SCIENTIFIC COMMITTEE
NINETEENTH REGULAR SESSION

Koror, Palau

16-24 August 2023

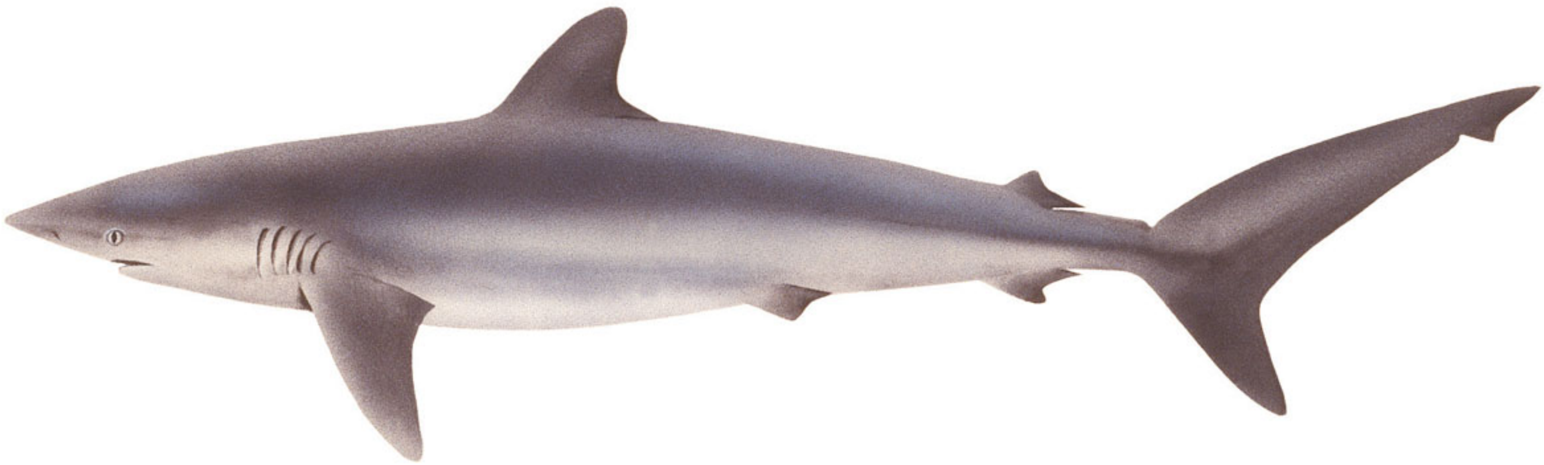
Characterisation of the fisheries catching Silky sharks (*Carcharhinus falciformis*) in the Western and Central Pacific Ocean

WCPFC-SC19-2023/SA-IP-09

Stephen Brouwer[1], Kath Large[2] and Philipp Neubauer[2]

[1] Saggitus Consulting

[2] Dragonfly Data Science



Characterisation of the fisheries catching Silky sharks (*Carcharhinus falciformis*) in the Western and Central Pacific Ocean

Report prepared for WCPFC SC19

Authors:
Stephen Brouwer
Kath Large
Philipp Neubauer

DRAGONFLY
Data Science

SAGGITUS

Cover Notes

To be cited as:

Brouwer, Stephen; Large, Kath; Neubauer, Philipp (2023). Characterisation of the fisheries catching Silky sharks (*Carcharhinus falciformis*) in the Western and Central Pacific Ocean, 50 pages. Report prepared for WCPFC SC19.

CONTENTS

EXECUTIVE SUMMARY

The next stock assessment for silky shark (*Carcharhinus falciformis*) is scheduled for 2024. The work leading up to the assessment will be undertaken over two years. This paper, as well as Neubauer et al. (2023), represent the background work for the SC19s consideration and information for feedback into the SC20 assessment. Silky shark are caught as bycatch in longline fisheries targeting tuna, billfish and blue sharks between 10^{o}N and 20^{o}S, and as bycatch in the tropical purse seine fisheries of the WCPO. No target fisheries exist for silky sharks and since 1st July 2014 their retention has been prohibited within the WCPO. Since 2015, almost all silky sharks have been discarded or cut-free from longline sets and more than half of those are released alive and healthy. Similarly, in the purse seine fishery, all silky sharks have been released since 2015, but release condition is largely unknown.

This paper describes the longline gear designs that catch silky sharks; presents information on fate and condition; length data; raw CPUE information; and discusses the impact of vessel flag and observer program on the spatio-temporal distribution of the catch and provides recommendation for the 2024 stock assessment.

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

1. Observer programs and/or vessel flag be included along with gear characteristics as variables in CPUE and length analysis standardisation.
2. Incorporate post release survival of silky sharks into other analyses evaluating measures to reduce fishing-related mortality.
3. Noting that there are very few data for the release condition of silky sharks landed on purse seine vessels, it is recommended that observers on purse seine vessels be encouraged to collect data on shark release condition.
4. It is recommended that the 2024 stock assessment explicitly provide commentary on the recent trends in fishing mortality since the inception on CMM2019-04.

1. INTRODUCTION

Silky sharks (*Carcharhinus falciformis*) are wide ranging across the Pacific Ocean. They are caught as bycatch in tropical and sub-tropical longline fisheries targeting tuna, billfish and blue sharks throughout the Western and Central Pacific Ocean (WCPO). Silky sharks are also caught in the purse seine fisheries of the WCPO. Unlike blue shark, where some target fisheries exist in the South Pacific Ocean, no target fisheries exist for silky sharks (Williams and Ruaia 2021). While silky sharks were caught as bycatch and were retained in large numbers historically, since 1^{st} July 2014 silky sharks within the WCPFC have been required to be released (WCPFC 2013).

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 observer effort is not representative of the fishing effort distribution (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, Large et al. 2022).

While it appears that there are a reasonable amount of observer and logsheet data available for undertaking catch reconstructions and catch per unit effort (CPUE) standardisations, for the development of a silky shark stock assessment, these analyses and those in the accompanying analysis (Neubauer et al. 2023) highlight the deficiencies in both the quantity and quality of these data. The data are patchy in space and time and by fleets, and therefore any catch reconstruction is expected to have a high uncertainty (Brouwer et al. 2022, Brouwer and Hamer 2023). These authors also note that past management interventions may complicate the CPUE standardisation, along with:

1. the impact of regulatory changes on fishery dependent data;
2. generally low observer coverage in longline fleets particularly in the high seas; and,
3. for most fleets after CMM2013-08 (silky shark CMM) came into force, most silky sharks have been released, with a high proportion of releases being alive and healthy at release.

Brouwer and Hamer (2020) report there are good biological data for silky sharks (e.g. Clarke et al. 2015, Galvan-Tirado et al. 2015, Oshitani et al. 2003, Santander-Neto et al. 2021), but some uncertainties remain particularly the estimates of longevity which may be related to a high degree of spatial variability in biological parameter estimates and different size ranges of individuals from different analyses. In addition, there is evidence that there may be two stocks of silky sharks in the Pacific ocean (Clarke et al. 2015).

While there are length samples from the 1990s to present, these are not available for all fleets, and have not recorded consistently through time. These data are limited mostly to vessels flagged to China, Fiji and Chinese Taipei with samples from other fleets being sparse, and are difficult to interpret due to changes in overall reporting and the time periods covered by the data from different flags (Brouwer and Hamer 2023). Large sharks may break free from the gear and in recent years be released without being brought on-board rendering length data less useful as indicators of trends in biomass of mature sharks.

In order to overcome problematic shark reporting, WCPO shark catch reconstructions have been undertaken to estimate shark catch for a number of species using observed catch data (Lawson 2011, Rice 2012, Tremblay-Boyer and Takeuchi 2016, Peatman et al. 2018, Neubauer et al. 2021b, Large et al. 2022) or fin trade information (Clarke 2009). However, these indices were found to be variable among data sources, and potentially in conflict.

This work underpins the catch reconstruction that is developed in Neubauer et al. (2023) and is aimed at assisting the SC19 make decisions around stock assessment options for the scheduled 2024 stock assessment.

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 effort estimates by day, flag, latitude and longitude, catch and effort.
  - Operational (logsheet[1]) catch and effort data from 1970-2022, 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 effort 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.

[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 CCMs in some years for the silky shark stock assessment and related analyses.

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, 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 Neubauer et al. (2023).

The total silky 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.

Silky 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 line hook was allocated a number 0 as they are the shallowest hooks. 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 silky shark length as upper jaw to fork in tail (UF). A small proportion of observers record other length metrics, such as total length (TL) fork length (LF) or pre-caudal length (PC).

3. RESULTS

3.1 Overall catch and effort

The longline fishing effort in the WCPO extends form over 40^{o}N to over 40^{o}S, but effort is not evenly distributed through the area. Fishing effort is highest in the tropics and subtropics but with less effort along the equator (Figure 1). Reported silky shark catch from logsheet reporting, on the other hand, is highest from 10^{o}N to 20^{o}S and with hotspots of high reported catch in Papua New Guinea, Palau, Fiji, the Marshall Islands and the Solomon Islands (Figure 1).

Reported silky shark catch generally increased from the mid-2000s to 2019 but has declined since then, while observers have been reporting silky sharks since the mid-1990s (Figure 2). Observer reported catch was highest in the early 2010s, but has been low since 2020. For most CCMs catch of silky sharks was not well reported prior to 2005, was highest in the 2010s and has been low in recent years. The highest catch was reported by Chinese Taipei, Vanuatu, Fiji, Federated States of Micronesia and Papua New Guinea (Figure 3). These trends were also evident in the distribution of the reported catch where in the 1990s most catch was reported around American Samoa, in the 2000s high catch densities appear around Hawaii, Australia through the Solomon Islands and around American Samoa, the Cook Islands and French Polynesia, whereas in the 2010s the catch is broadly reported across the tropical and sub-tropical Western Pacific (Figure 4).

3.2 Fate and condition

Prior to 2015 most silky sharks were retained (Figure 5). In 2015 there was a fairly abrupt change to the fate of silky sharks and about half of the fish have been discarded since. An additional 25% were cut-free, suggesting that, since 2015, almost all fish are discarded or cut-free. These trends were not consistent between vessel flag nor observer program (Figure 6 and Figure 7). Prior to 2015, most CCMs retained silky sharks, changing to discarding and cutting them free between 2000 and 2015. French Polynesia began discarding silky sharks in around 2010 and the United States of America vessels have been releasing silky sharks since 2000 with most of those being cut free. The observer program data showed that while fewer records are available form the earlier time period, most of those fish were retained but with higher numbers of sharks reported as being released after 2010. This trend was partly a result of increased observer coverage and increased reporting requirements on sharks at that time.

Most silky sharks arrived at vessels alive and healthy, with lower survival rates on Japanese, French Polynesian and Papua New Guinea vessels flagged vessels (Figure 8). At release however, most fish were discarded dead, but on some vessels, e.g. those flagged to Fiji, since 2015 more than half the silky sharks are released alive and healthy (Figure 9). Overall, in the most recent 5-7 years a high proportion of the silky sharks are released, and while the condition at capture has changed little, improvements in the condition at release are evident (Figure 10).

For purse seine fishing vessels, similar to the longline fishery, a high proportion of silky sharks were retained prior to 2010, but thereafter most were released. The condition at capture data were not well collected prior to 2015. The more recent data show that only about 25% of the silky sharks are alive and healthy, with most of the remainder recorded as dead (Figure 11). There are not enough data on release condition from purse seine vessels to be informative.

3.3 Hook depth

Within each basket, hooks were numbered from 1 (closest to the float) to the middle of the basket (highest number) and then back to 1, with hook number 0 referring to fish caught on shark lines (lines attached to the float). These data show that silky sharks are caught on the shallowest hooks (Figure 12). Assessing these data in five-year time bins show that the use of shark hooks has declined, but the trends in the more recent decade are relatively consistent (Figure 13). With the exception of the shark hooks (hook zero), which catch a high frequency of small sharks, the catch at size does not change dramatically with depth where the shallow and deep hooks have similar size frequencies (Figure 14).

Grouping the hooks into shallow (hooks 0-6) and deep (hooks 7+) show that the shallow hooks catch more large fish (Figure 15). Both deep and shallow hooks have a peak at 110 cm UF and a similar size range if silky sharks.

3.4 Length data

Silky shark length data have been collected by fishery observers since the late 2000s. Most silky sharks were measured to a single length measurement type (UF). The length data were relatively evenly split between males and females and there are not obvious differences in the size of males and females. These data show that prior to 2010 few length data were collected, but in the early and late 2010s large numbers of length samples were collected (Figure 16). In addition, overall the length data were slightly bimodal with peaks around 110 cm and 160 cm FL. Through time the length data were relatively stable, but declined in the most recent period.

Catch by flag information showed that some flags such as the Cook Islands, Japan and French Polynesia caught mostly small fish while Chinese vessels catch large silky sharks (Figure 17). Papua New Guinea and Fiji have a bimodal distribution in silky shark length. There are no obvious trends in silky shark size by latitude or quarter (Figure 18). Nor are there obvious trends in changes in the distribution by maturity (Figure 19).

3.5 Catch ratios

Figure 20 presents the species proportions by depth, these data indicate that a higher proportion of the catch in shallow sets is made up of swordfish and sharks, mostly blue sharks but also silky sharks. The data also indicate that the proportion of sharks in the catch has declined since 2010. Albacore make up a higher proportion of the catch in the most recent decade. The silky shark catch proportions in the shallow sets reflect the retention rates reported with higher catch proportions around 2000 and the early 2010s.

While blue sharks make up the majority of the shark catch (Figure 21 A & B), excluding blue sharks from the data reveal increases in silky shark catch but also a change in reporting where sharks coded to the generic shark code (SHK) are greatly reduced and species specific reporting has increased recently (Figure 21 C & D). The catch proportions by flag show high reported catch of sharks by New Zealand, Papua New Guinea and

United States vessels (Figure 22). Papua New Guinea, Chinese Taipei and China have the highest catch proportions of silky sharks. Japanese vessels had high catch proportions of blue sharks prior to 2000 but that has declined substantially since then. Generally speaking, flag CCMs with high catch of swordfish also have high catch of sharks.

3.6 Gear attributes

Overall the longlines gear that are set in the WCPO consists of lines with 2000-3000 hooks; 200 baskets; 20-29 hooks between floats; float lines of around 30m long; branchlines of 20m long; with 40m between branchlines; 500 lightsticks per line; and various bait types (Figure 23). For the sets that catch silky sharks, sets with few hooks between floats accounted for about half of the sets prior to 2000 but with higher numbers of hooks between floats thereafter (Figure 24). Similarly, the numbers of hooks set has increased, but the number of baskets set has declined (Figure 24). Bait use is relatively varied where between 1995 and 2000 squid was most common as was mackerel and other fish bait, however, other bait types are most frequently used from 2000 onwards (Figure 24).

The observed hooks between floats by flag showed that Australian vessels had fewer hooks between floats, China and Chinese Taipei vessels have increased their hooks between floats between 1995 and 2022. The Unites States vessels have used relatively similar hooks between floats throughout the time period (Figure 25). The number of hooks set varies between flags and through time (Figure 26). Generally speaking the Australian and Papua New Guinea vessels set fewer hooks, whereas China, Fiji, Korea and the United States have increased the number of hooks set. French Polynesia and New Caledonia have had relatively consistent number of hooks at around 1500-3000 hooks set. The number of baskets set is relatively similar between flags, with most setting 100-300 baskets, but the Unites States vessels have increased theirs through time and Papua New Guinea and Chinese Taipei vessels have mostly had higher numbers of baskets set (Figure 27). Many WCPFC CCMs used squid, mackerel, or general fish bait in the late 1990s but most have used other bait types since 2000 (Figure 28).

The temporal trends in branch line length have show banchline length decreasing through time but increasing somewhat since 2015. Branchline distance has also decreased and floatline length has increased, lightstick use is difficult to interpret but seems to increase in prevalence in the last 3 years (Figure 29). By flag, branchline length is relatively higher in the more recent years for Chinese and Japanese vessels, few other fleets show any strong temporal trends. Similarly branchline distance show few trends except for China, Chinese Taipei, Fiji and Papua New Guinea whose vessels have reduced the branchline distance in the most recent decade (Figure 30). Branch line distance shows few clear temporal trends, however, China vessels have reduced the branchline distance as have the Chinese Taipei vessels few other flags have clear trends (Figure 31). Floatline length varies by flag and by year with no definitive trends, the only consistent flag is the United States vessels who very consistently use floatline lengths of 20-29m (Figure 32). The lightstick data are poorly documented with only Chinese Taipei showing any temporal trends with an increase in lightstick reporting in 2019-2022 (Figure 33). Overall a small number of vessels have 100% light stick use i.e. one lightsick for every hook set, but most have zero (Figure 34).

Prior to and around 2010 about half of the vessels reported using Japanese hooks with most of the remainder being circle hooks a small proportion of vessels use J-hooks ate other hook types, but since 2013 most (∼75%) vessels were observed using circle hooks with the remainder relatively evenly split between J-hooks and Japanese hooks (Figure 35). Hook type is thought to impact the survivability of sharks, overall the data show that silky sharks of all conditions are landed on all hook types with fish of all conditions observed on all hook types (Figure 36).

