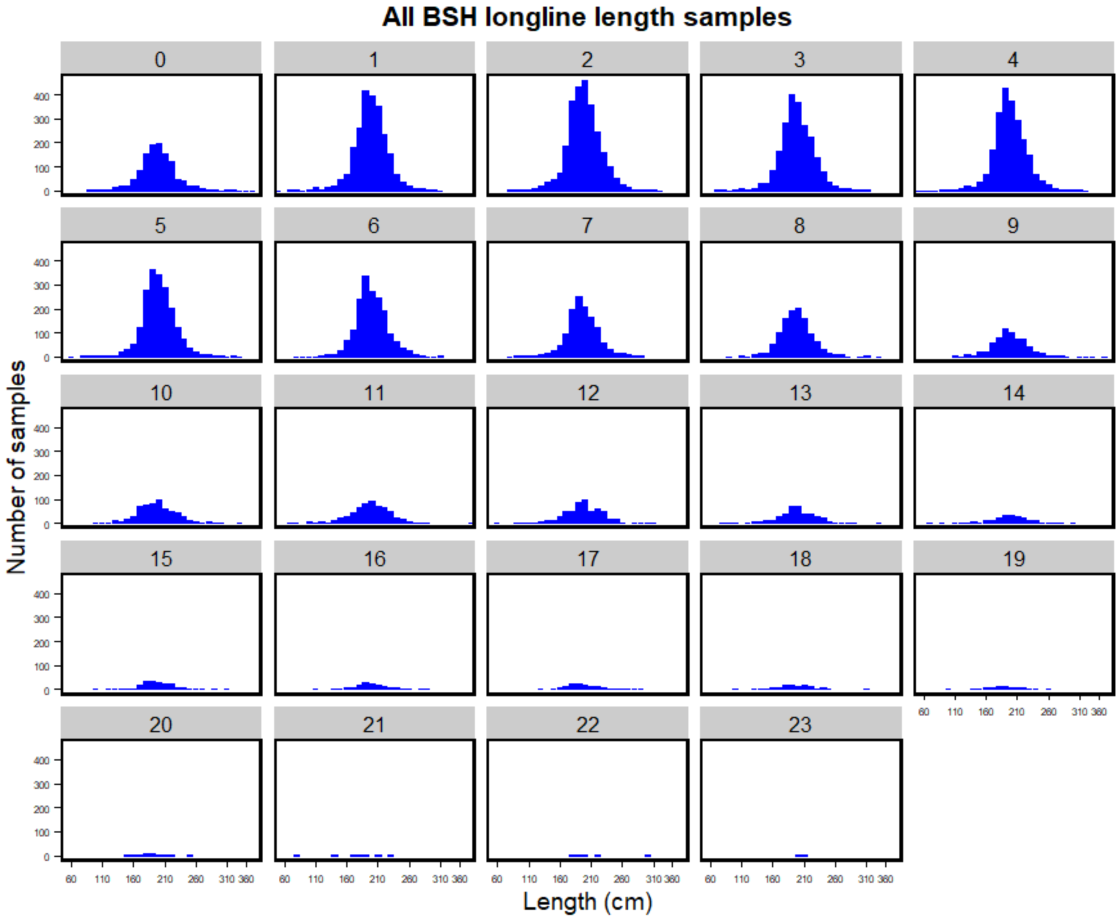


**Figure 17:** Length frequency distributions, for fish measures to UF only, of south Pacific blue sharks observed in the WCPFC between 2000 - 2020 caught by hook number.

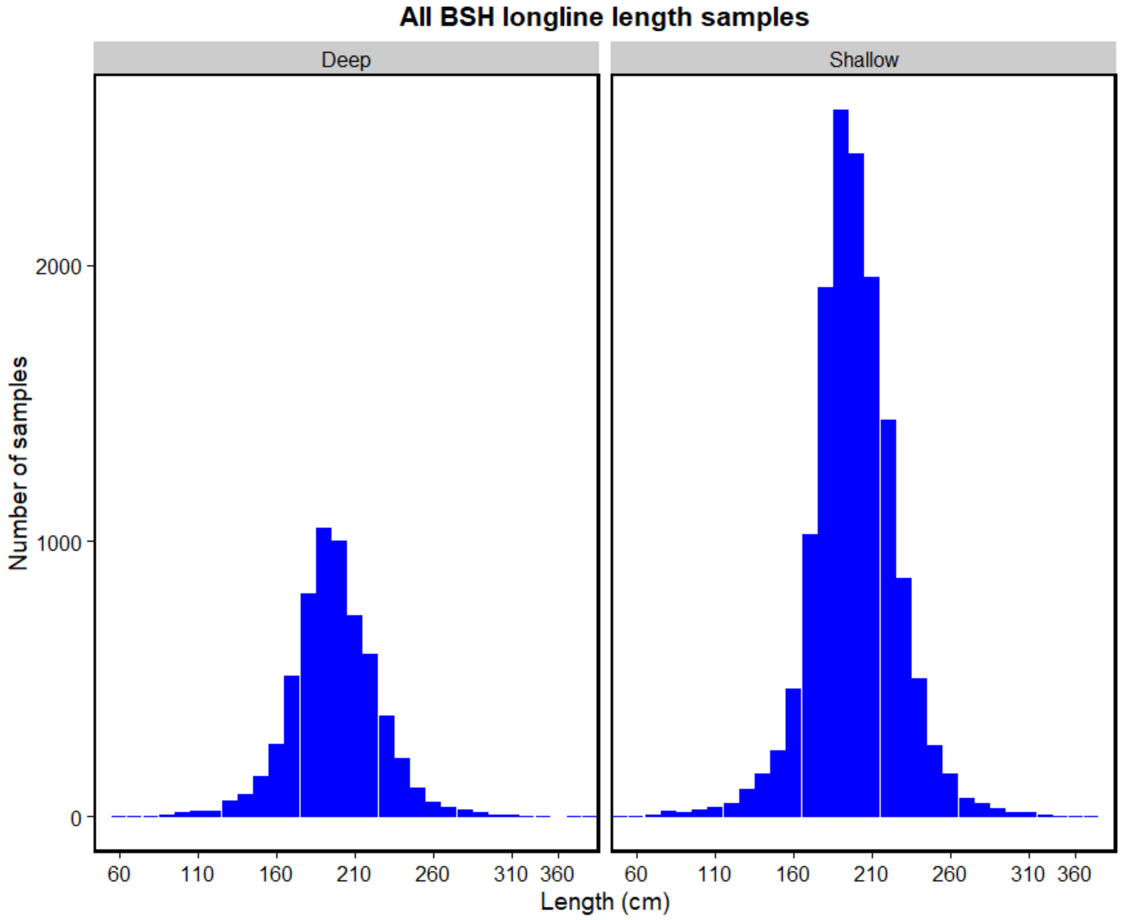


**Figure 18:** Length frequency distributions, for fish measures to UF only, of south Pacific blue sharks observed in the WCPFC between 2000 - 2020 caught by depth group where shallow hooks are hook numbers 6 or less and deep are hook numbers 7 and higher.

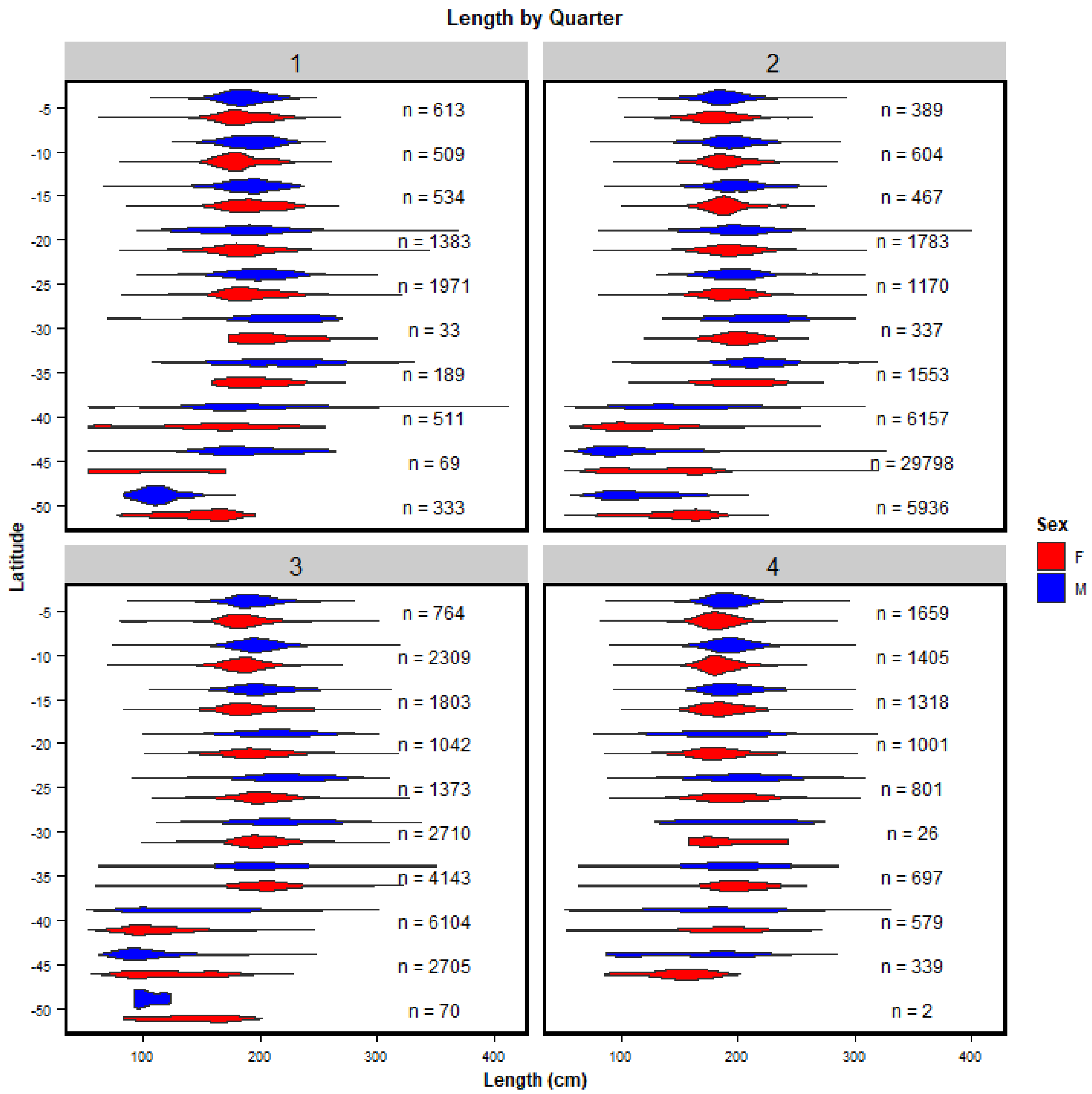


**Figure 19:** Length distribution by latitude, year quarter and sex, of south Pacific blue sharks observed in the WCPFC between 2000 - 2020. n = the total number of samples (male and female combined) by latitude group.