3.7 Observer program data

The observed number of sets varied by observer program and sets containing silky sharks form a small part of the dataset (Figure 37). For many observer programs the data were recent and sparse or patchy. However, some, such as Hawaii, New Caledonia, New Zealand and French Polynesia have a relatively long history of observer data. The observed sets reported by the Hawaii observer program have slowly increased through time and have been relatively high and consistent since 2000. The New Zealand observer program has also had a high number of sets through the analysis period, however sets containing silky sharks are very few. The New Caledonia and French Polynesia observer programs have shown a steady increase in observed sets through time and reported a moderate number of sets with silky sharks.

The number of observed sets has increased in recent years for China, Fiji, Japan, Korea, Tonga, Chinese Taipei and Vanuatu, and all of these flags have sets containing silky sharks. New Zealand observed sets has declined in the most recent years and Australian observed sets began declining in 2010 and stopped altogether in 2015 as that CCM switched to electronic monitoring and those data are not available in the SPC datasets at this stage.

4. DISCUSSION

Brouwer and Hamer (2023) note that the next stock assessment for silky sharks is scheduled for 2024. These authors also note that the work leading up to the assessment will be undertaken over two years. This paper as well as Neubauer et al. (2023) represent the background work for the SC19s consideration and information for feedback into the SC20 assessment.

Silky sharks are caught as bycatch in longline fisheries targeting tuna, billfish and blue sharks throughout the Western and Central Pacific Ocean (WCPO) between 10^oN to 20^oS and with hotspots of high catch in Papua New Guinea, Palau, Fiji, the Marshall Islands and the Solomon Islands. They are also caught in the tropical purse seine fisheries of the WCPO. Unlike blue shark, where some target fisheries exist in the South Pacific Ocean, no target fisheries exist for silky sharks (Williams and Ruaia 2021). Although silky sharks have not been very well reported, they were caught as bycatch and retained in large numbers.

Since 1^{st} July 2014 silky sharks within the WCPFC have been required to be released (WCPFC 2013). This management intervention seems to have been effective as reported silky shark catch has declined in the recent years. Prior to 2015 most silky sharks were retained. In 2015 there was a fairly abrupt change to the fate of silky sharks. Around 2015, about half of silky sharks were discarded and and additional 25% were cut-free, whereas since 2015 almost all fish were discarded or cut-free. But differences in observer coverage have impacted the overall impression of the overall data. For example, in the most recent decade more observer data come from Fiji and due to the stringent requirements on the release of silky and other sharks in that EEZ the overall data show high proportions of released silky sharks with many being cut-free. This has also impacted the estimated overall size of fish, where larger fish were cut free. As a result these fish were not measured, as they are harder to handle. Small sharks, which are easier to handle, still get brought onboard and the observers have the opportunity to measured them before being released. This creates the overall impression that the mean fish size is declining, but that trend is likely an observer effect.

Other observer programs and/or vessel flag effects were seen in the differences in the characterisations of the gear, where gear characteristics will vary by depending on the target species. While specific target is not well documented, gear characteristics are relatively well documented by observers and some are captured on longline logsheets. These gear characteristics will impact the catchability of sharks (Ward et al. 2008, Godin et al. 2012). As a result, different observer programs and/or vessel flag information will likely impact the interactions with silky sharks. Vessels setting gear with the characteristics that make the gear lie shallower in the water will increase the ability of that gear to catch a silky shark. Furthermore, the practice of the vessel and the law on the EEZ within which they are fishing will determine if a fish is cut-free, caught and discarded or retained.

Observer programs may be a proxy for flag, nevertheless and observer program and/or vessel flag should be included as variables in CPUE and length analysis standardisation. Brouwer and Hamer (2023) note the spatio-temporal issues of observer coverage and suggest that fishery data standardisations should take these into account if possible. These data along with the relatively sparse data compared to other shark species suggest that catch reconstruction will be an essential part of this assessment. Additionally, ABNJ (2018) noted that the CPUE indices they attempted were informative with respect to assessing the long-term trends in stock abundance, however, that time-series was relatively short (only 14 years for the WCPO) and the overall trend may have been influenced by the prevailing oceanographic conditions at the start and end of their CPUE series. All of these factors will need to be considered when undertaking catch reconstruction and CPUE analyses for the planned 2024 stock assessment of silky sharks.

WCPFC (2019) and its predecessors require that silky sharks be released when captured on all gear. A high proportion of silky sharks are alive and healthy when captured by longline vessels and while abut 75% of them are dead when captured in purse seine gear, those that are alive are considered alive and healthy. While some work has been done on the post release survival of silky sharks from purse seine (Hutchinson et al. 2012) and longline (Hutchinson et al. 2021) gears, these estimates will need to be incorporated into other analyses evaluating measures to reduce fishing-related mortality (e.g. Bigelow and Carvalho 2021). There are very few data for the release condition of silky sharks on purse seine vessels, this has made evaluating the proportion of fish released alive and healthy challenging. In addition, it makes extrapolating the results of Hutchinson et al. (2012) to the wider fleet difficult. Notwithstanding our poor understanding of longline gear and release survival, it appears that considering the high proportion of silky sharks cut-free and discarded as well as the relative improvements in release condition in the most recent years for silky sharks that fishing related mortality from longline gear should have decreased since the inception of the shark CMM (WCPFC 2019).

Finally, the hypothesis that silky shark fishing related mortality has decreased since 2015 should be tested as part of the 2024 stock assessment, which should also provide commentary on the relative impact of (WCPFC 2019) since 2015. That assessment will also need to rely on catch reconstruction and CPUE methods developed for, and evaluated by SC19.

5. RECOMMENDATIONS

The following recommendations are proposed for SC19 to consider:

1. Observer programs and/or vessel flag be included along with gear characteristics as variables in CPUE and length analysis standardisation.
2. Incorporate post release survival of silky sharks into other analyses evaluating measures to reduce fishing-related mortality.
3. Noting that there are very few data for the release condition of silky sharks landed on purse seine vessels, it is recommended that observers on purse seine vessels be encouraged to collect data on shark release condition.
4. It is recommended that the 2024 stock assessment explicitly provide commentary on the recent trends in fishing mortality since the inception on CMM2019-04.

6. ACKNOWLEDGMENTS

The authors would like to thank SPC, particularly Peter Williams, Emmanuel Schneiter and Aurélien Panizza for providing the WCPFC Members data for these analyses. We would also like to thank Paul Hamer 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 108.

7. REFERENCES

ABNJ (2018). *Pacific-wide silky shark (Carcharhinus falciformis) stock status sssessment* (tech. rep. No. WCPFC-SC14-2018/SA-WP-08). WCPFC.

Bigelow, K. & Carvalho, F. (2021). *Review of potential mitigation measures to reduce fishing-related mortality on silky and oceanic whitetip sharks (Project 101)* (tech. rep. No. SC17-2021/EB-WP-01). WCPFC.

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

Brouwer, S. & Hamer, P. (2023). *Shark research plan 2021-2025 mid-term review* (tech. rep. No. SC19-EB-WP-06). WCPFC.

Brouwer, S. & Harley, S. (2015). *Draft Shark Research Plan: 2016-2020* (tech. rep. No. SC11-EB-WP-01). WCPFC.

Brouwer, S.; Large, K., & Neubauer, P. (2022). *Characterisation of the fisheries catching South Pacific shortfin mako sharks (*Isurus oxyrinchus*) in the Western and Central Pacific ocean* (tech. rep. No. WCPFC-SC18-2022/SA-IP-07). WCPFC.

Clarke, S. (2009). *An alternative estimate of catches of five species of sharks in the Western and Central Pacific Ocean based on shark fin trade data* (tech. rep. No. SC5-EB-WP-08). WCPFC.

Clarke, S.; Coelho, R.; Francis, M.; Kai, M.; Kohin, S.; Liu, K. M.; Simpfendorfer, C.; Tovar-Avila, J.; Rigby, C., & Smart, J. (2015). *Report of the Pacific shark life history expert panel workshop, 28-30 April 2015* (tech. rep. No. SC11-EB-IP-13). WCPFC.

Galvan-Tirado, C.; Galvan-Mahana, F., & Ochoa-Baez, R. I. (2015). Reproductive biology of silky sharks (Carcharhinus falciformis) in the southern Mexican Pacific. *Journal of the Marine Biological Association of the United Kingdom*, *95*(3), 561–567.

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.

Hutchinson, M.; Itano, D.; Muir, J.; Leroy, B., & Holland, K. (2012). *The post-release condition of FAD associated silky sharks (Carcharhinus falciformis) caught in tuna purse seine gear* (tech. rep. No. SC8-EB-WP-12). WCPFC.

Hutchinson, M.; Siders, Z.; Stahl, J., & Bigelow, K. (2021). *Quantitative estimates of post-release survival rates of sharks captured in Pacific tuna longline fisheries reveal handling and discard practices that improve survivorship* (tech. rep. No. Data Report DR-21-001). PIFSC. doi:https://doi.org/10.25923/0m3c-2577

Large, K.; Neubauer, P.; Brouwer, S., & Kai, M. (2022). *Input data for the 2022 South Pacific Shortfin Mako Shark stock assessment* (tech. rep. No. WCPFC-SC18-2022/SA-IP-13). WCPFC.

Lawson, T. (2011). *Estimation of catch rates and catches of Key Shark Species in tuna fisheries of the Western and Central Pacific Ocean using observer data* (tech. rep. No. SC7-EB-IP-02). WCPFC.

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.; Kai, M.; Tasi, W., & Liu, K. (2021b). *Input data for the 2021 South Pacific blue shark (Prionace glauca) stock assessment* (tech. rep. No. WCPFC-SC17-2021/SA-IP-18). WCPFC.

Neubauer, P.; Large, K.; Kim, K., & Brouwer, S. (2023). *Analysing potential inputs to the 2024 Stock assessment of Western and Central Pacfic silky shark)* (tech. rep. No. WCPFC-SC19-2023/SC19-SA-WP-10). WCPFC.

Oshitani, S.; Nakano, H., & Tanaka, S. (2003). Age and growth of the silky shark Carcharhinus falciformis from the Pacific Ocean. *Fisheries Science*, *69*, 456–464.

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* (tech. rep. No. WCPFC-SC14-2018/ST-WP-03). WCPFC.

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

Rice, J. (2012). *Alternate catch estimates for silky and oceanic whitetip sharks in Western and Central Pacific Ocean* (tech. rep. No. SC8-SA-IP-12). WCPFC.

Santander-Neto, J.; Barreto, R.; Santana, F. M., & Lessa, R. P. T. (2021). Age, growth and demography of the silky shark Carcharhinus falciformis from the southwestern Atlantic. *Endangered Species Research*, *45*, 237–249.

Tremblay-Boyer, L. & Takeuchi, Y. (2016). *Catch and CPUE inputs to the South Pacific blue shark stock assessment* (tech. rep. No. SC12-SA-WP-09). WCPFC.

Ward, P.; Laweence, E.; Darbyshire, R., & Hindmarsh, S. (2008). Large-scale experiment shows that nylon leaders reduce shark bycatch and benefit pelagic longline fishers. *Fisheries Research*.

WCPFC (2013). *Conservation and Management Measure for silky sharks* (tech. rep. No. Conservation and Management Measure 2013-08). WCPFC.

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.

Williams, P. & Ruaia, T. (2021). *Overview of tuna fisheries in the Western and Central Pacific Ocean, including economic conditions - 2020* (tech. rep. No. WCPFC-SC17-2021/GN-IP-01). 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
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

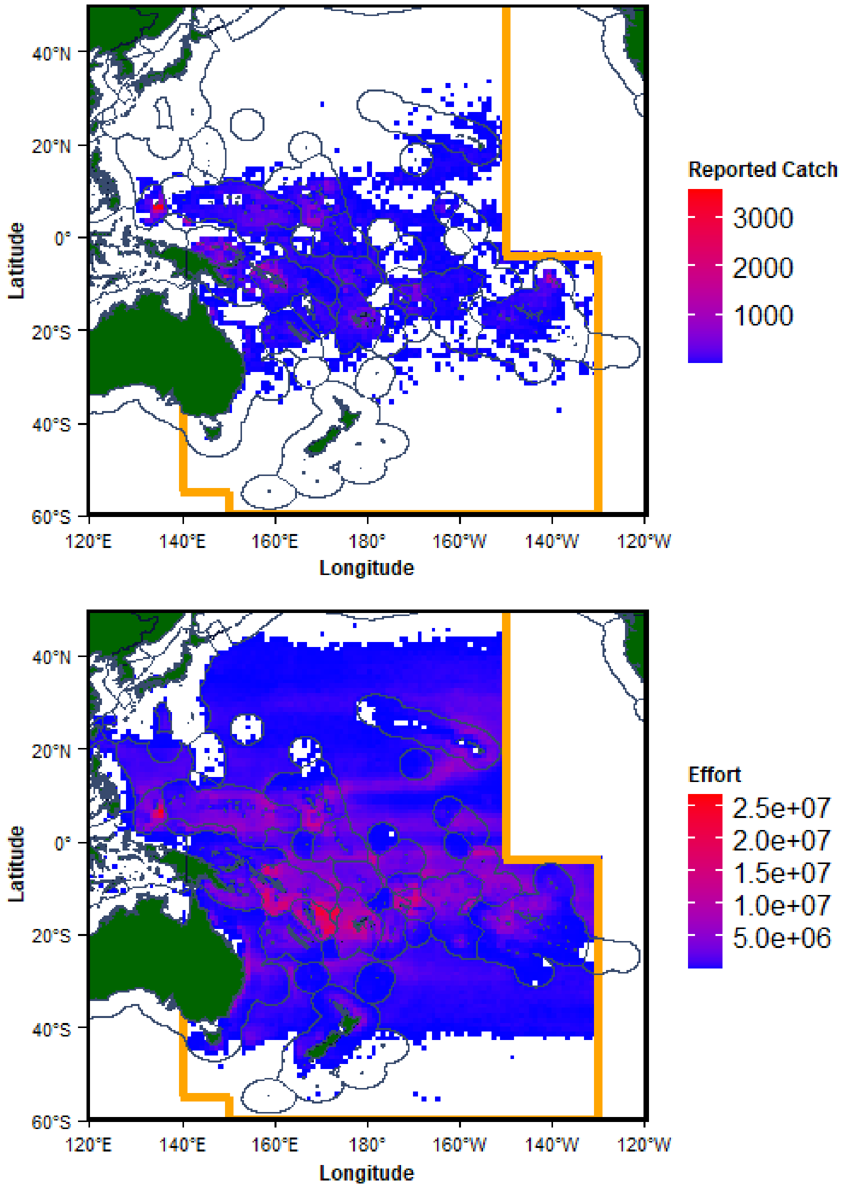


Figure 1: Longline silky shark catch in tonnes (top) fishing effort in hooks set (bottom) as reported on the available logsheets in the WCPFC Convention area 1995 - 2022.

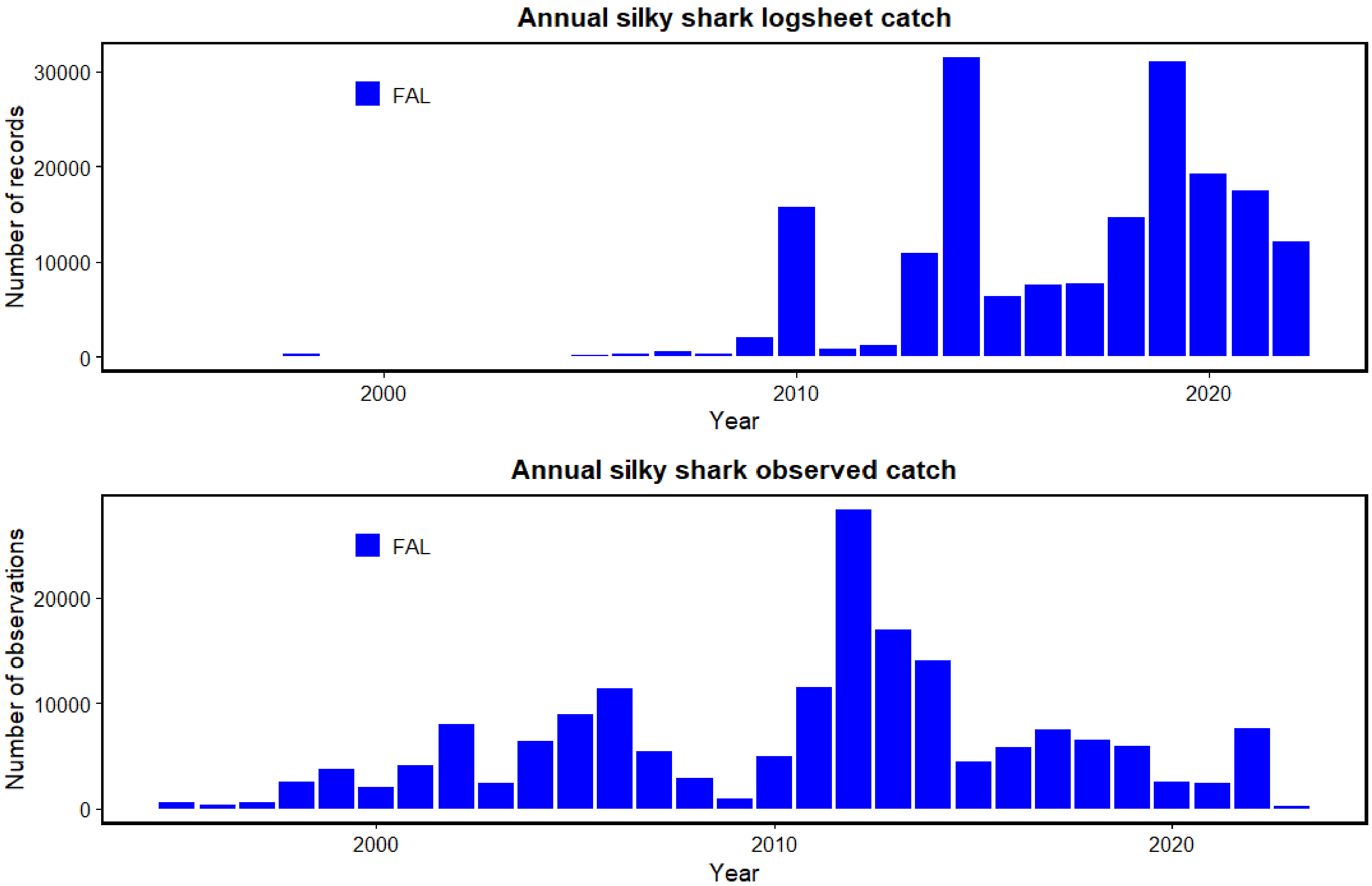


Figure 2: Longline catch reported on logsheets (top) and and by observers (bottom).

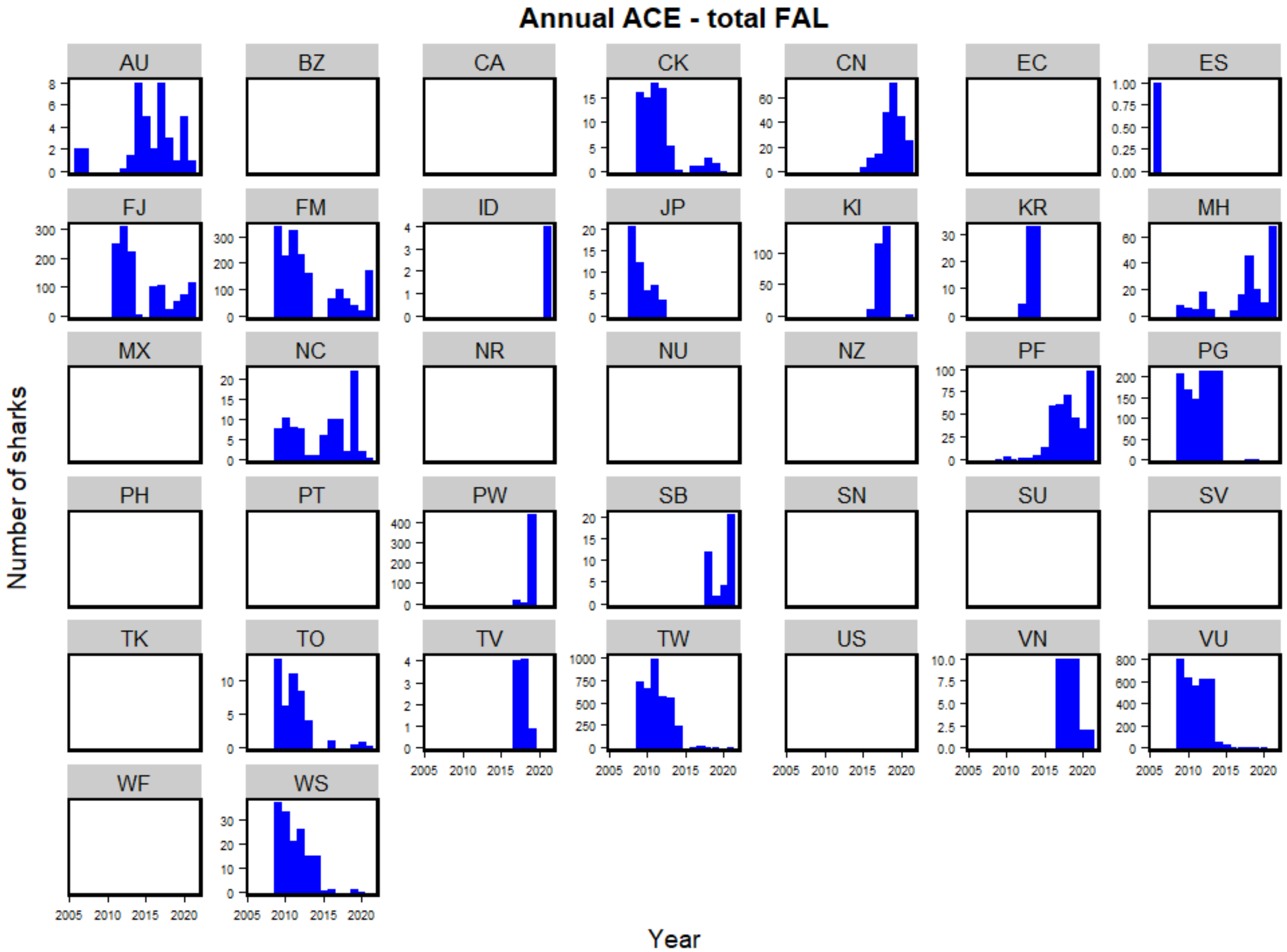


Figure 3: Longline silky shark annual catch estimates reported by flag states in WCPFC the WCPFC Convention area 2000 - 2022.

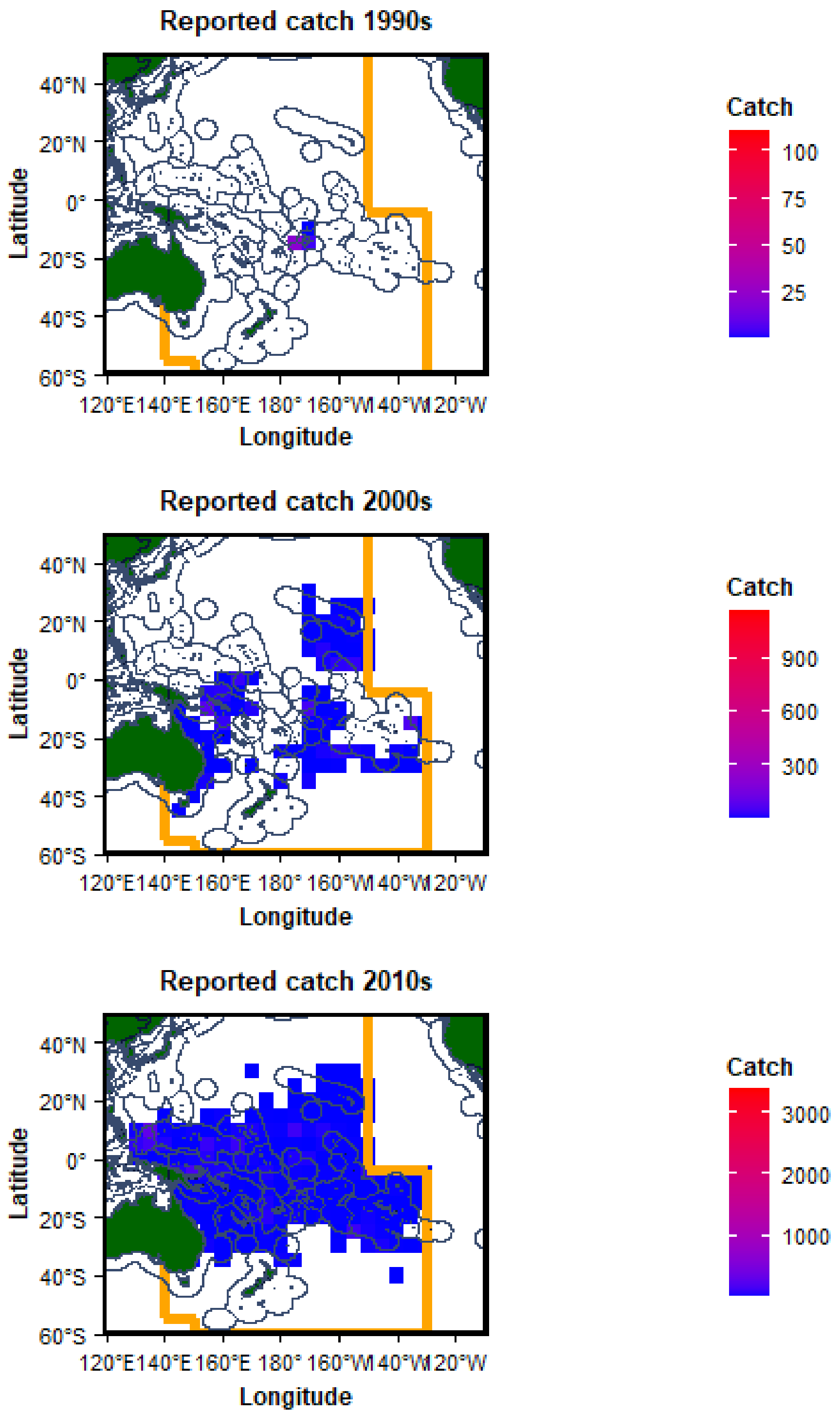


Figure 4: Reported logsheet catch by decade of silky sharks in the WCPFC from 1990-2021 aggregated to 1x1 degree squares across all fleets and months of the year.

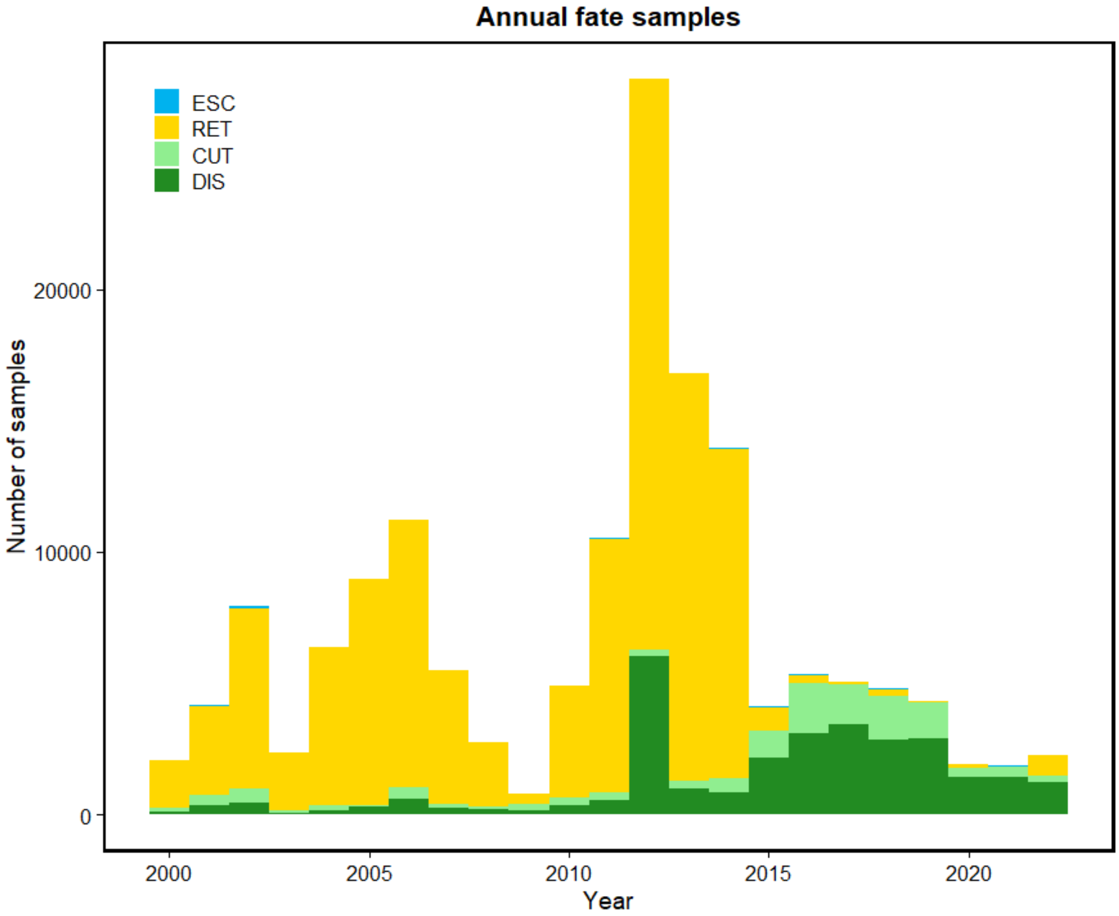


Figure 5: Fate of longline caught silky shark observed by flag 2000-2021. ESC = Escaped, RET = Retained, DIS = Discarded, CUT = Cut free.

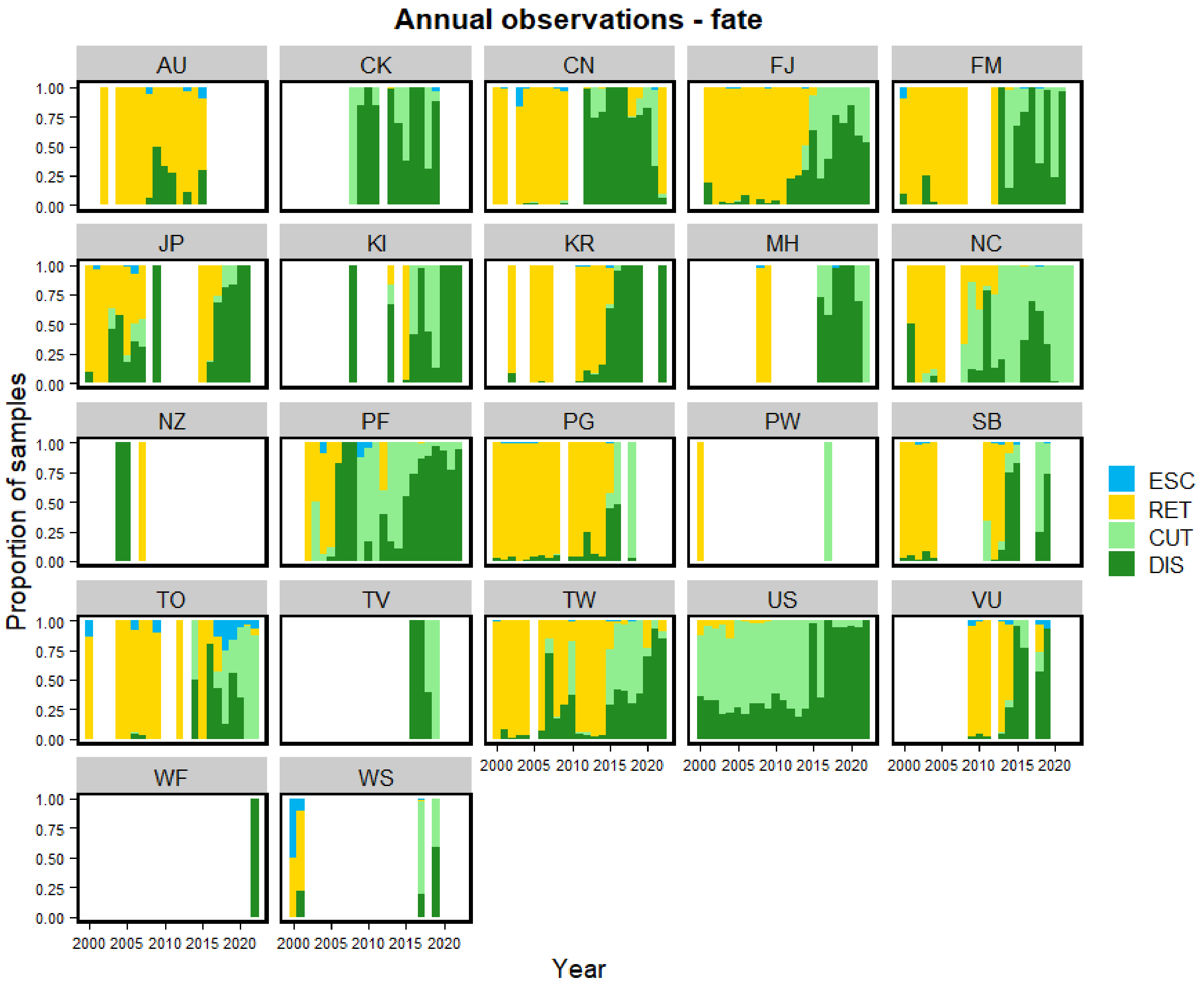


Figure 6: Fate proportions by flag of longline caught silky shark observed by flag 2000 - 2022. ESC = Escaped, RET = Retained, DIS = Discarded, CUT = Cut free.