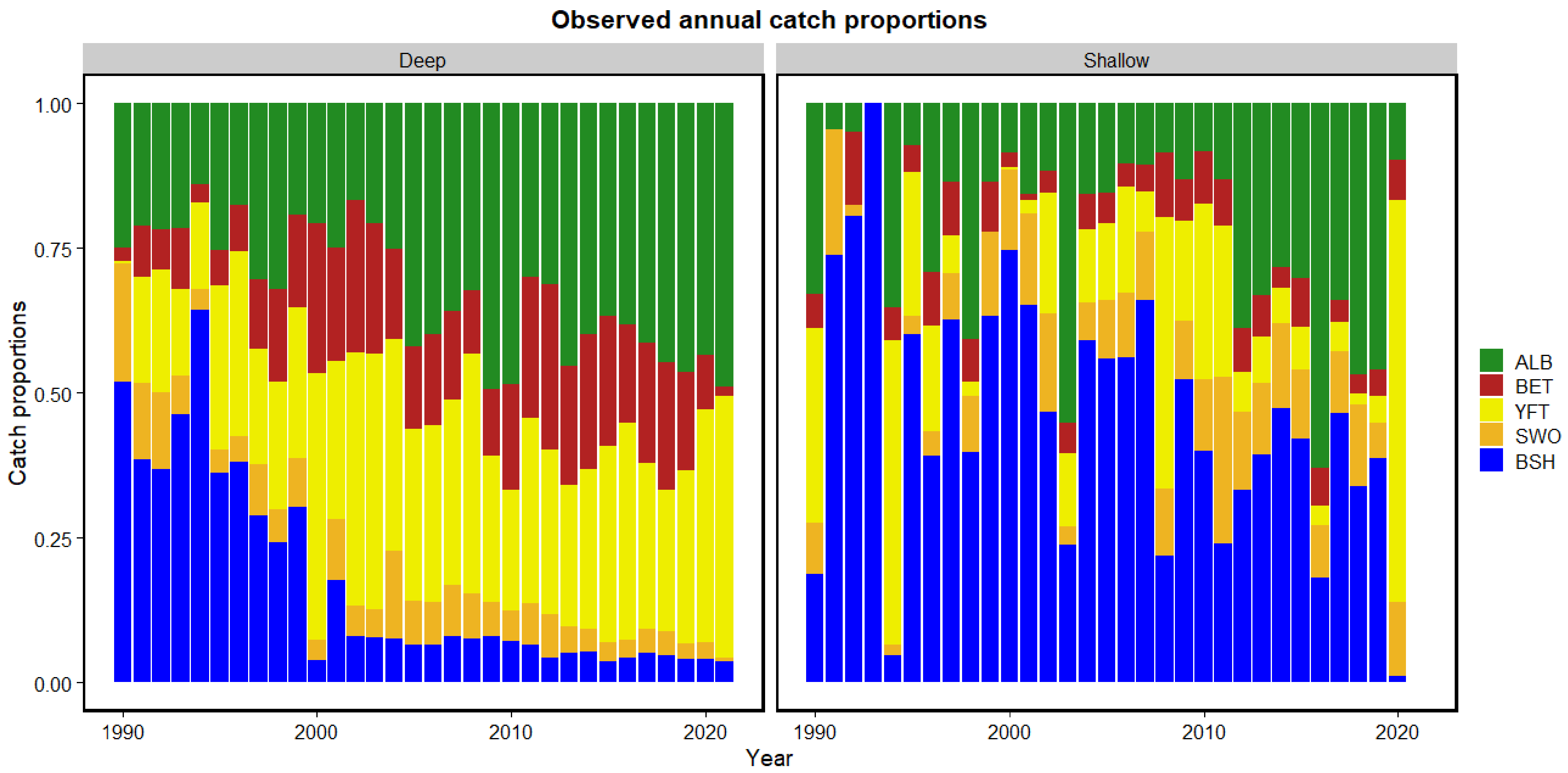


**Figure 20:** Species proportions of tuna swordfish and south Pacific blue sharks observed in the WCPFC between 2000 - 2020 and separated into deep (left) and shallow (right) sets.

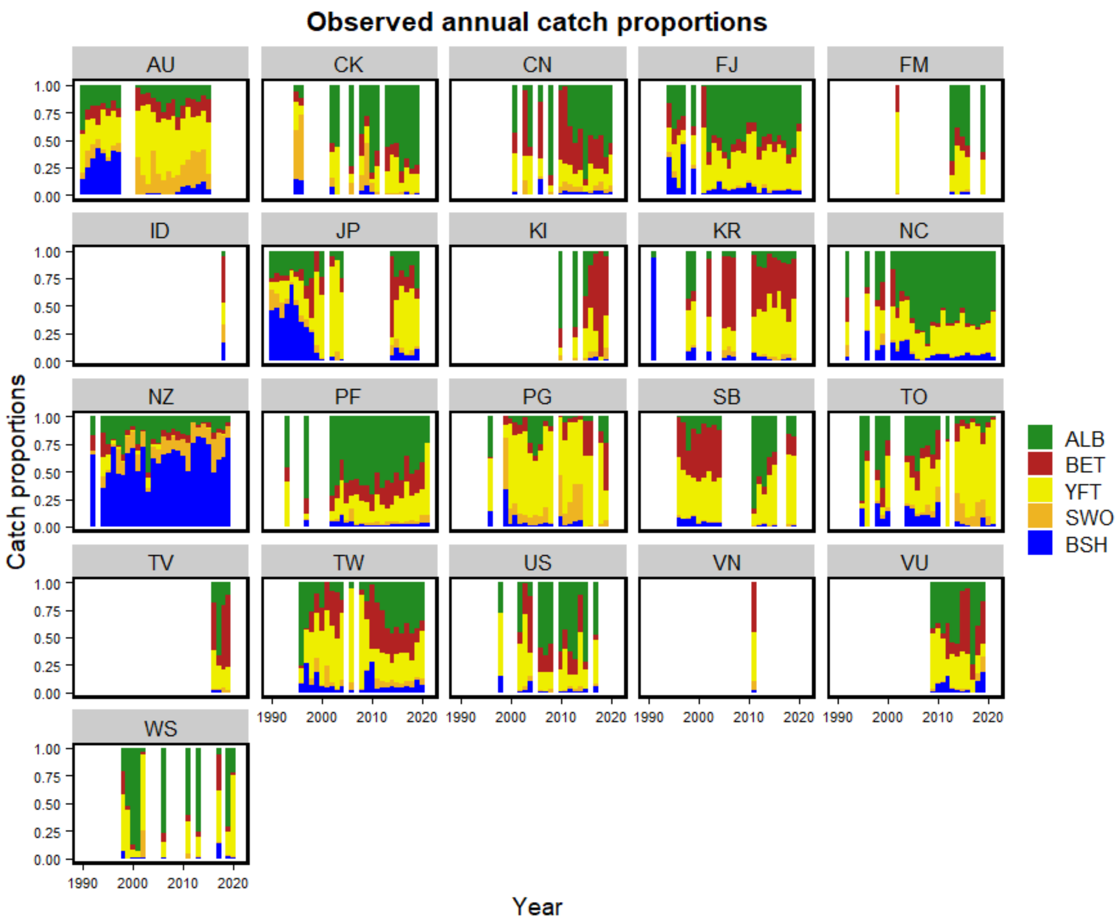


**Figure 21:** Species proportions of tuna, swordfish and south Pacific blue sharks observed in the WCPFC between 2000 - 2020 and separated by flag.

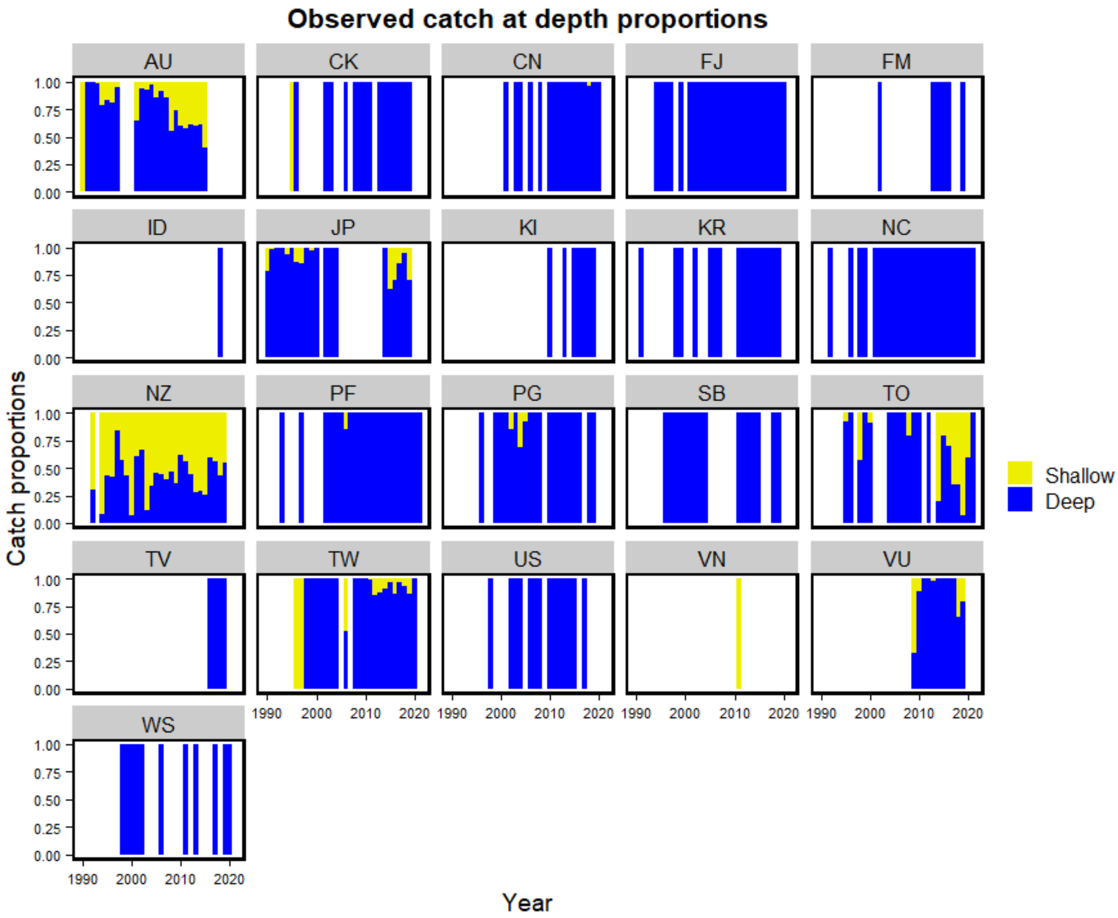


**Figure 22:** The ratio of shallow to deep sets by flag for sets made in the WCPFC between 2000 - 2020.

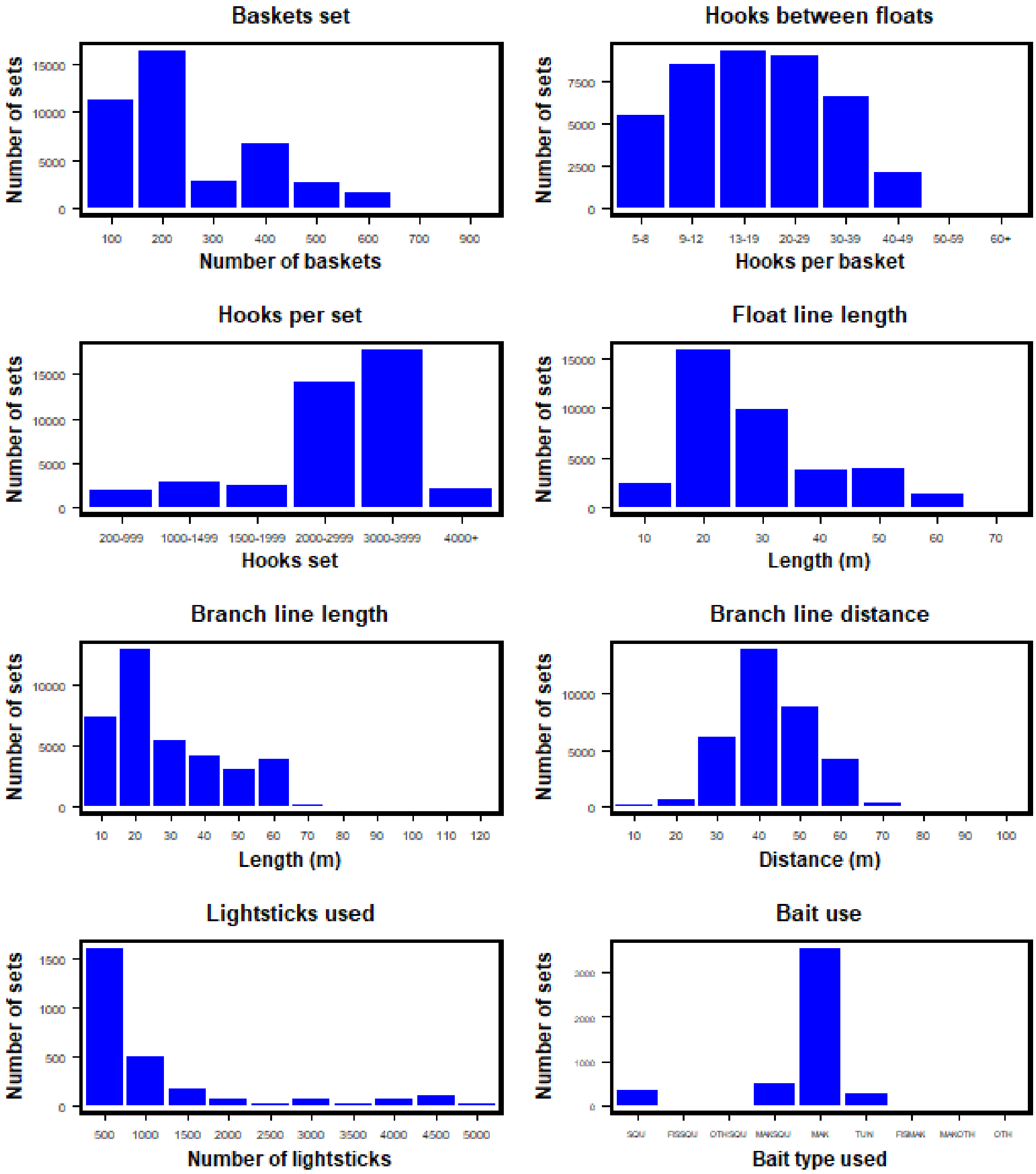


**Figure 23:** The observed baskets set, hook between floats,hooks set, float line length, branch line length, branch line distance, number of lightsticks used and reported bait use in sets made in the WCPFC between 1990 - 2020 from all fleets.

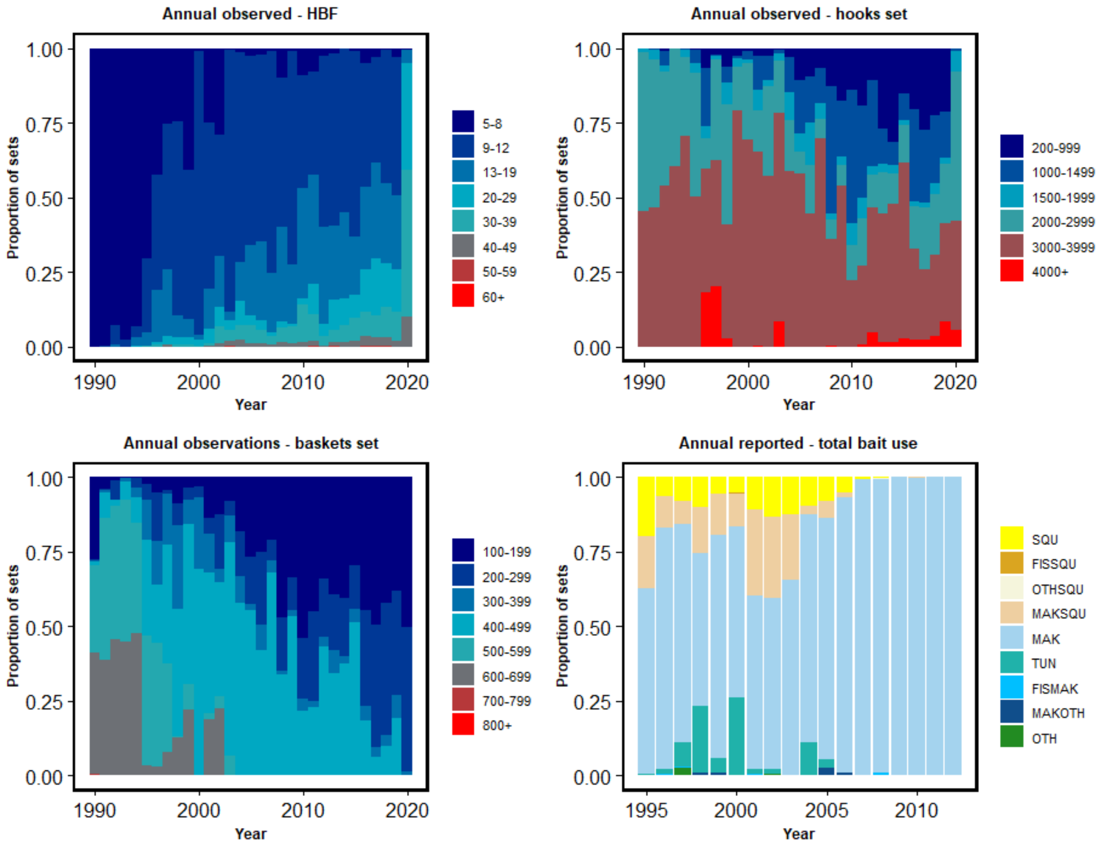


**Figure 24:** Observed hook between floats (HBF), hooks set, baskets set and reported bait use in sets made in the WCPFC between 1990 - 2020 from all fleets.