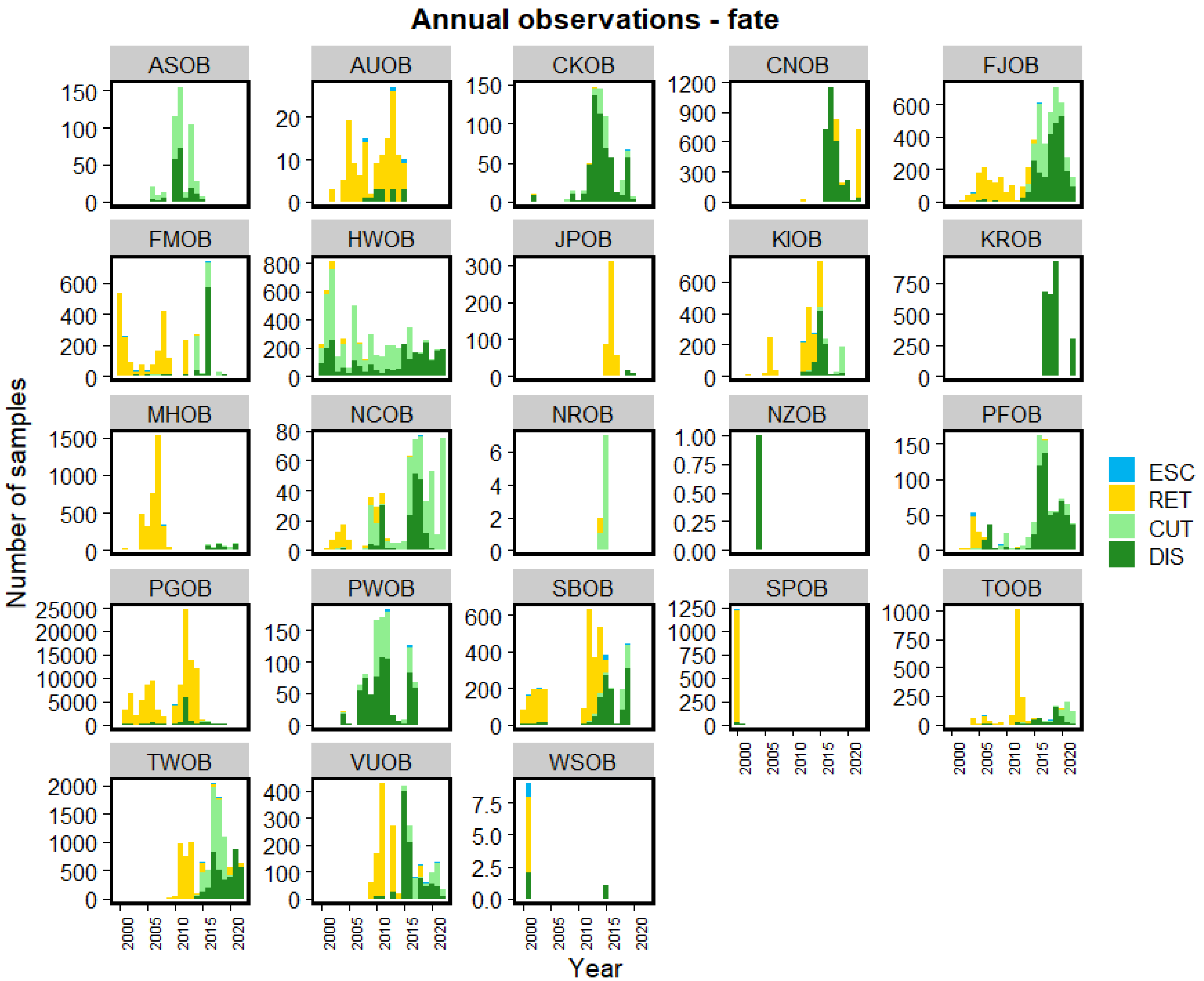


Figure 7: Fate totals by observer program of longline caught silky shark observed by flag 2000 - 2022. ESC = Escaped, RET = Retained, DIS = Discarded, CUT = Cut free.

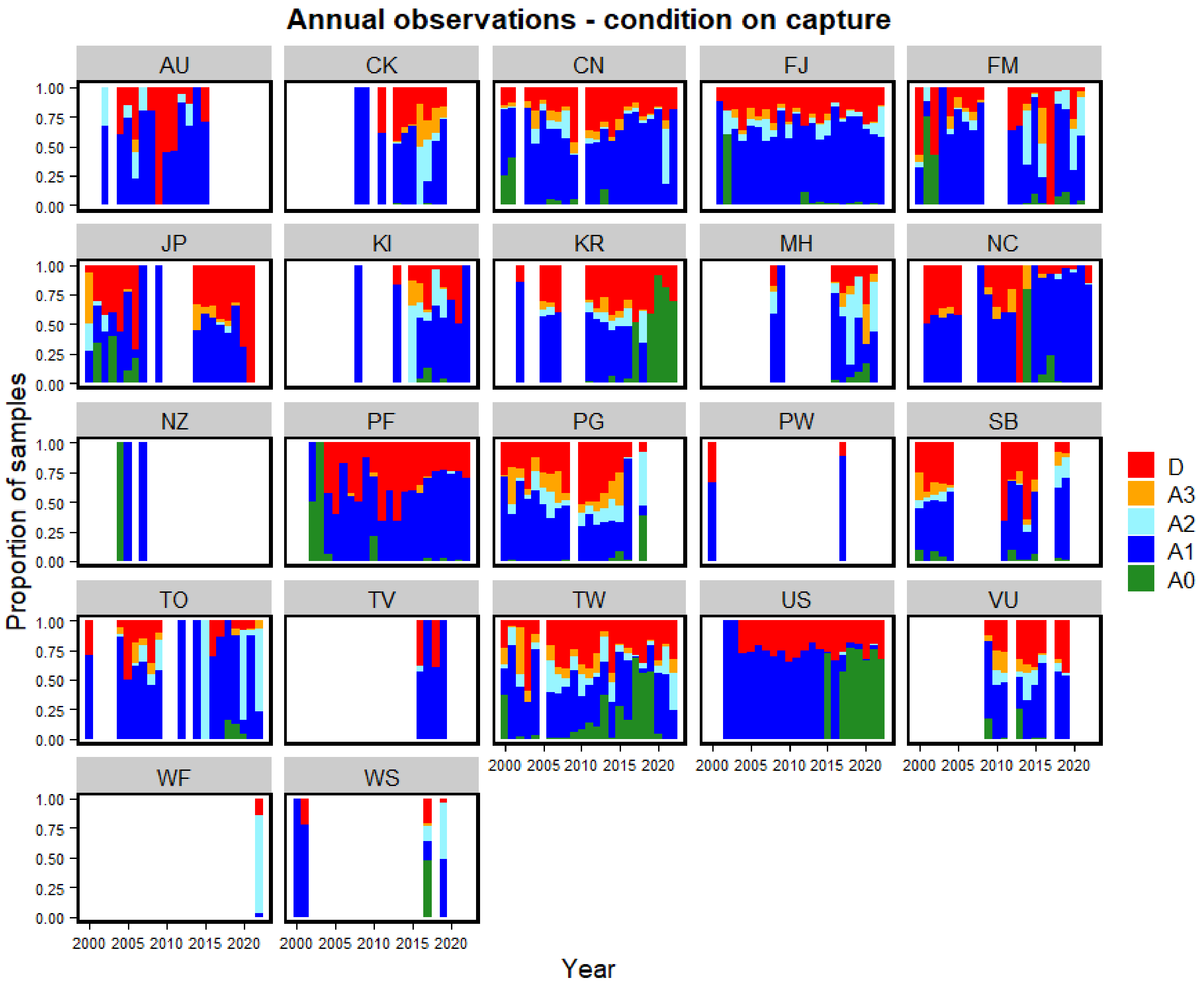


Figure 8: Condition at capture of longline caught silky shark observed by flag in the WCPFC between 2000 - 2022. D = Dead, A0 - A3 are various life states as defined in Table 2.

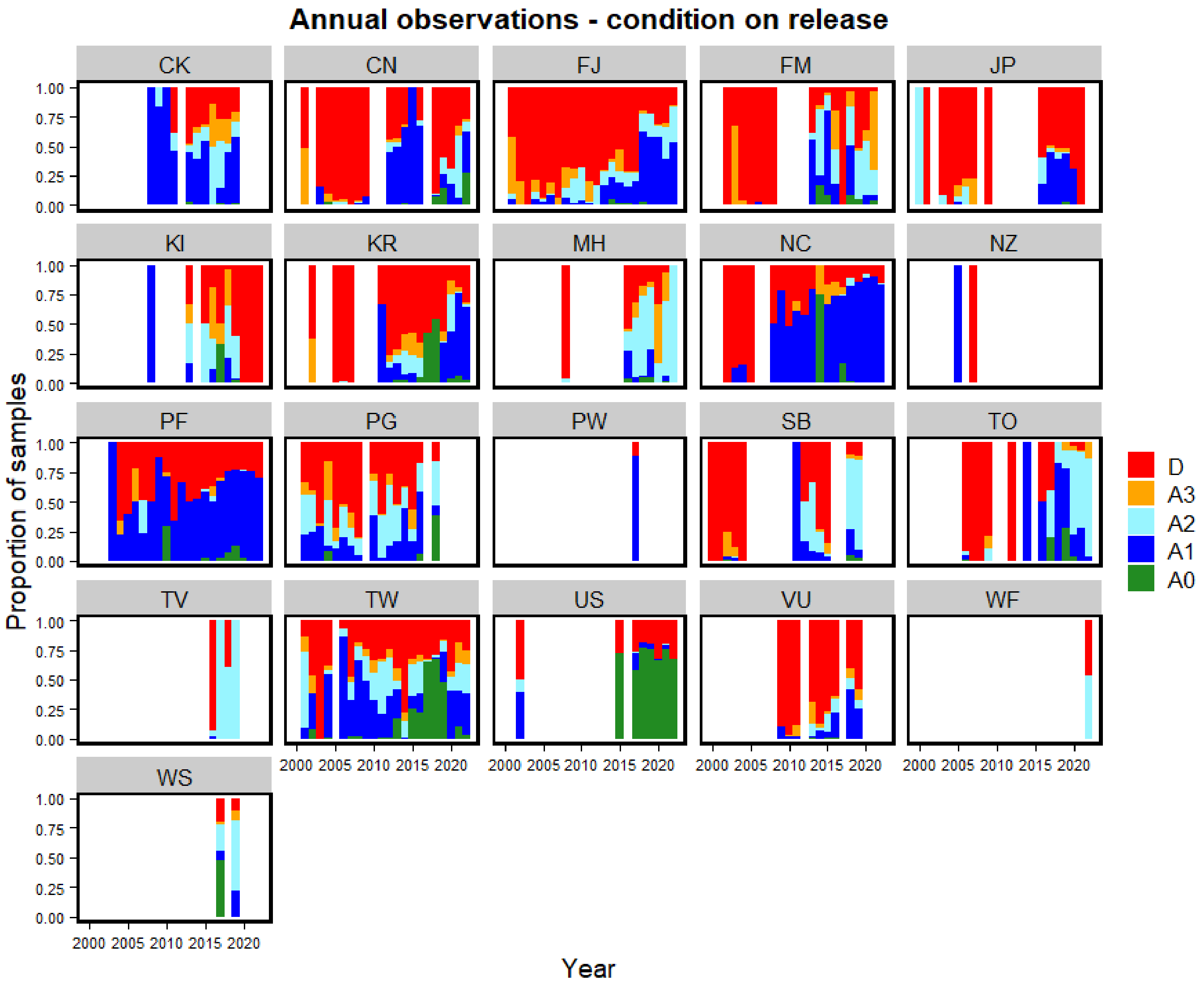


Figure 9: Condition at release of longline caught silky shark observed by flag in the WCPFC between 2000 - 2022. D = Dead, A0 - A3 are various life states as defined in Table 2.

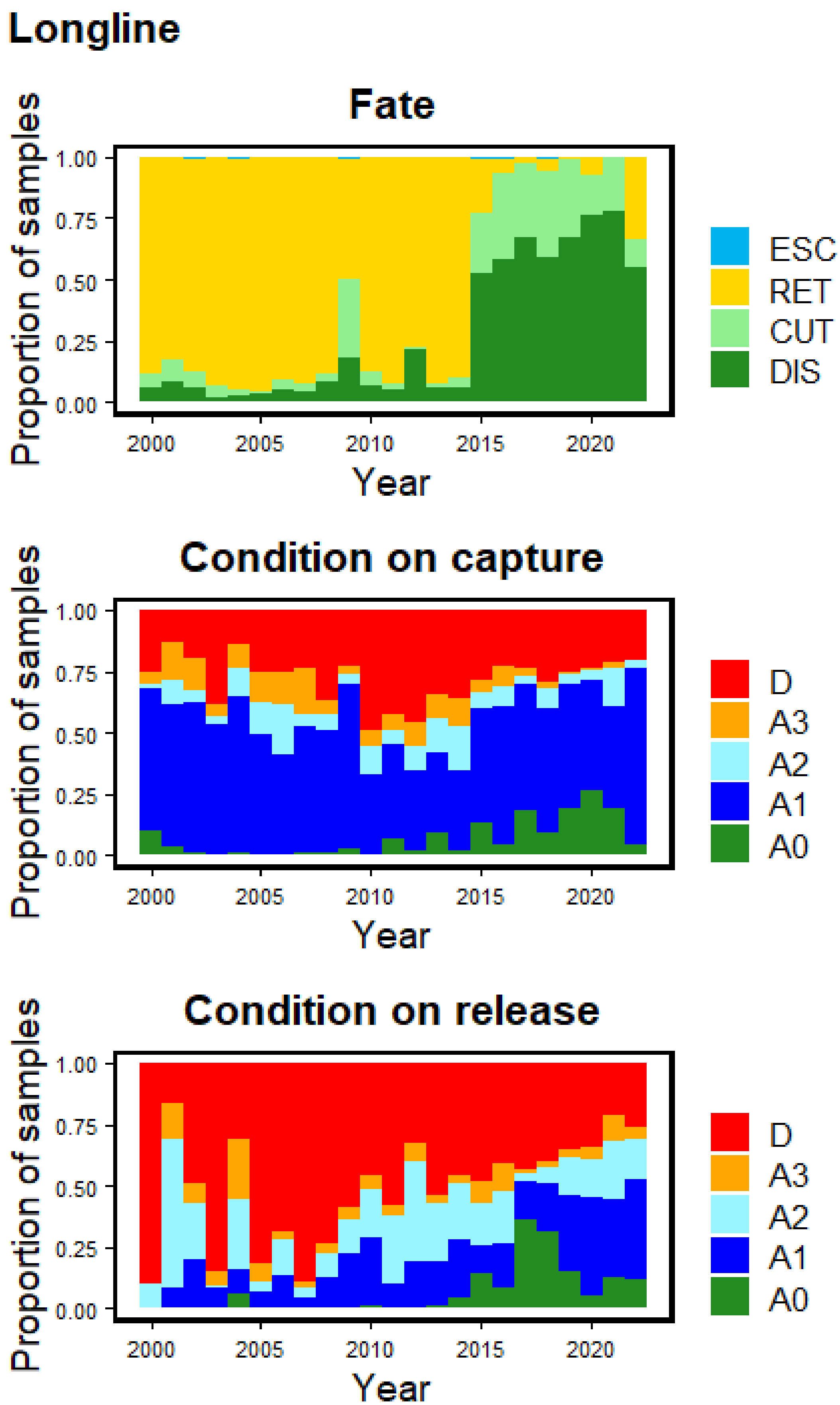


Figure 10: Fate of fish (top), condition at capture (middle) and release (bottom) of all longline caught silky shark observed in the WCPFC between 2000 - 2021. ESC = Escaped, RET = Retained, DIS = Discarded, CUT = Cut free, D = Dead, A0 - A3 are various life states as defined in Table 2.