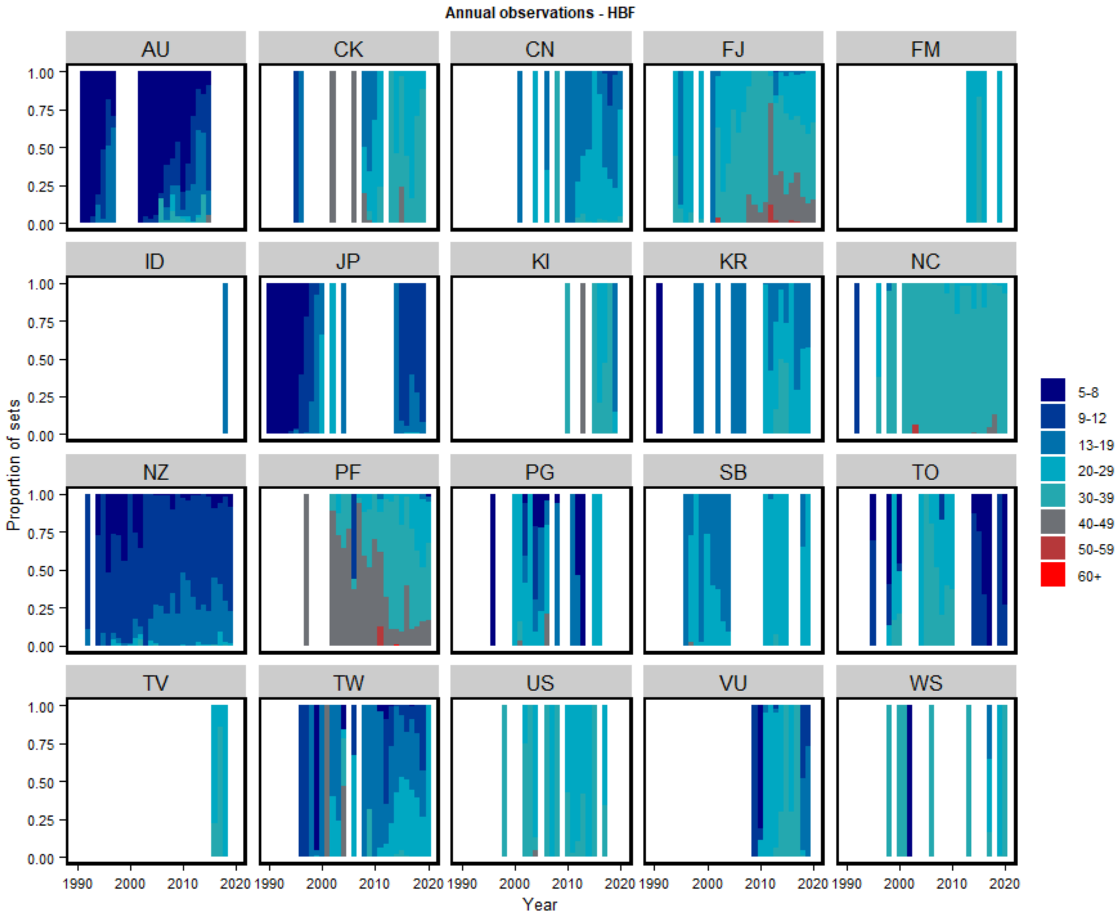


**Figure 25:** Observed hook between floats (HBF), by flag in the WCPFC between 1990 - 2020.

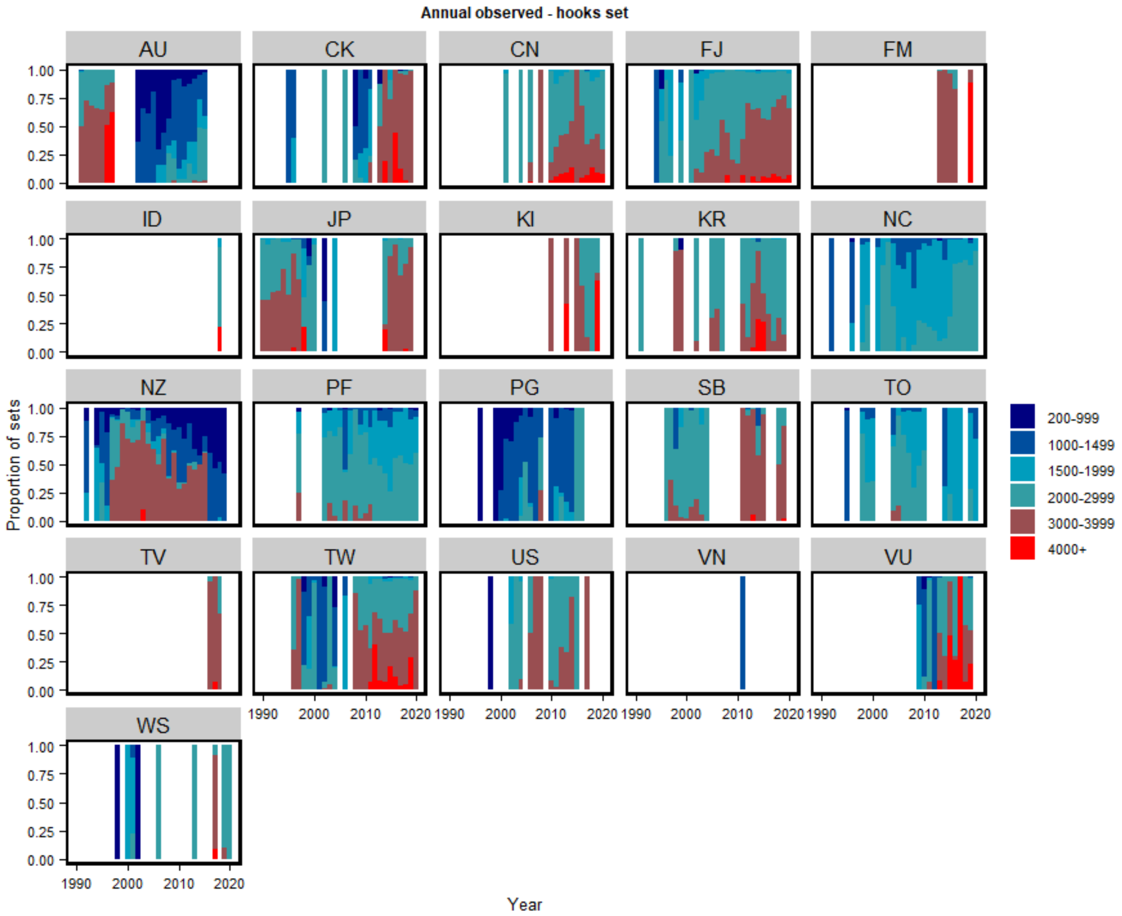


**Figure 26:** Observed hooks set on longline sets, by flag in the WCPFC between 1990 - 2020.

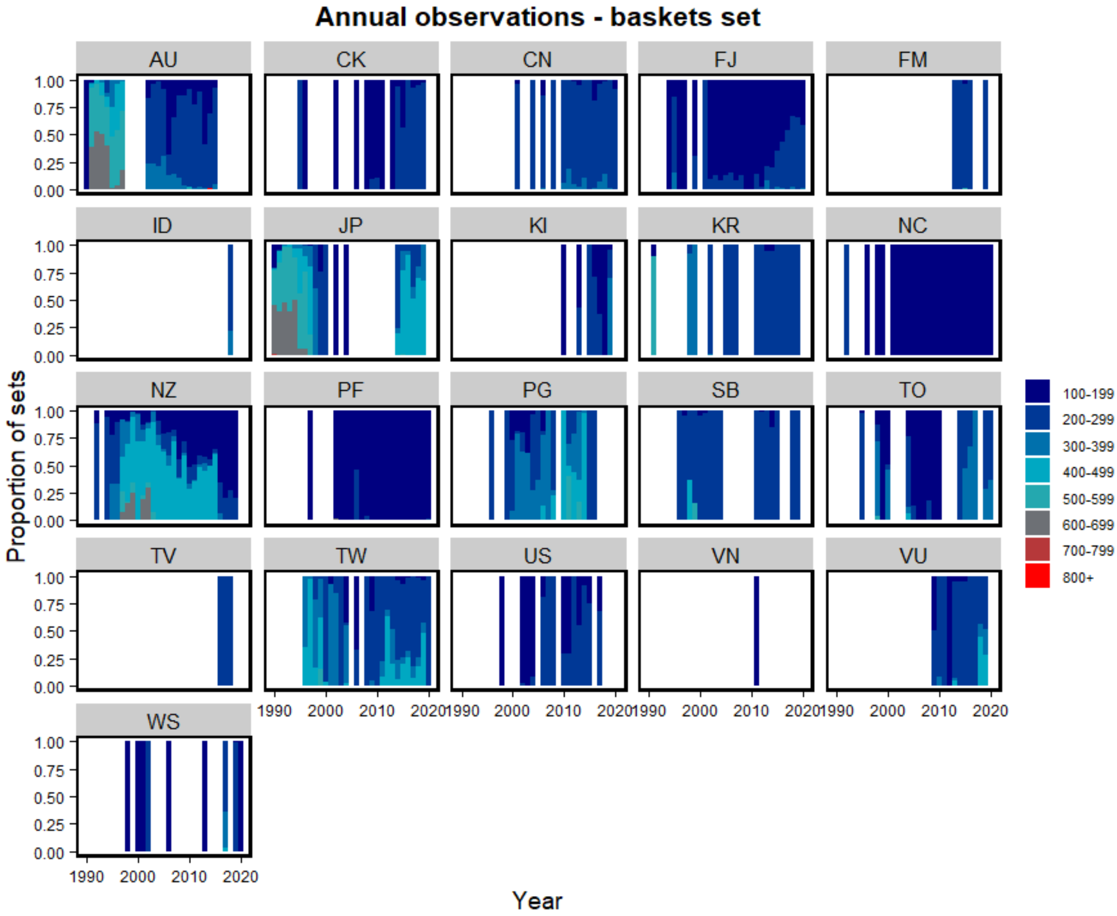


**Figure 27:** Observed baskets set on longline sets, by flag in the WCPFC between 1990 - 2020.

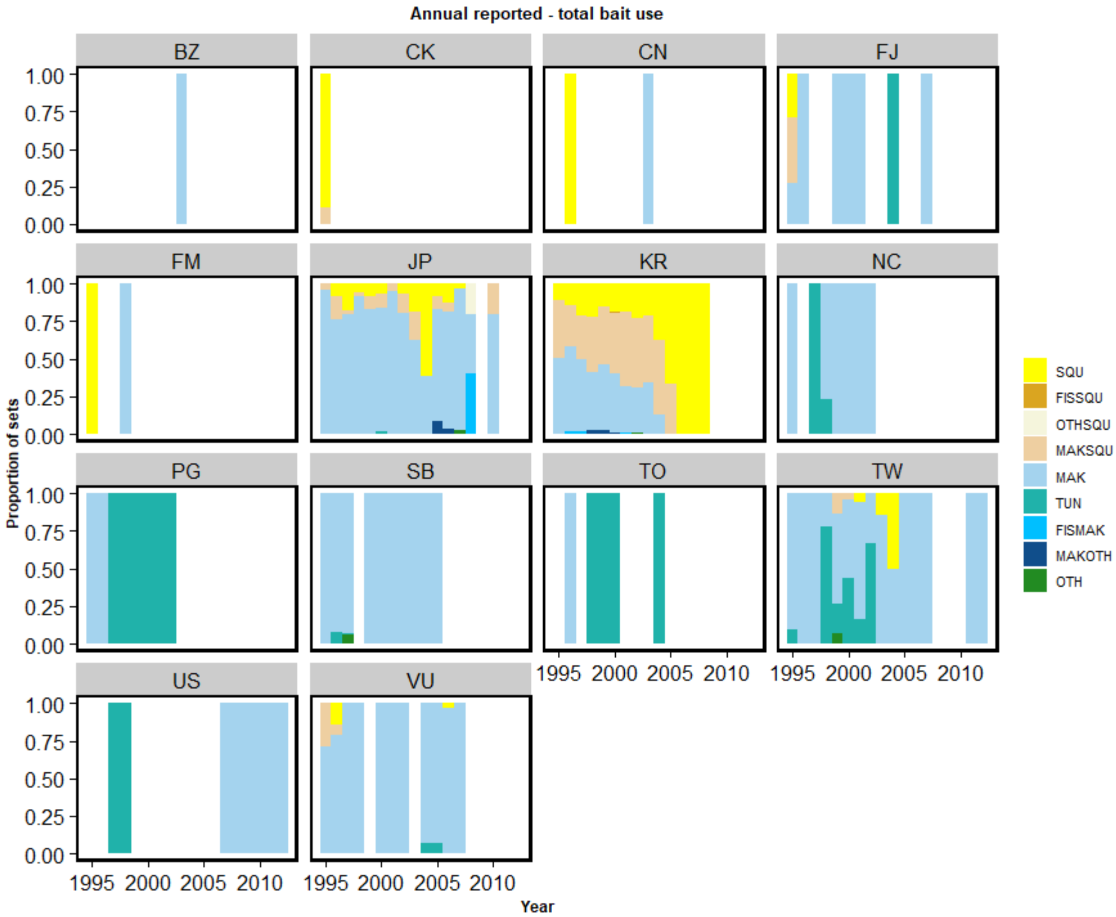


**Figure 28:** Reported bait use set on longline sets, by flag in the WCPFC between 1990 - 2020.

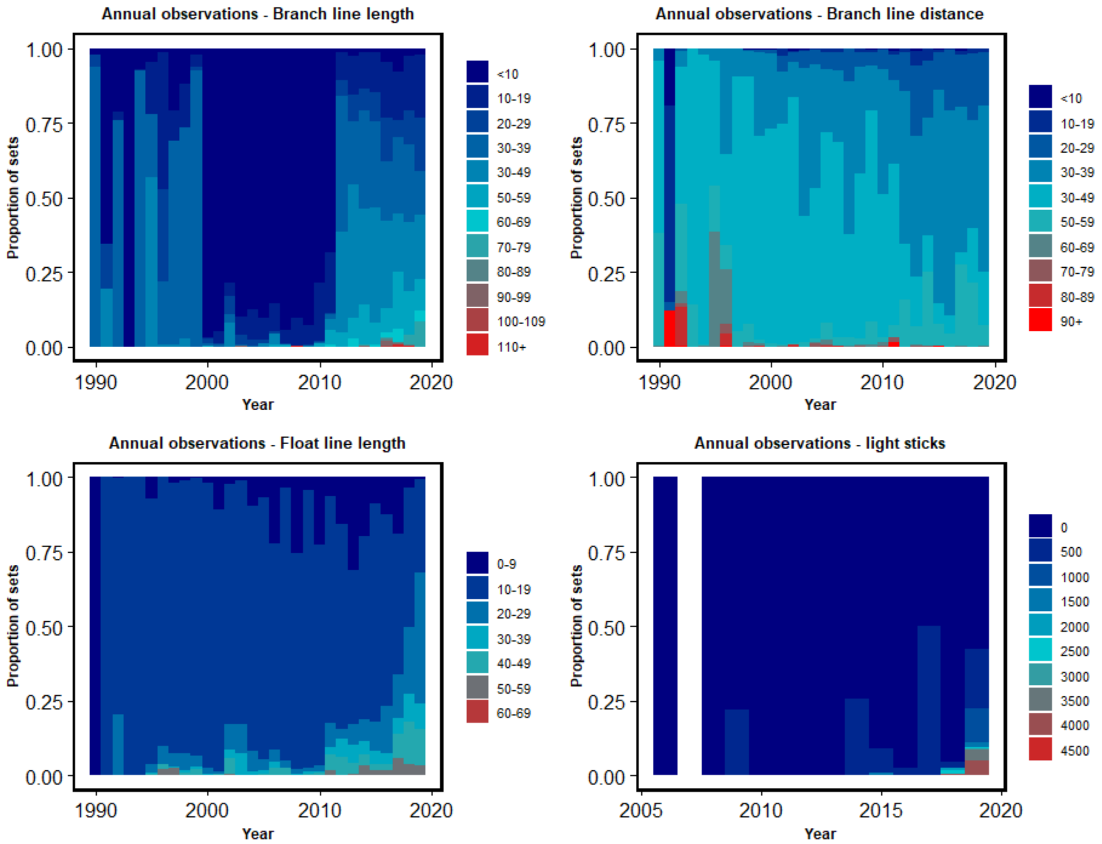


**Figure 29:** Observed branchline length, branchline distance, float line length and lightstick use on longline sets, in the WCPFC between 1990 - 2020.

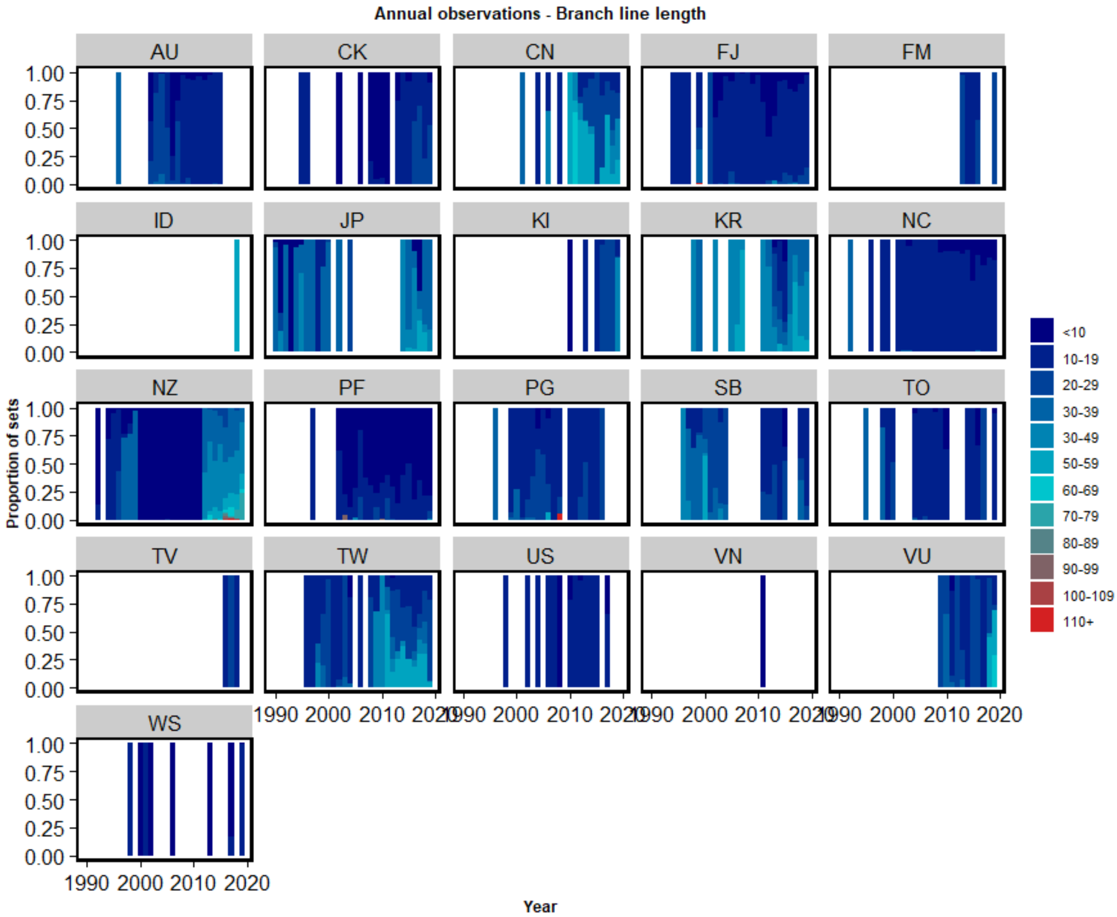


**Figure 30:** Observed branchline length, used on longline sets, by flag in the WCPFC between 1990-2020.

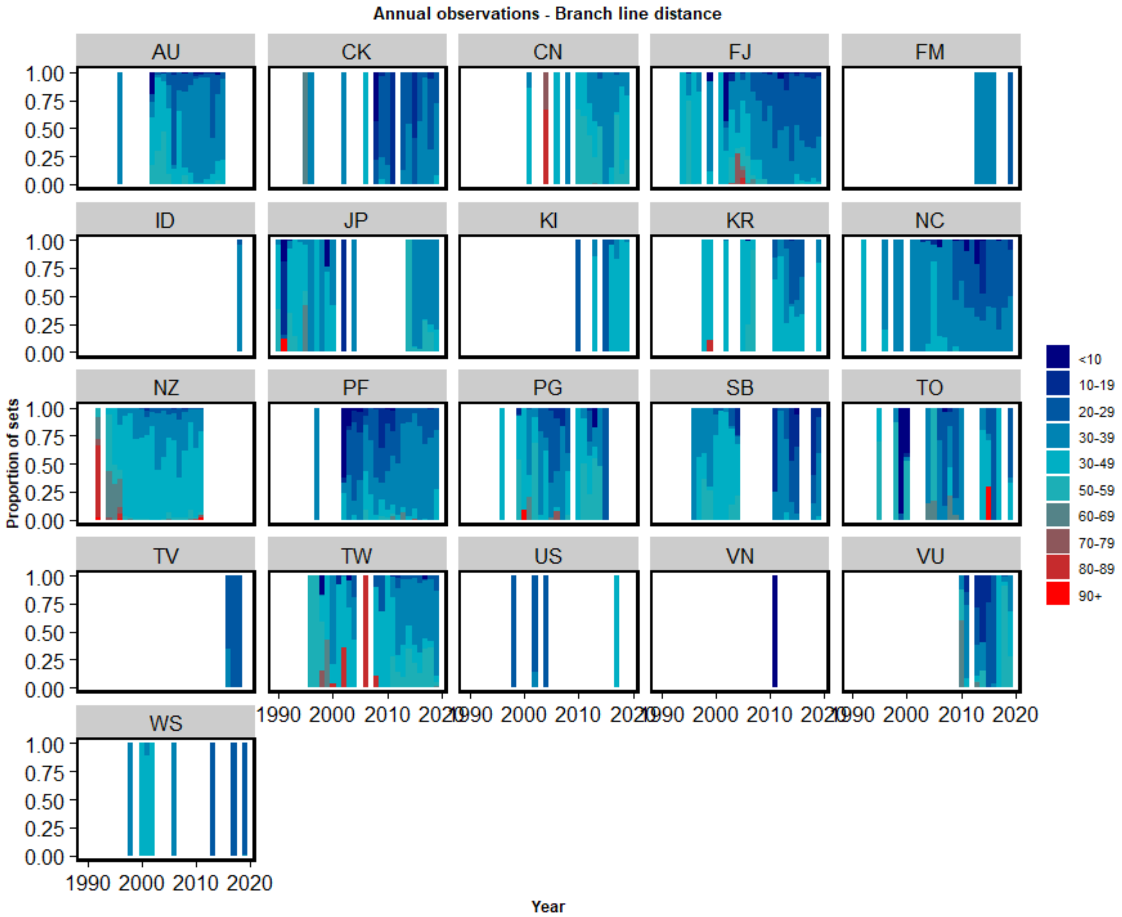


**Figure 31:** Observed branchline distance, used on longline sets, by flag in the WCPFC between 1990 - 2020.

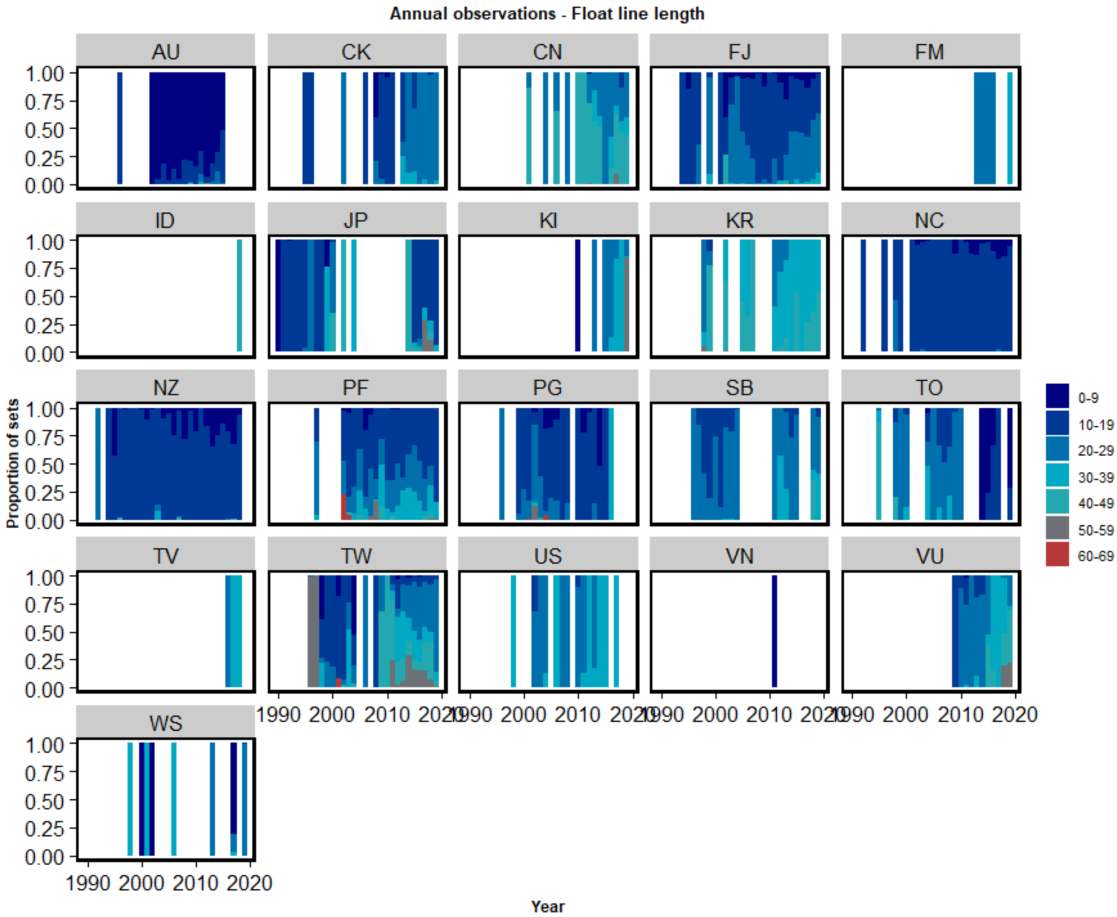


**Figure 32:** Observed float line length, used on longline sets, by flag in the WCPFC between 1990-2020.

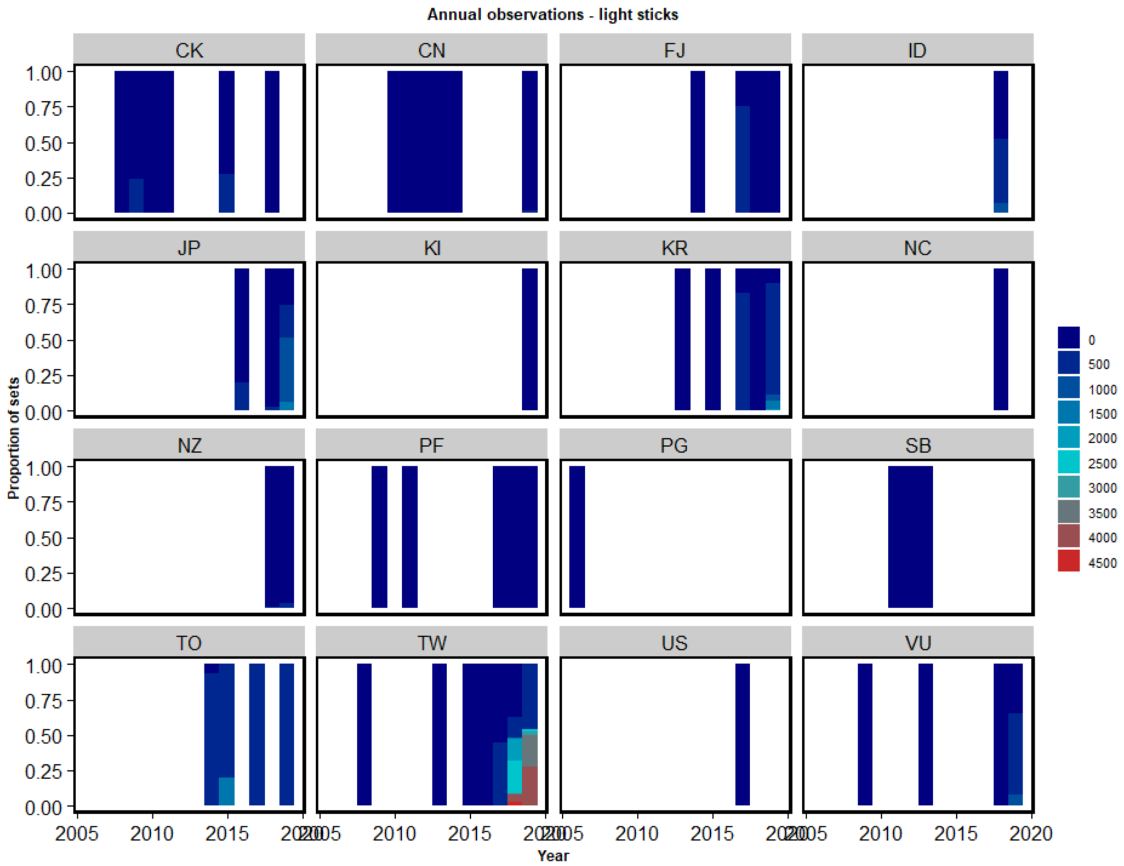


**Figure 33:** Observed lightstick use on longline sets, by flag in the WCPFC between 1990 - 2020.

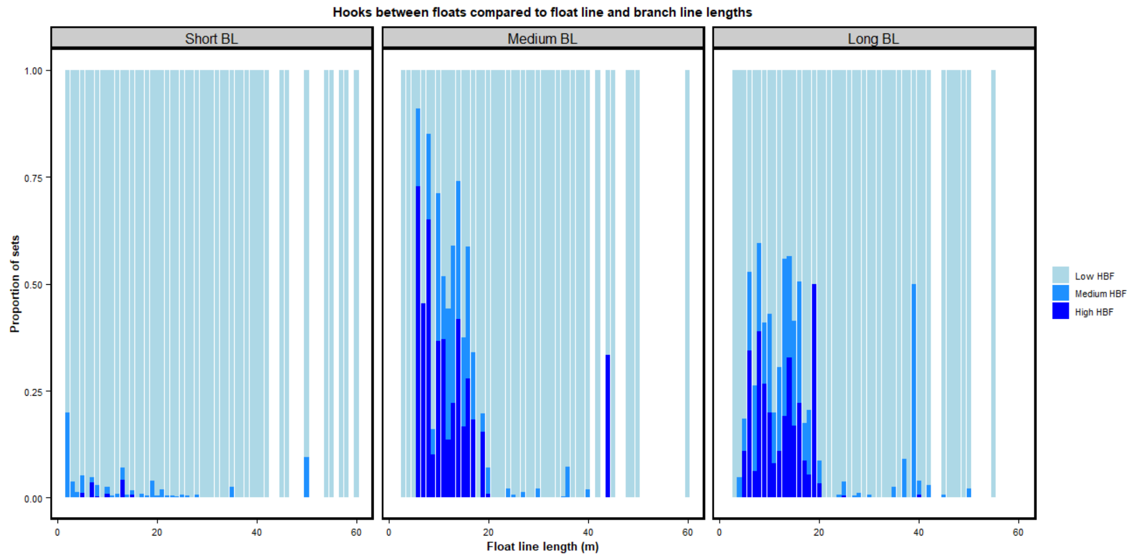


**Figure 34:** Comparison of the hooks between floats (HBF), branch line length (BL) (as three groups Short Medium and long) and float line length.