Purse seine

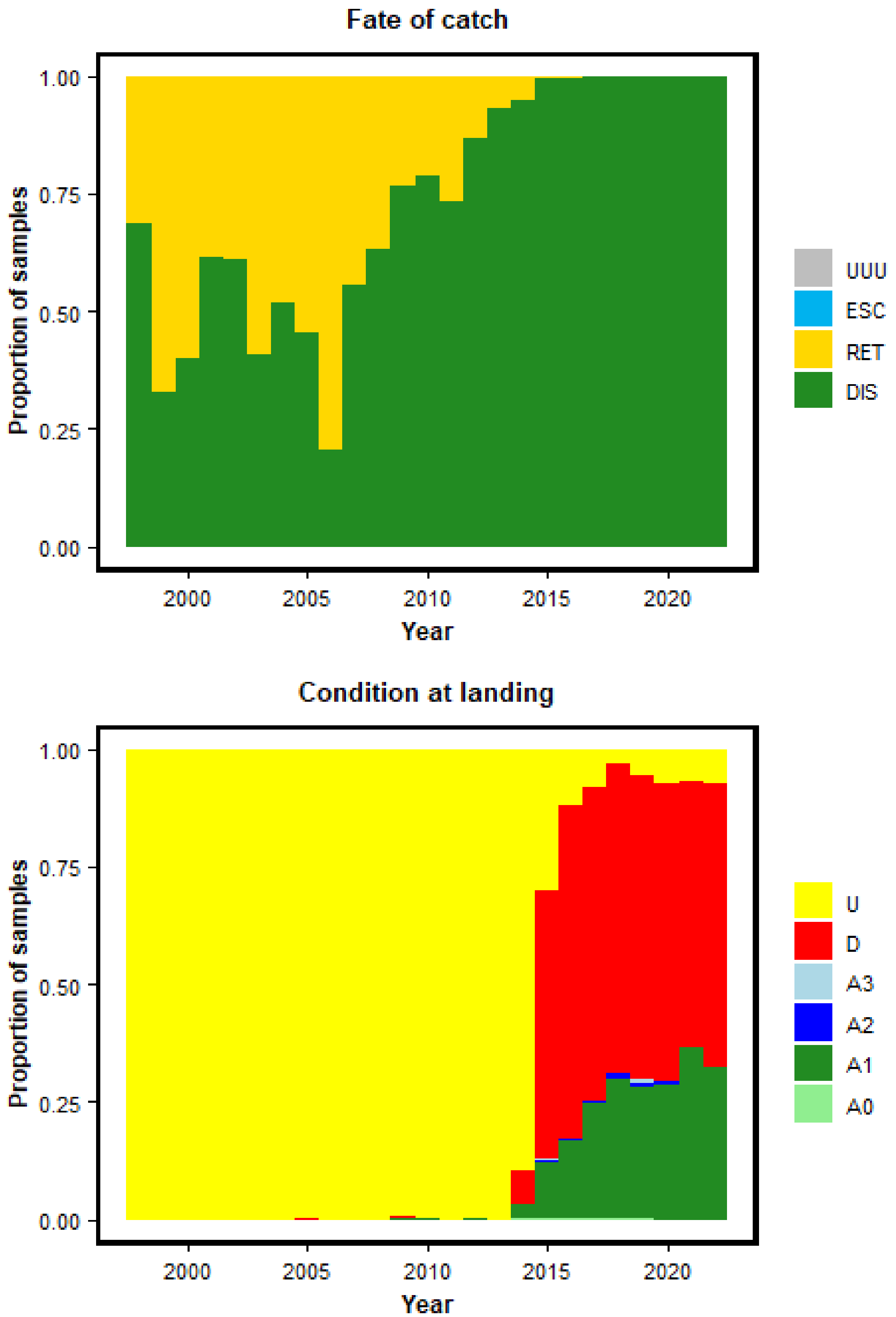


Figure 11: Fate of fish (top), condition at capture (bottom) of all purse seine caught silky shark observed in the WCPFC between 1998 - 2022. ESC = Escaped, RET = Retained, DIS = Discarded, UUU = unknown, D = Dead, A0 - A3 are various life states as defined in Table 2 and U = unknown.

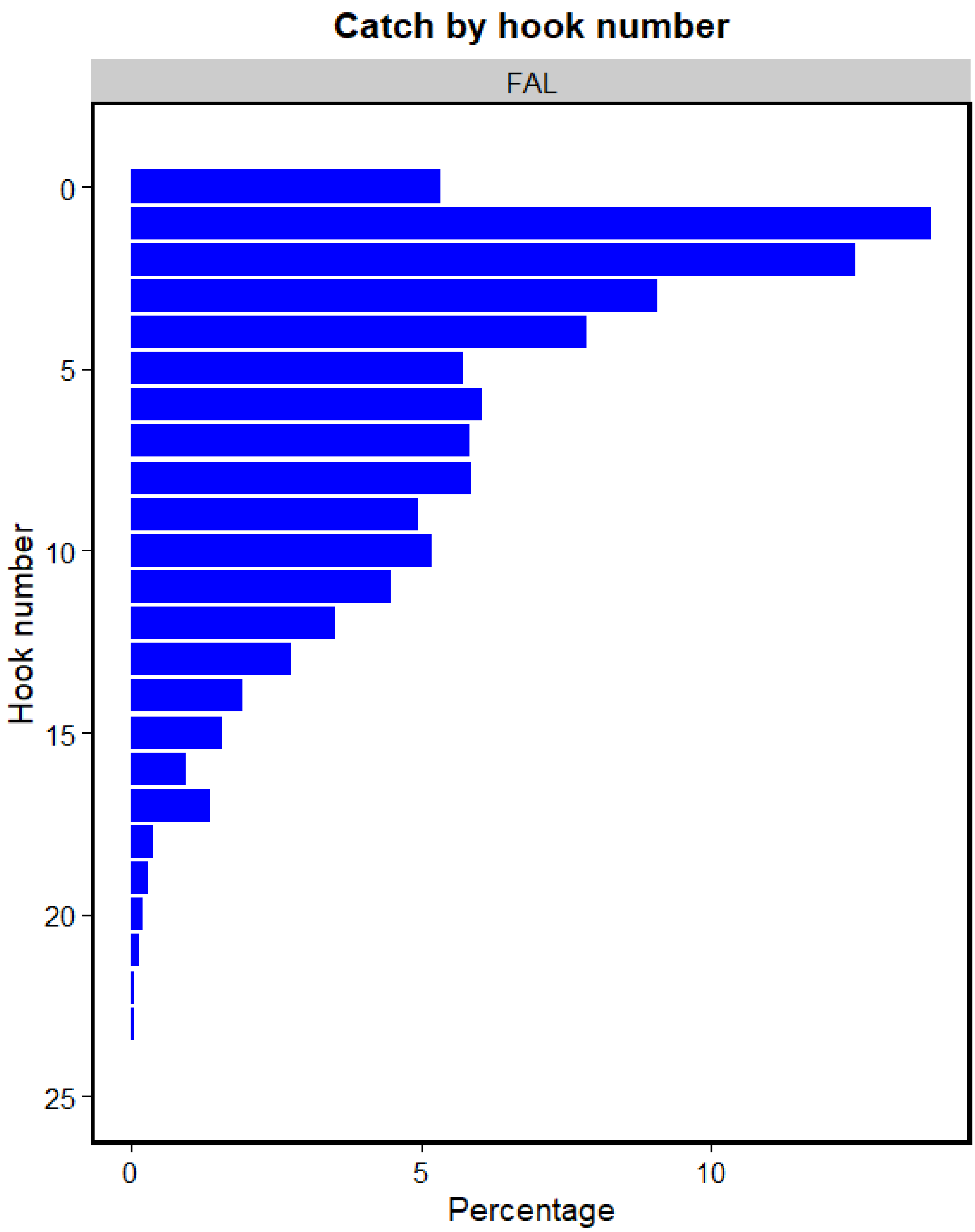


Figure 12: Catch of silky shark by hook number relative to the closest float observed in the WCPFC between 2000 - 2022. Hooks were numbered from 1 to the middle of the basket and then back to 1 hook number 0 refers to fish caught on shark lines that are attached to the float.

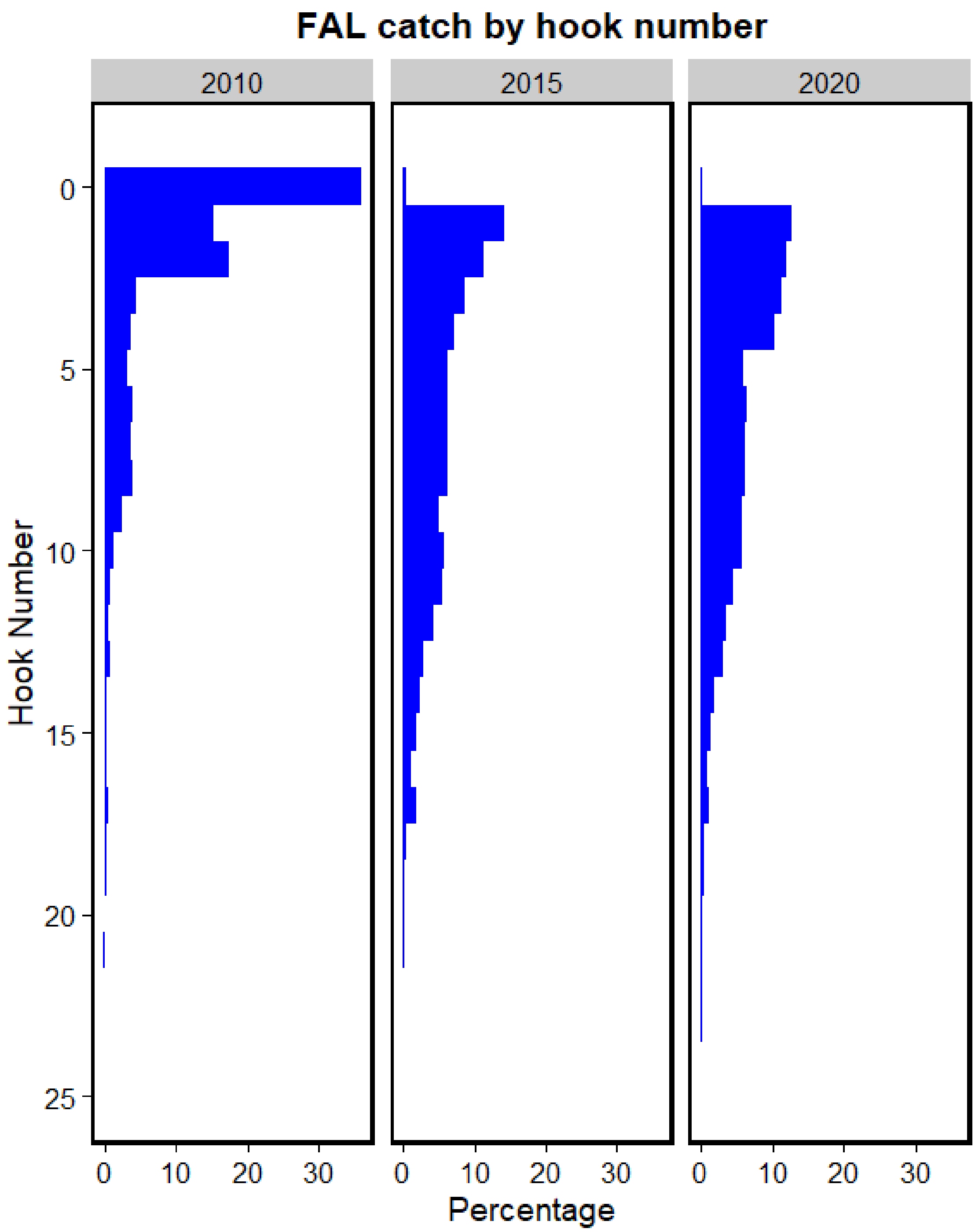


Figure 13: Catch of silky shark by hook number relative to the closest float observed in the WCPFC between 2000 - 2022 separated by decade. Hooks were numbered from 1 to the middle of the basket and then back to 1 hook number 0 refers to fish caught on shark lines that are attached to the float.

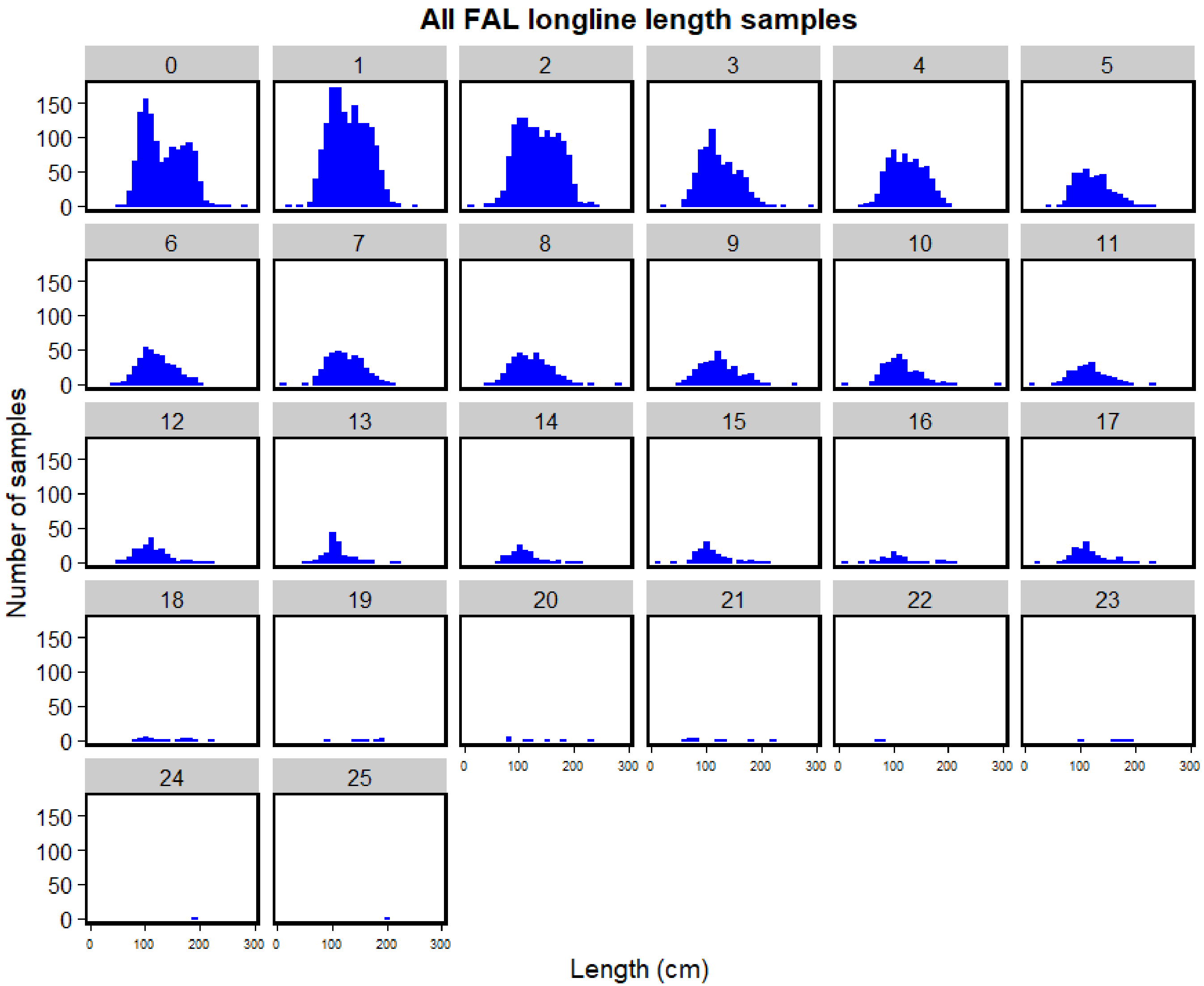


Figure 14: Length frequency distributions, for fish measures to UF only, of silky sharks observed in the WCPFC between 2000 - 2022 caught by hook number.

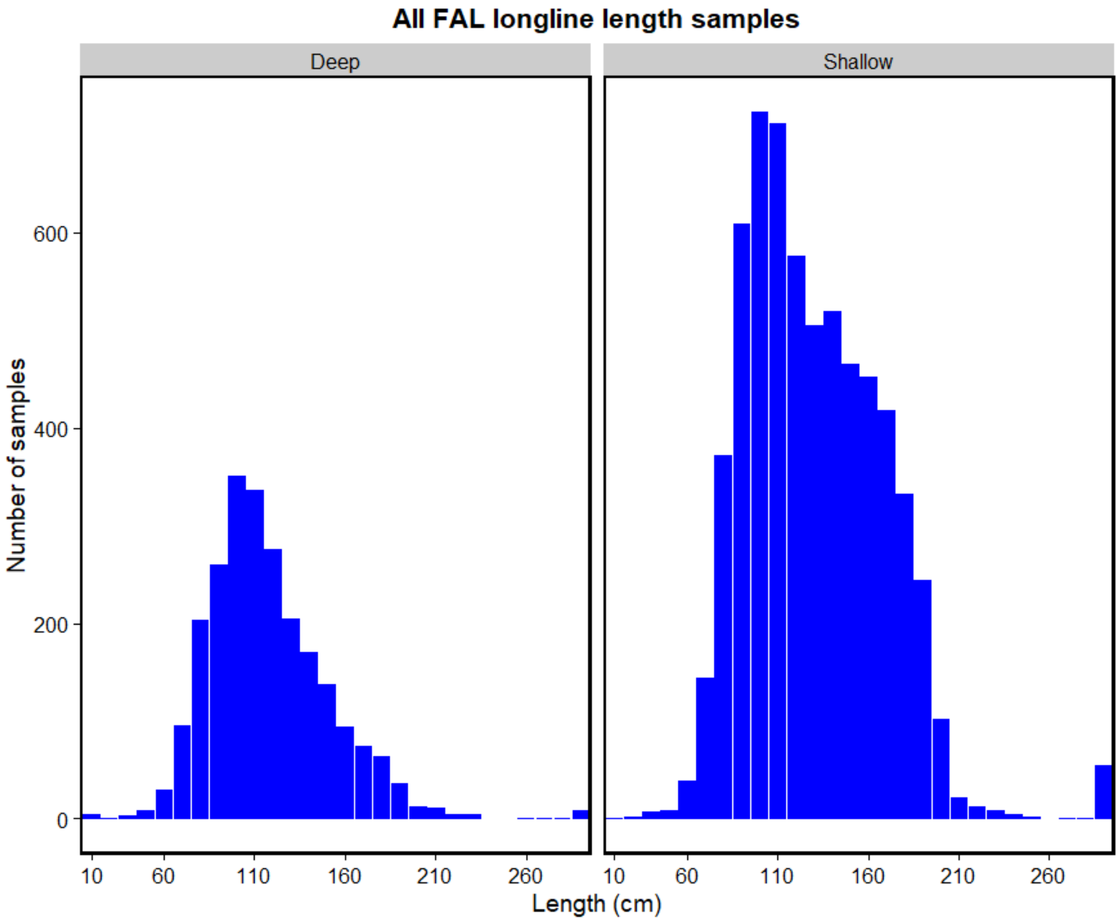


Figure 15: Length frequency distributions, for fish measures to UF only, of silky sharks observed in the WCPFC between 2000 - 2021 caught by depth group where shallow hooks are hook numbers 6 or less and deep are hook numbers 7 and higher.