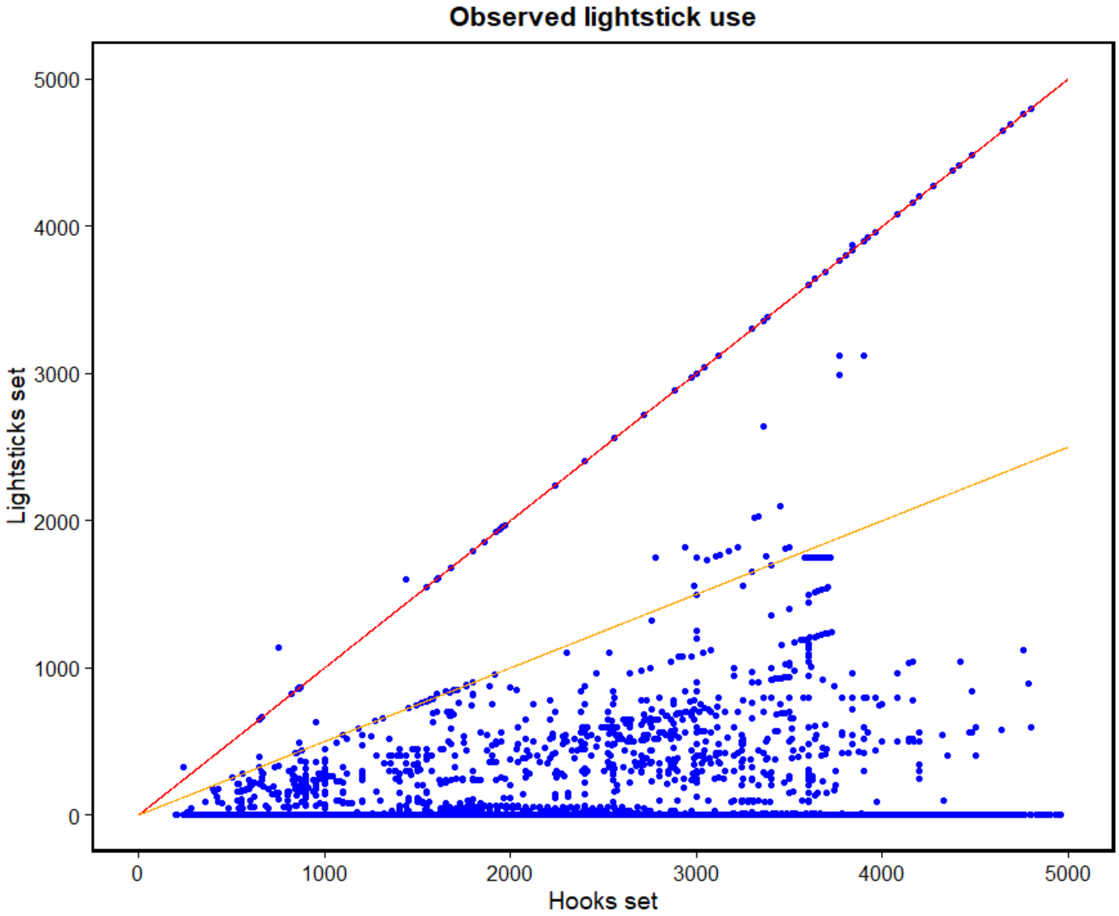


**Figure 35:** Comparison of the number of lightsticks to the number of hooks set. The red line represents the 1:1 ratio. The orange line represents the 1:0.5 ratio.

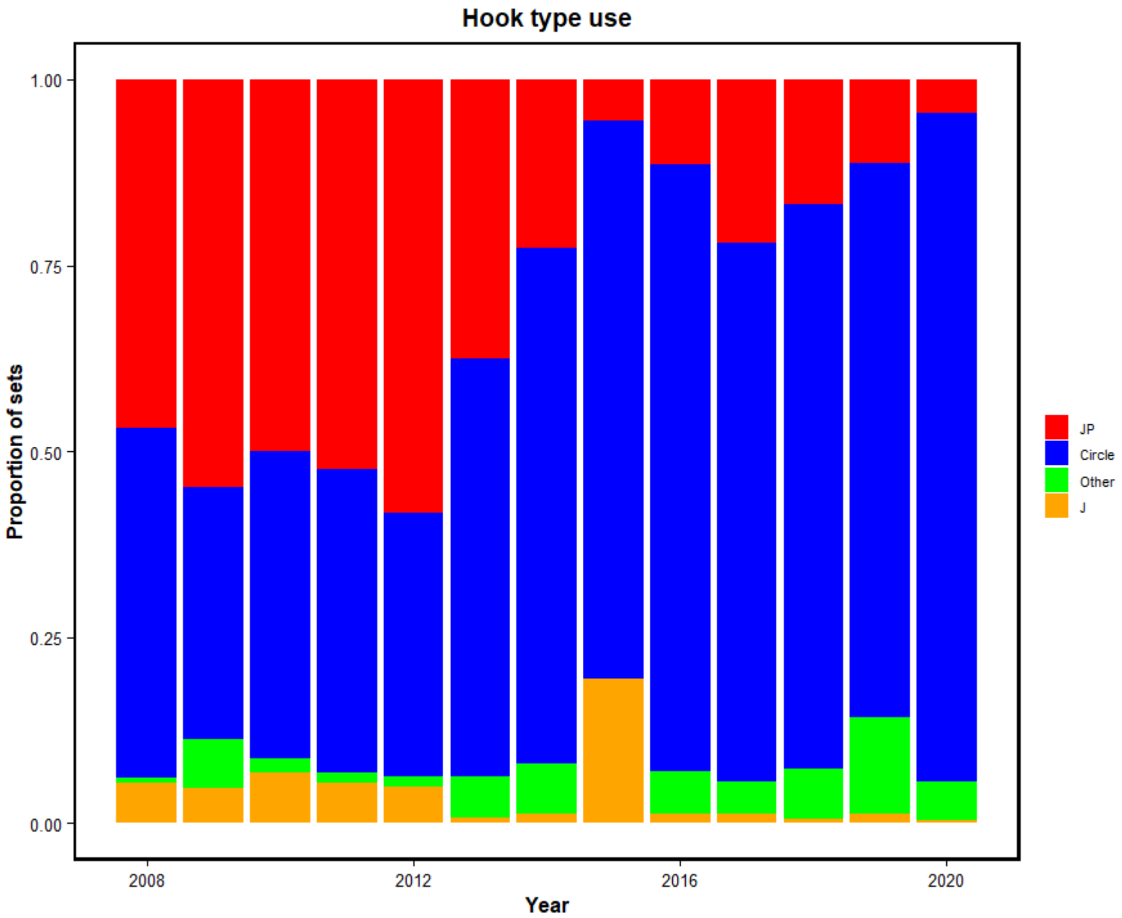


**Figure 36:** The use of hook types for all fleets combined in the WCPFC between 2008 - 2020.

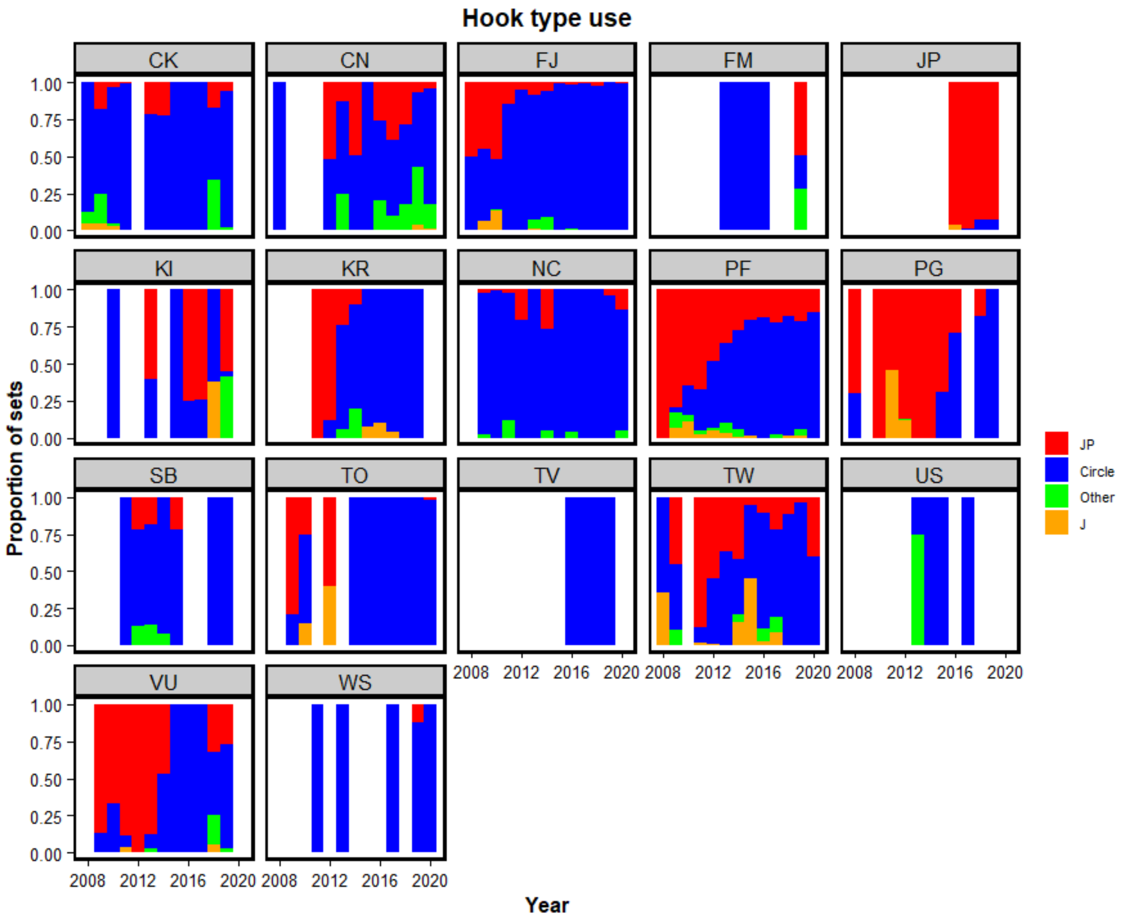


**Figure 37:** The use of hook types by flag in the WCPFC between 2008 - 2020.

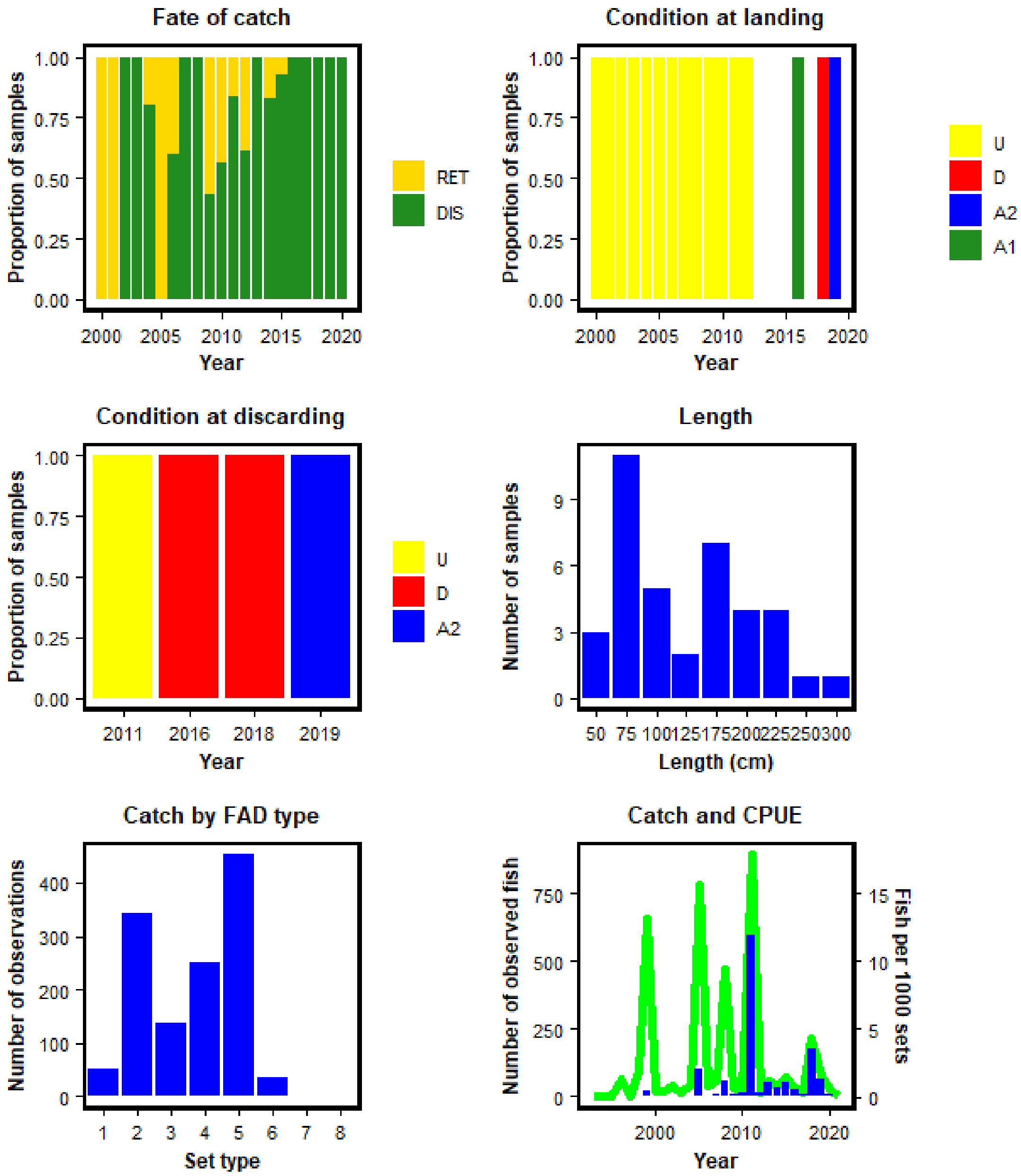


**Figure 38:** Observed purse seine fate and condition information as well as length catch by set type and catch and CPUE in the WCPFC between 1990 - 2020. RET = Retained, DIS = Discarded, D = Dead, A1 - A2 are various life states as defined in Table 2 and the set type codes are defined in Table 3.