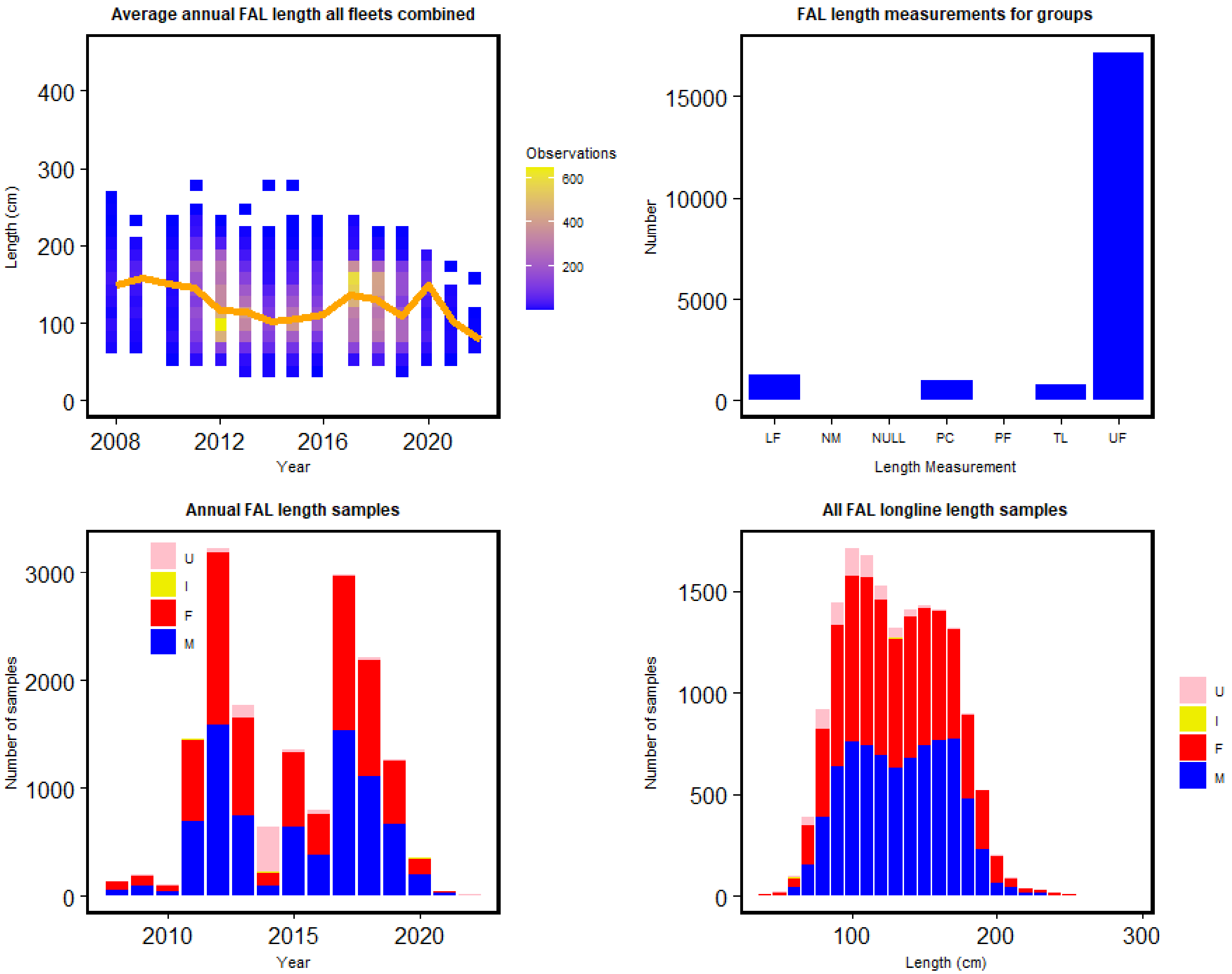


Figure 16: Length data availability of silky sharks observed in the WCPFC between 1990-2021, showing the average annual length (top left), the units of length measurements (top right), the number of samples collected by sex (bottom left) and the overall length frequency (bottom right). UL = Upper-jaw fork length; TL = Total Length; PC = Pre-caudal length; U = Sex unknown; I = Immature; F = Female; and M = Male.

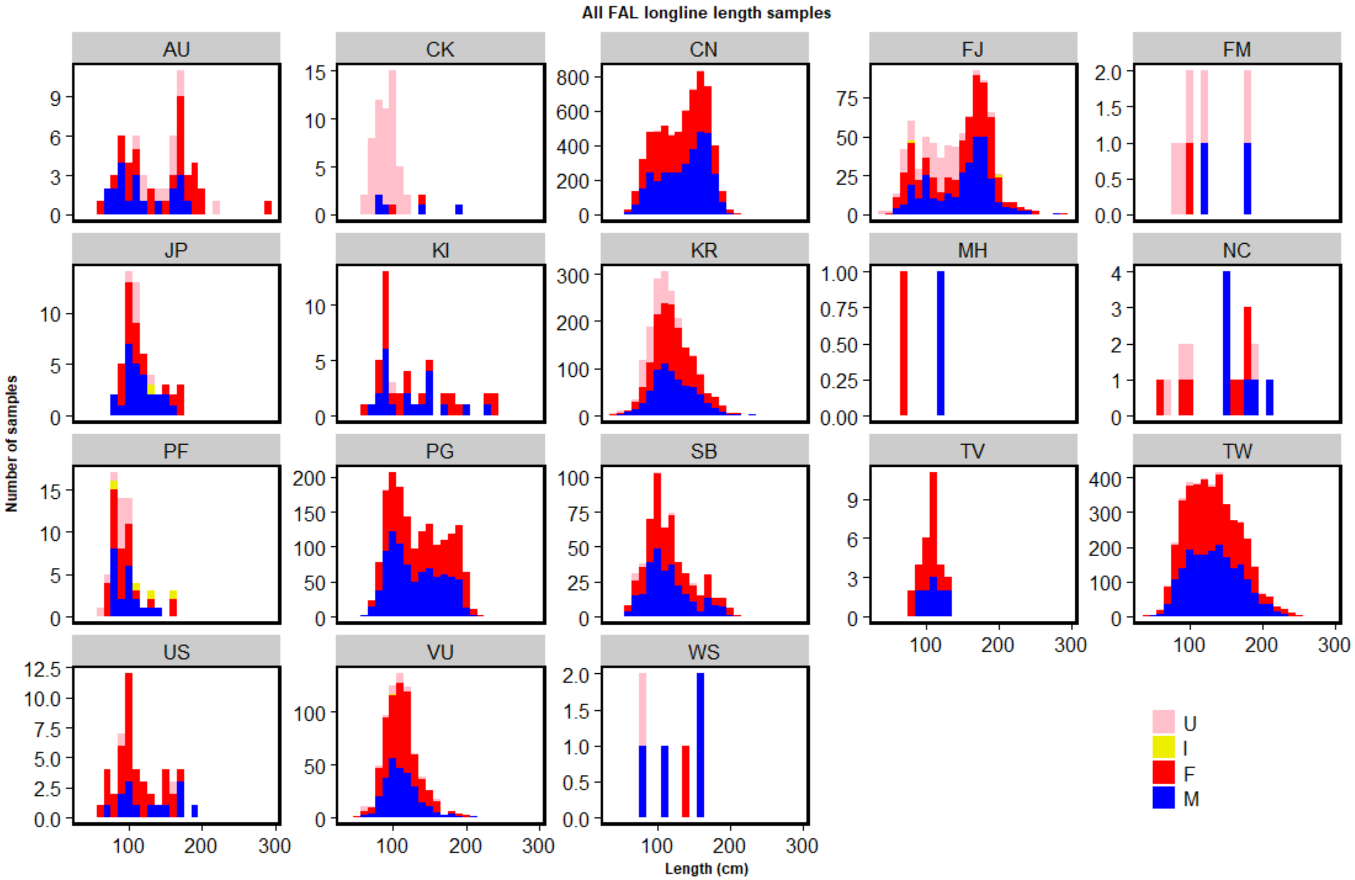


Figure 17: Length frequency distributions, of silky sharks observed in the WCPFC between 1990-2021 by flag. U = Sex unknown, I = Immature, F = Female and M = Male. Note: the y-axis scales are not the same between plots.

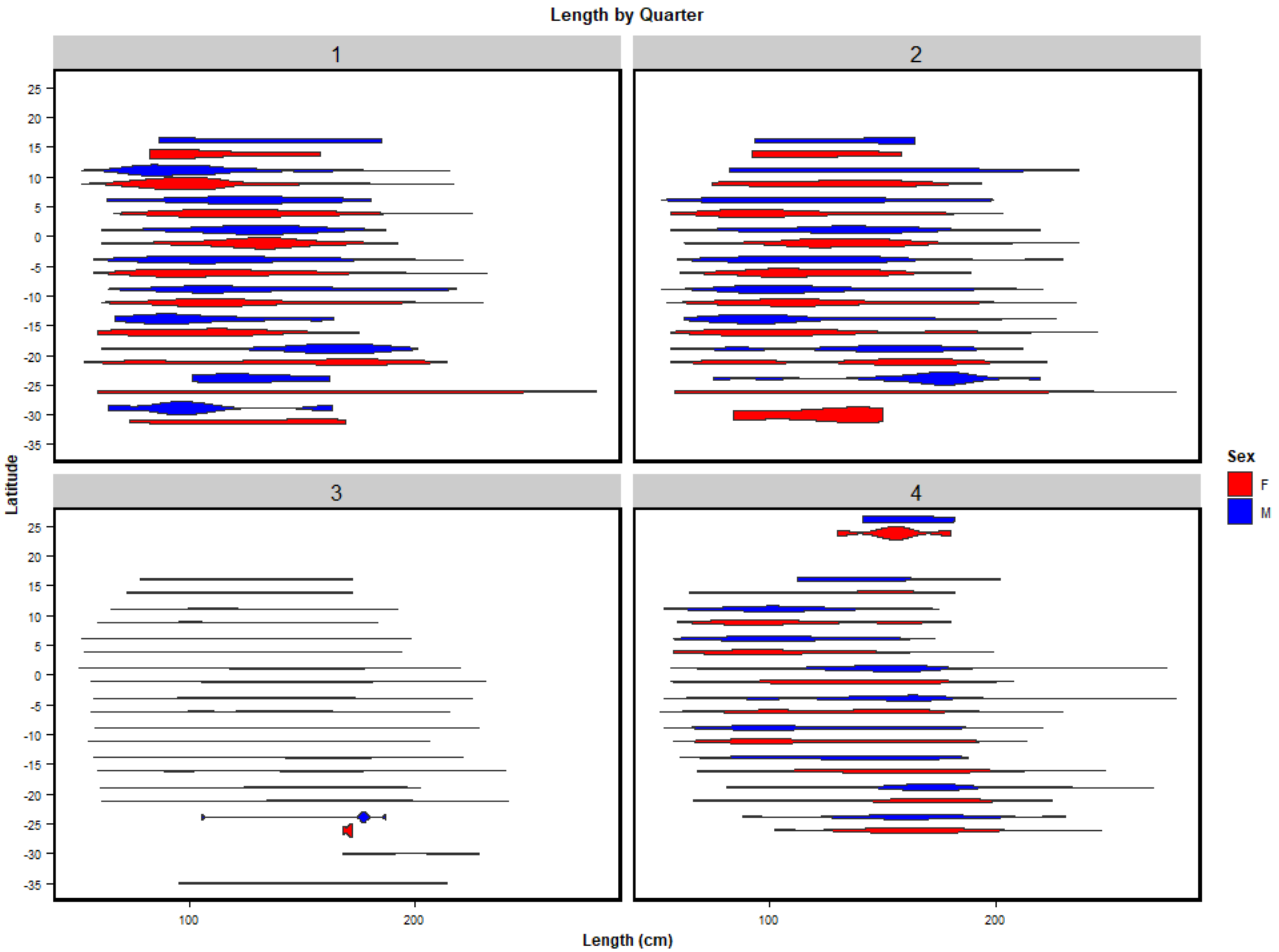


Figure 18: Length distribution by latitude, year quarter and sex, of silky sharks observed in the WCPFC between 2000-2021. n = the total number of samples (male and female combined) by latitude group.

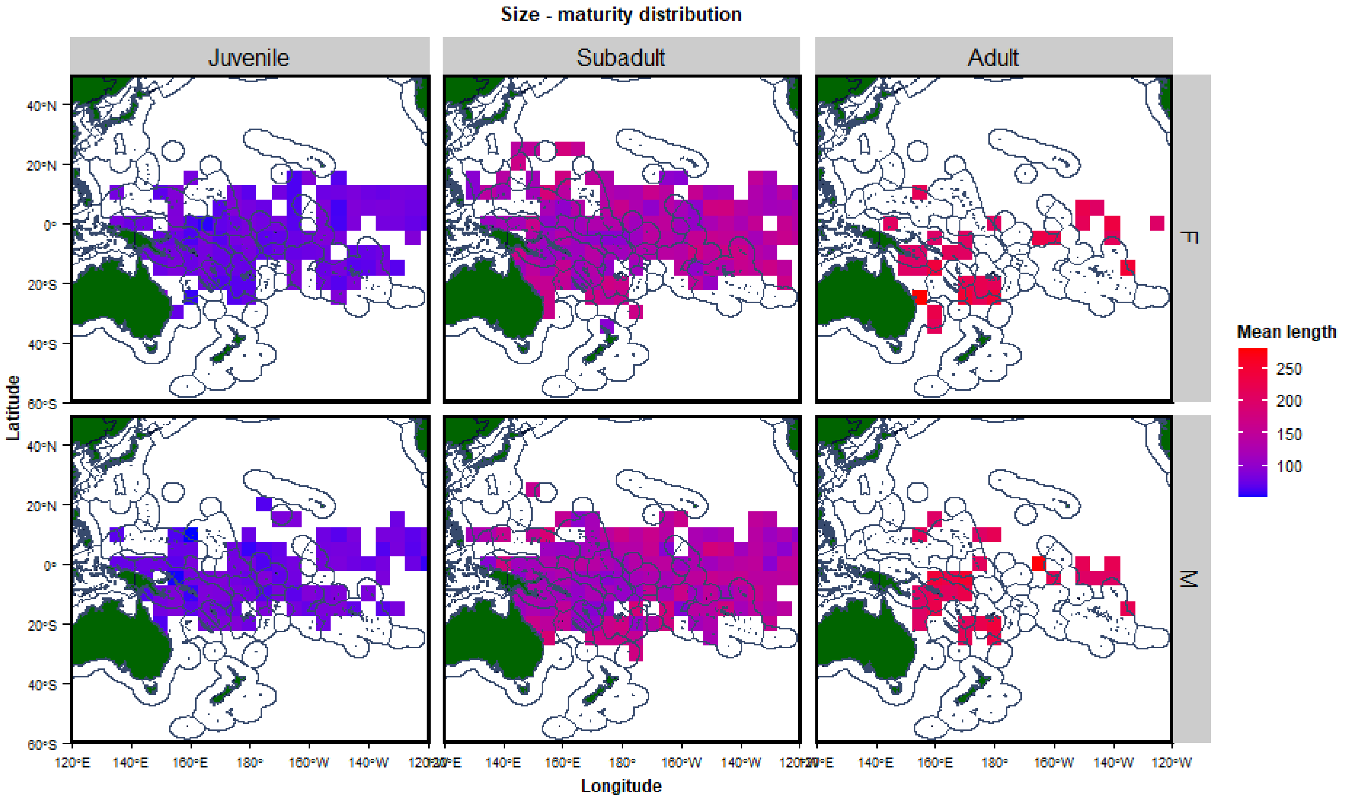


Figure 19: Length distribution by maturity, of silky sharks observed in the WCPFC between 2000-2021. Density = the total number of samples (male and female combined) by latitude group.