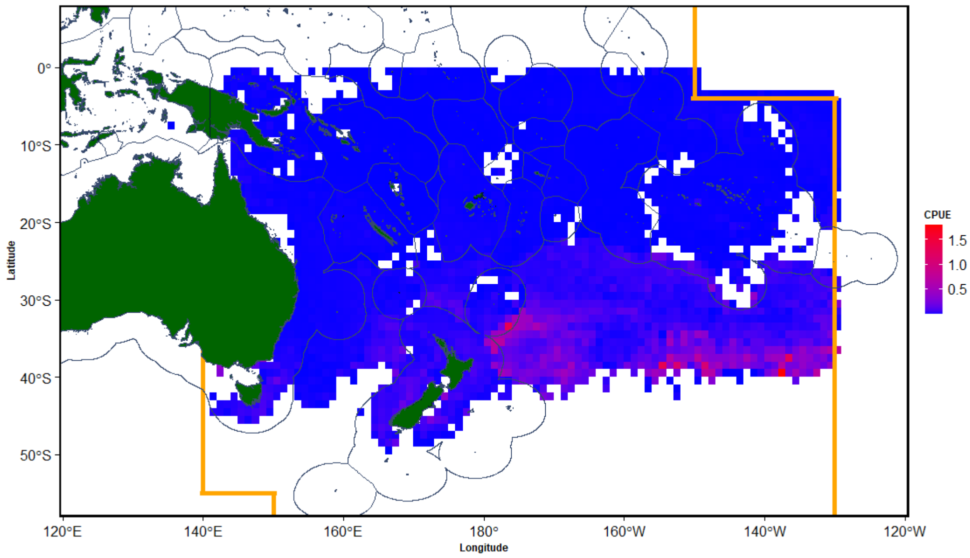


**Figure 39:** Longline logsheet nominal catch per unit effort (kg / 100 hooks) of south Pacific blue sharks caught per 1x1 degree square in the WCPFC Convention area between 1990 - 2020.

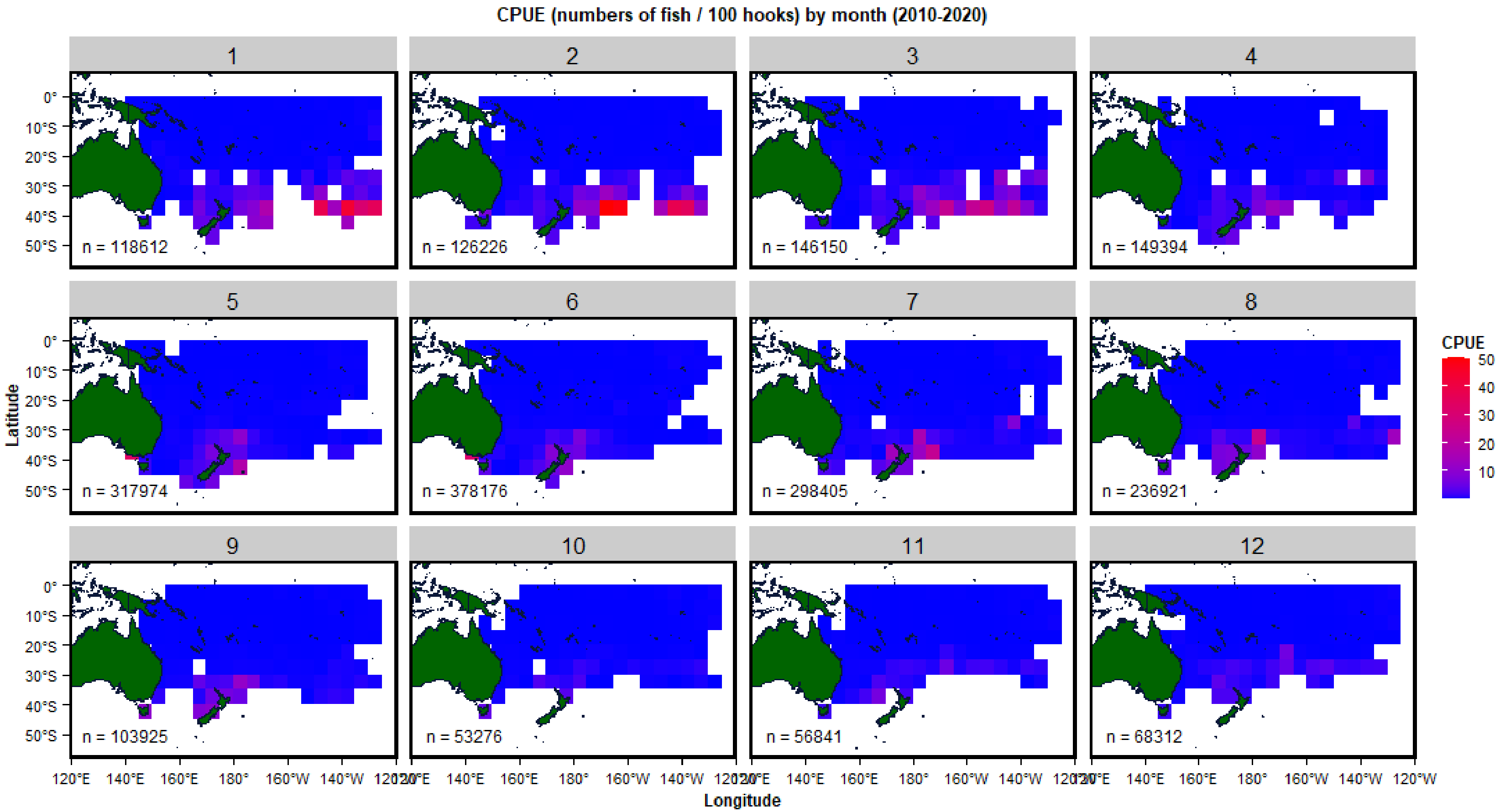


**Figure 40:** Longline logsheet nominal catch per unit effort (kg / 100 hooks) of south Pacific blue sharks caught by month and 5x5 degree square in the WCPFC Convention area between 1990 - 2020.