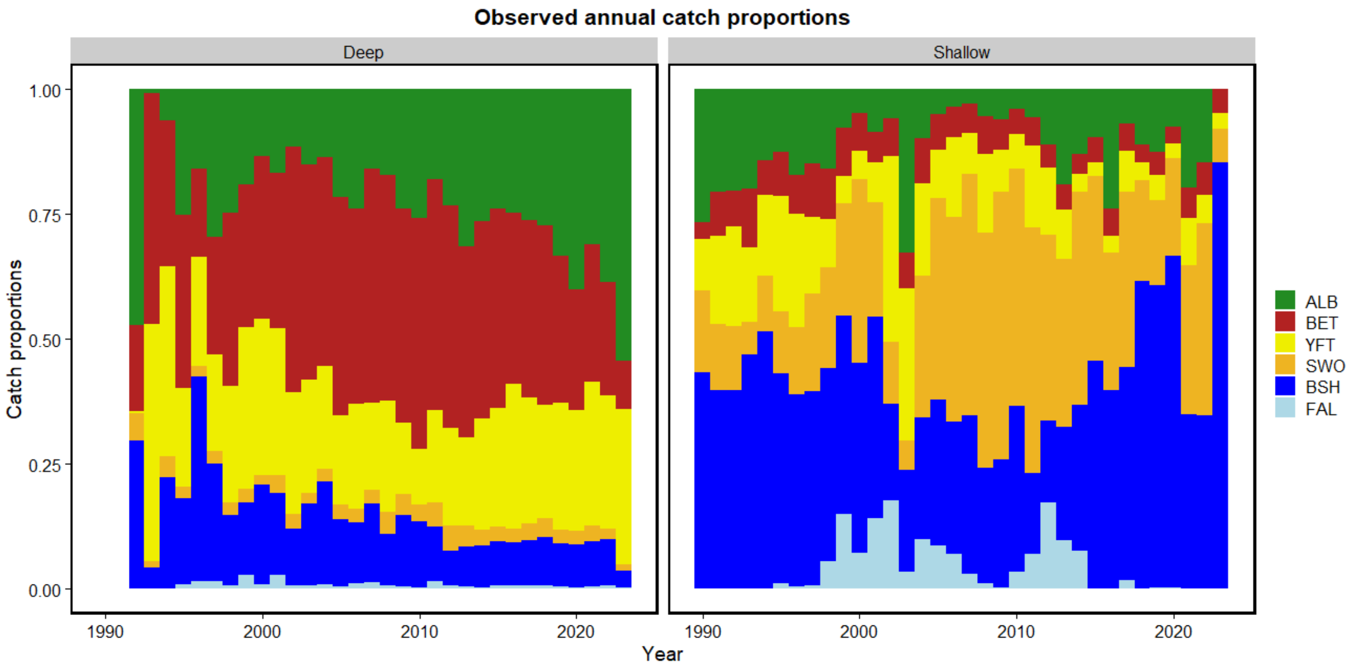


Figure 20: Species proportions of tuna swordfish and silky sharks observed in the WCPFC between 2000 - 2022 and separated into deep (left) and shallow (right) sets.

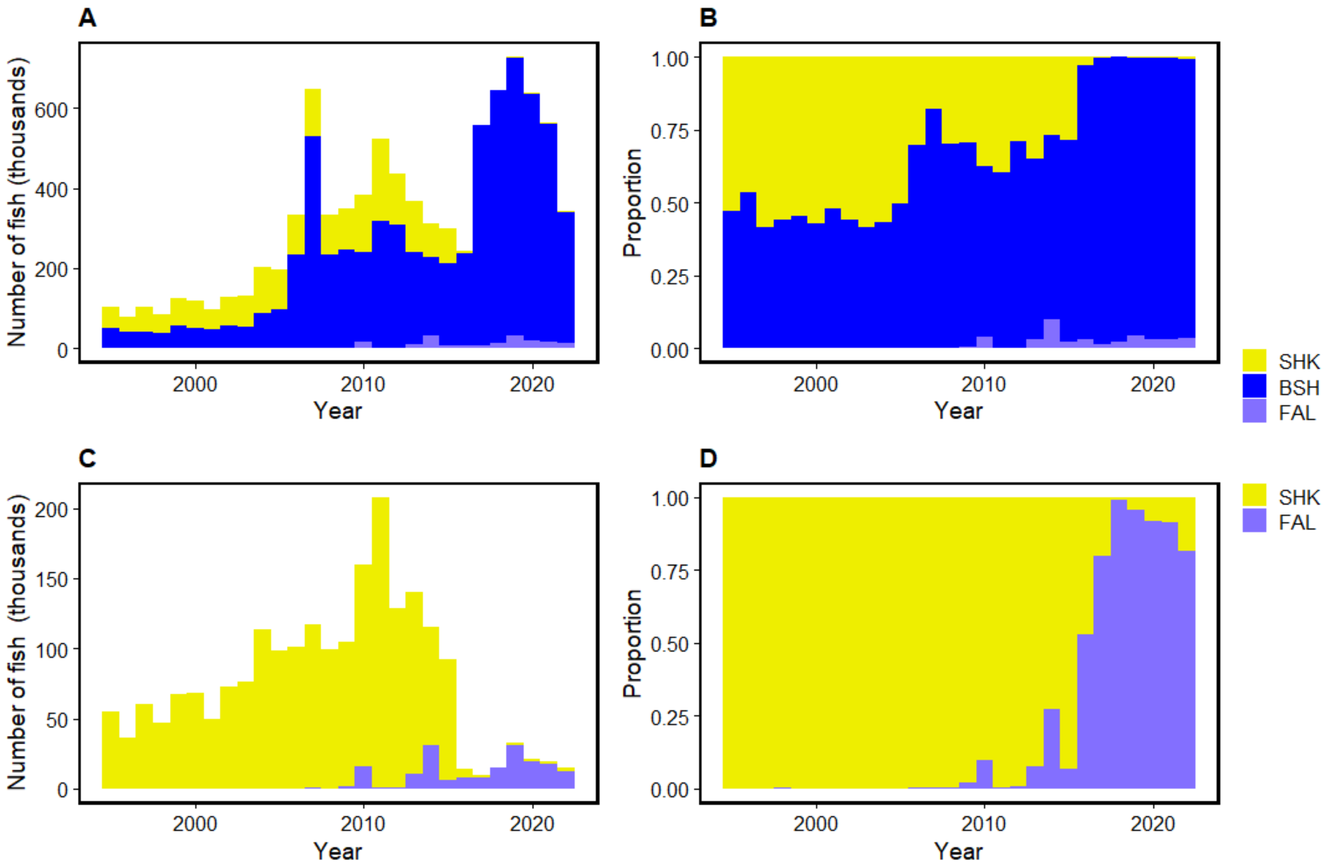


Figure 21: Species proportions of sharks observed in the WCPFC between 1990 - 2022 and separated into all sharks (A) proportion of all sharks (B) the number of silky sharks (C) and the proportion of silky sharks (D). SHK = generic shark code; BSH = blue shark; FAL = silky shark.

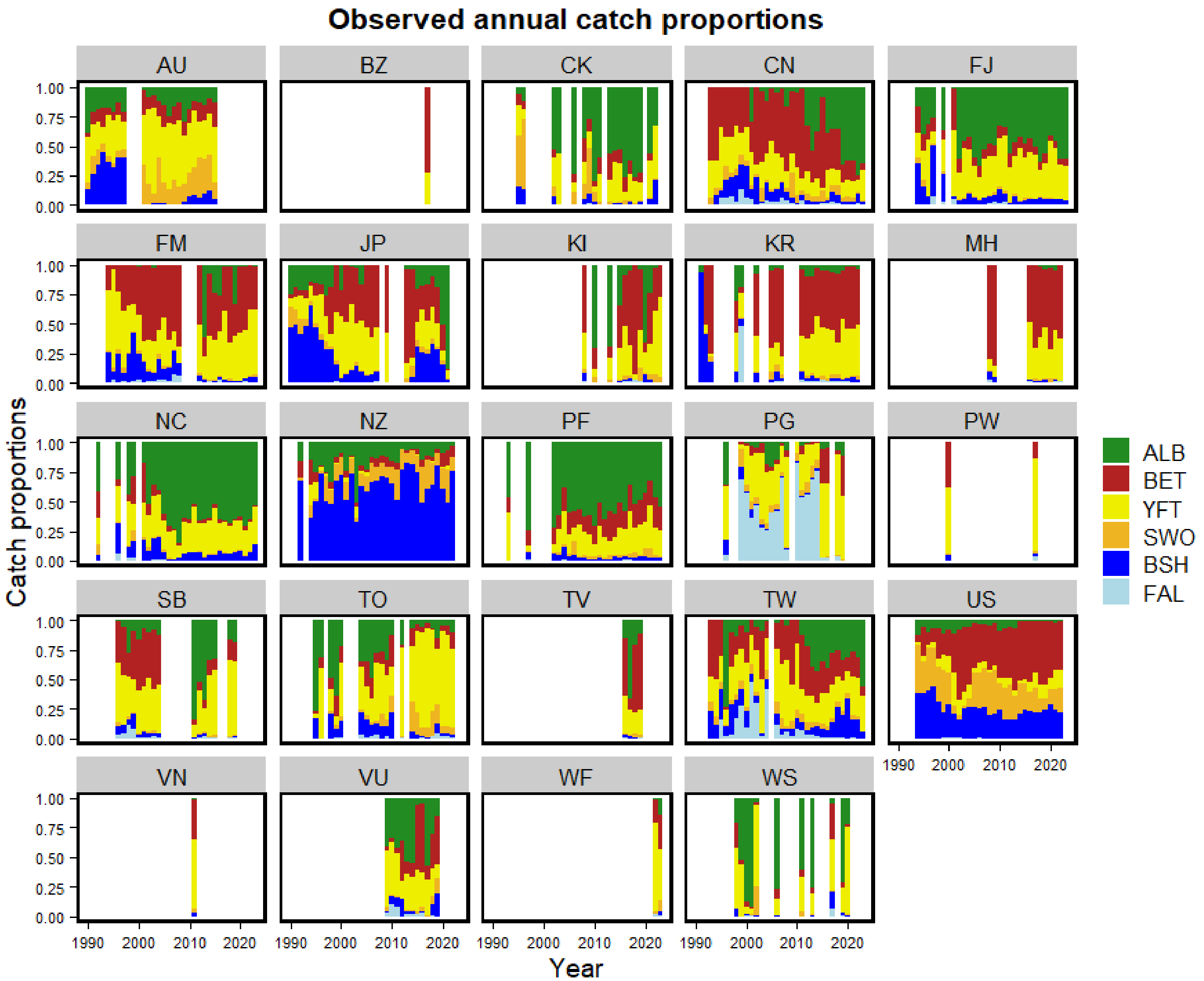


Figure 22: Species proportions of tuna, swordfish and silky sharks observed in the WCPFC between 2000 - 2022 and separated by flag.

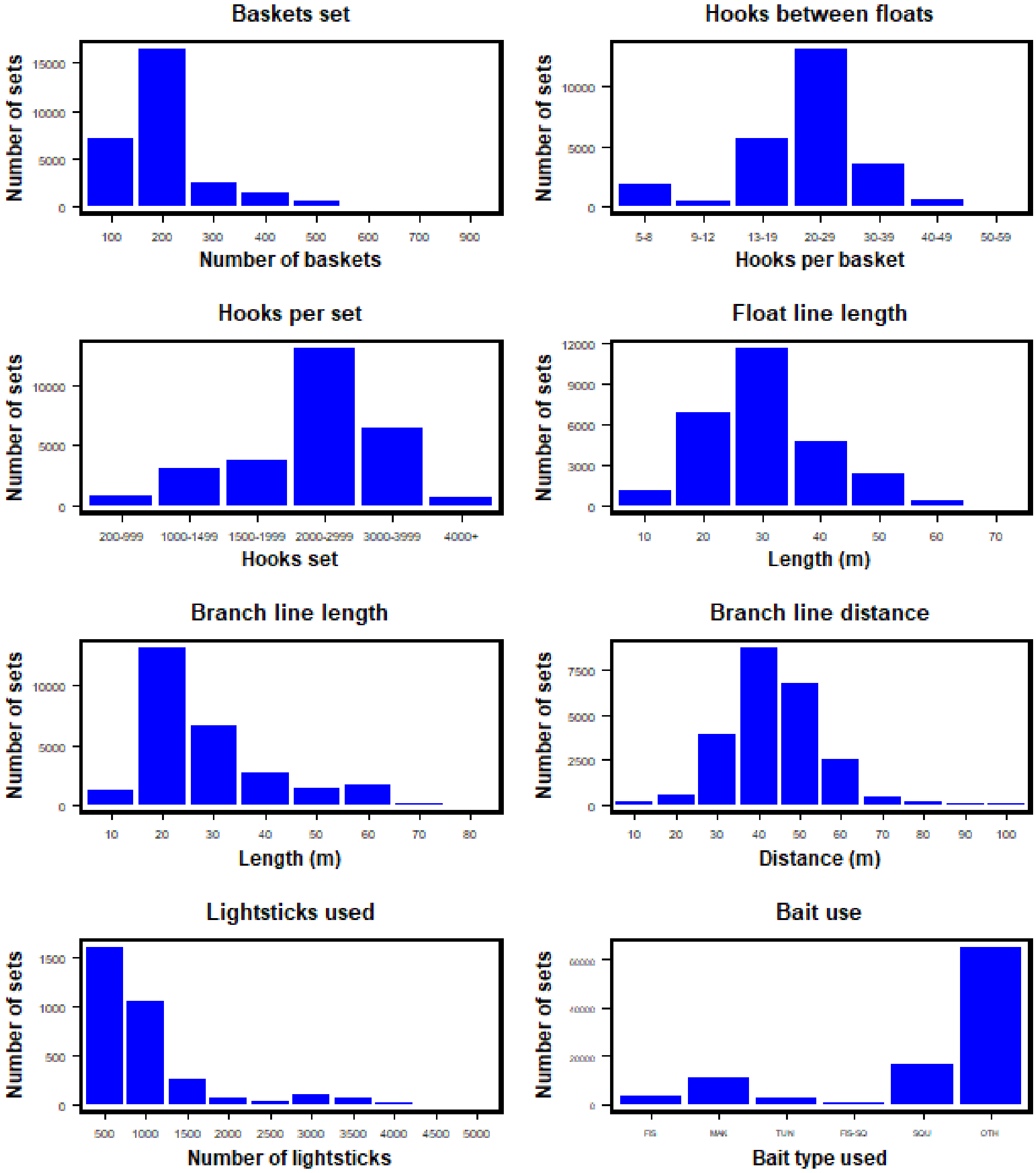


Figure 23: The observed baskets set, hook between floats,hooks set, float line length, branch line length, branch line distance, number of lightsticks used and reported bait use in sets made in the WCPFC between 1990 - 2022 from all fleets.

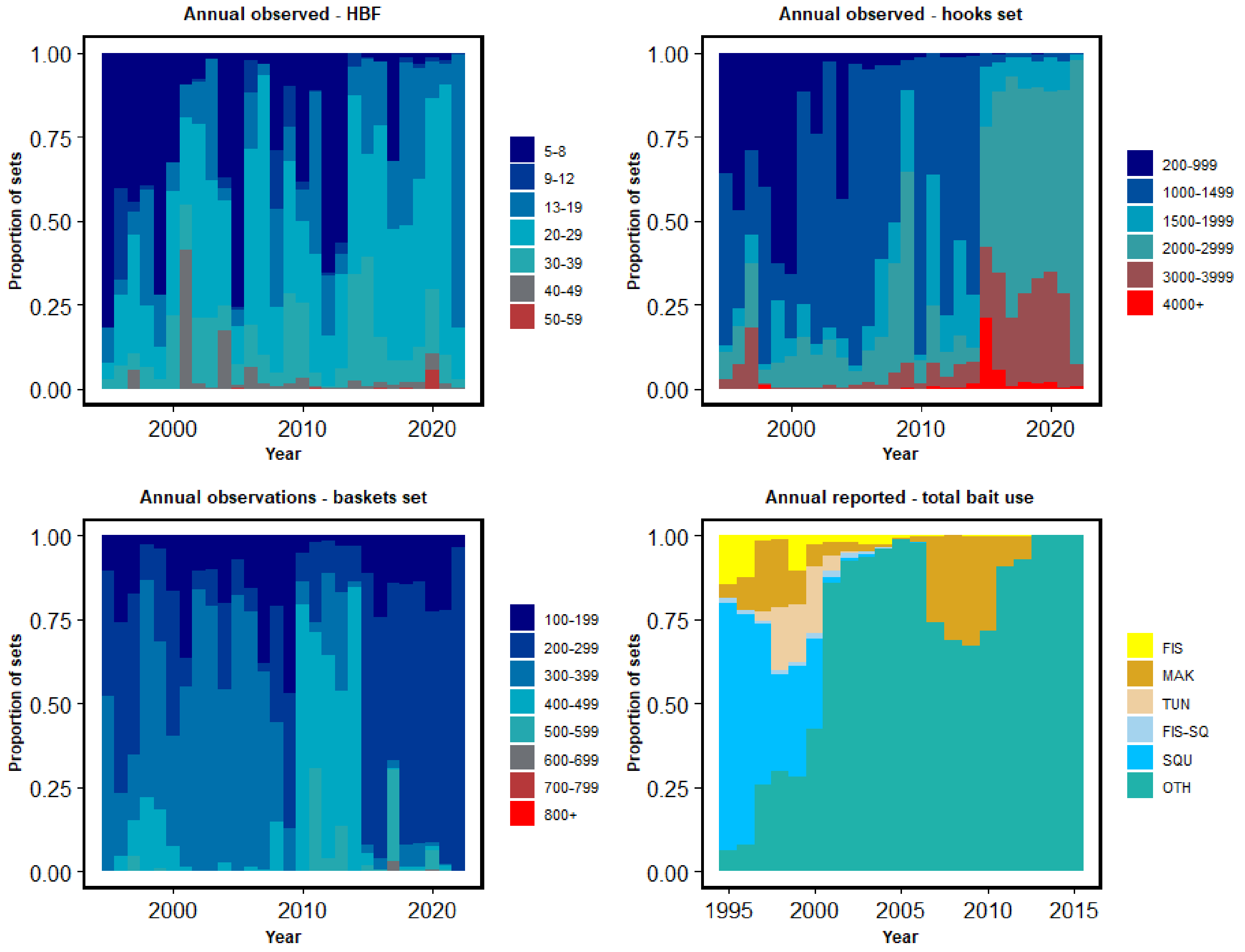


Figure 24: Observed hook between floats (HBF), hooks set, baskets set and reported bait use in sets made in the WCPFC between 1990 - 2022 from all fleets.

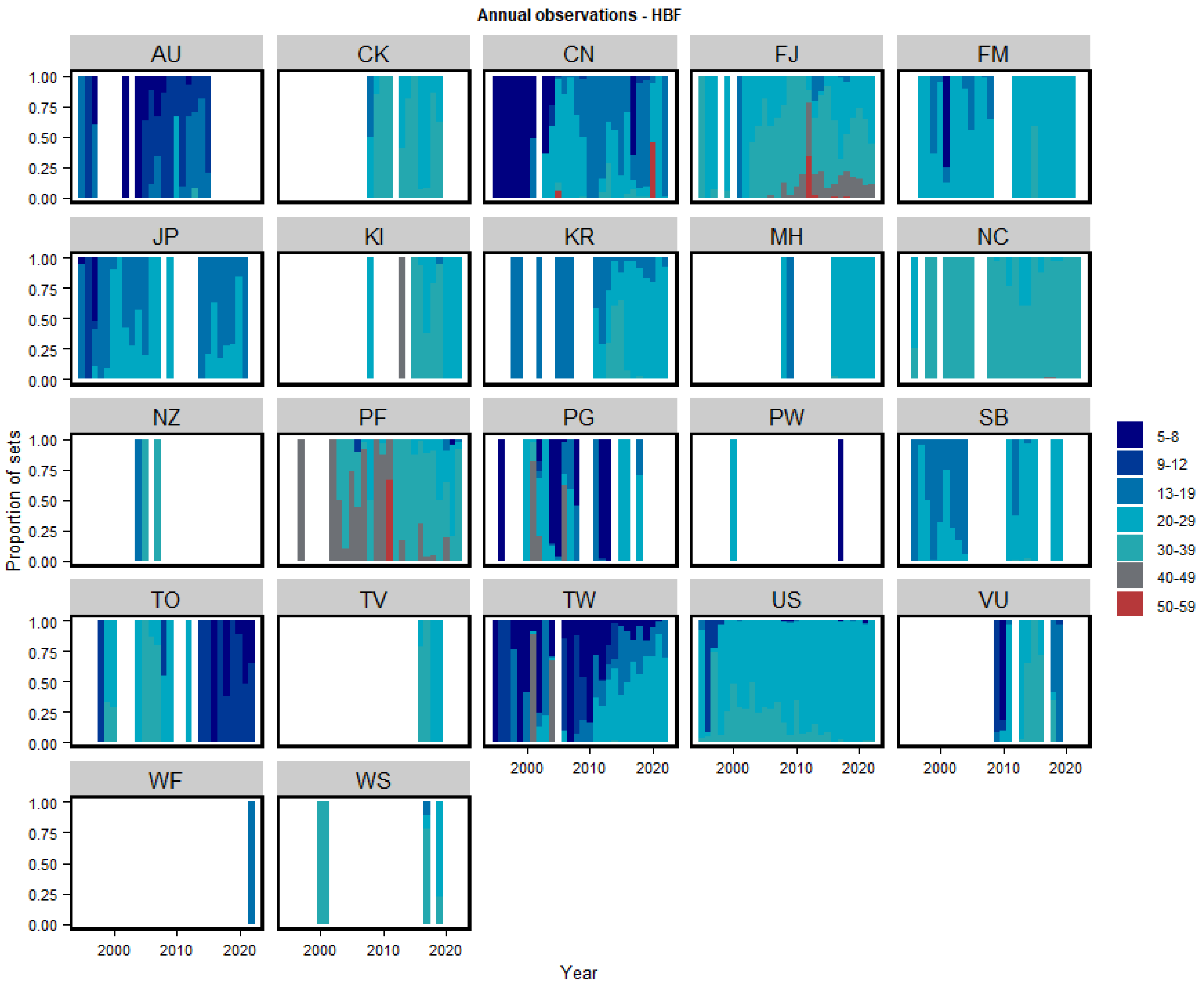


Figure 25: Observed hook between floats (HBF), by flag in the WCPFC between 1990-2022.

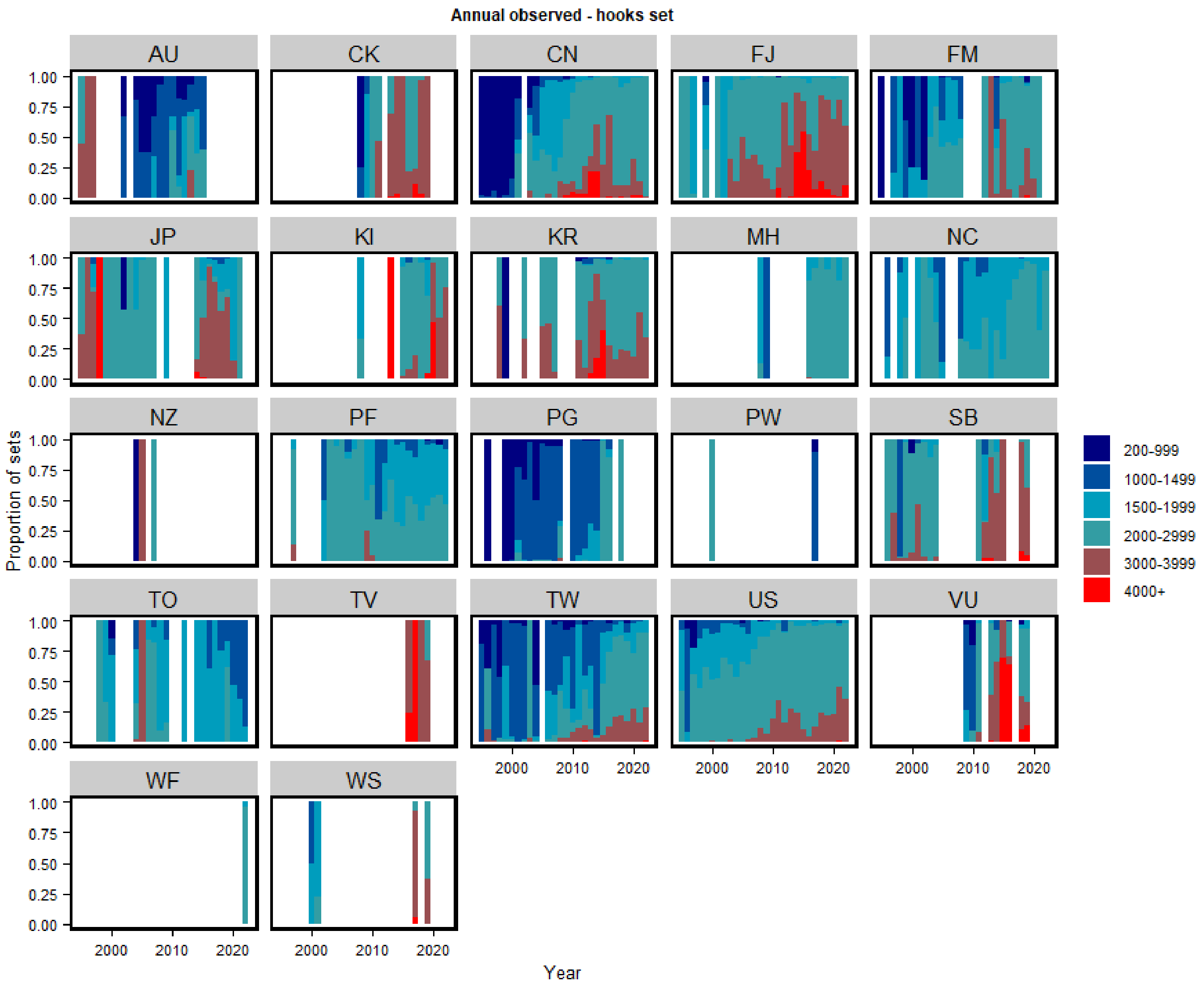


Figure 26: Observed hooks set on longline sets, by flag in the WCPFC between 1990 - 2022.

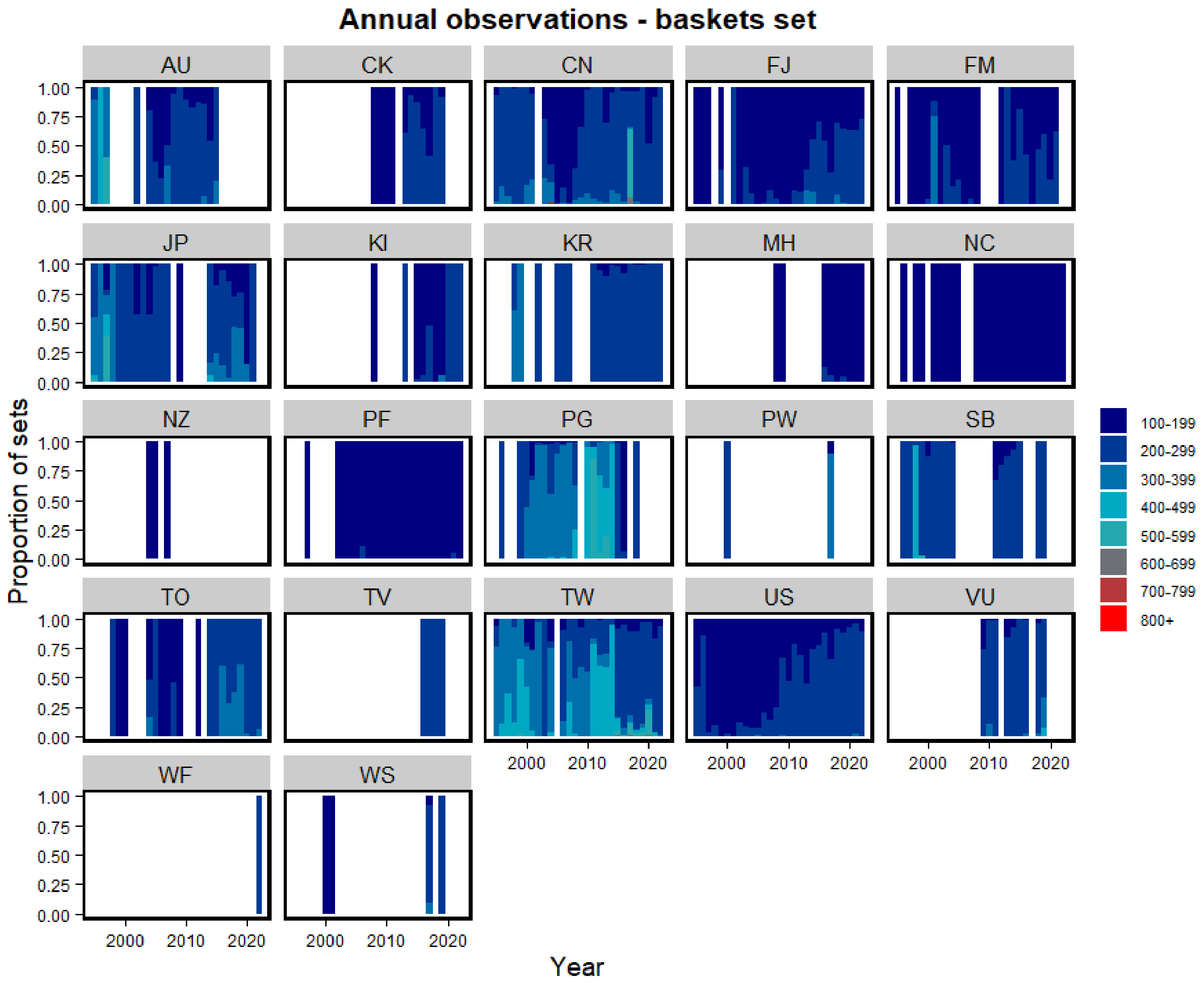


Figure 27: Observed baskets set on longline sets, by flag in the WCPFC between 1990 - 2022.

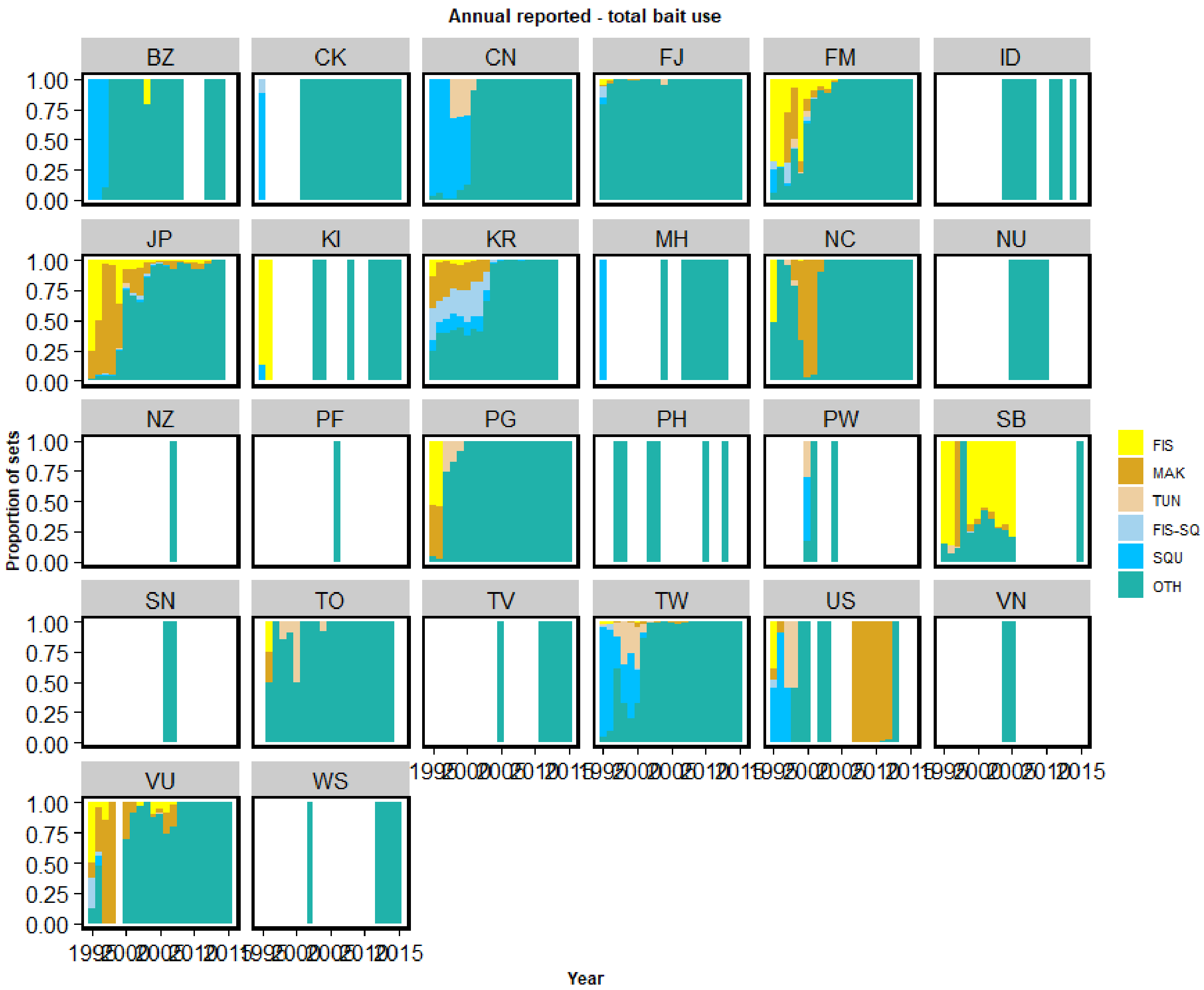


Figure 28: Reported bait use set on longline sets, by flag in the WCPFC between 1990 - 2022.

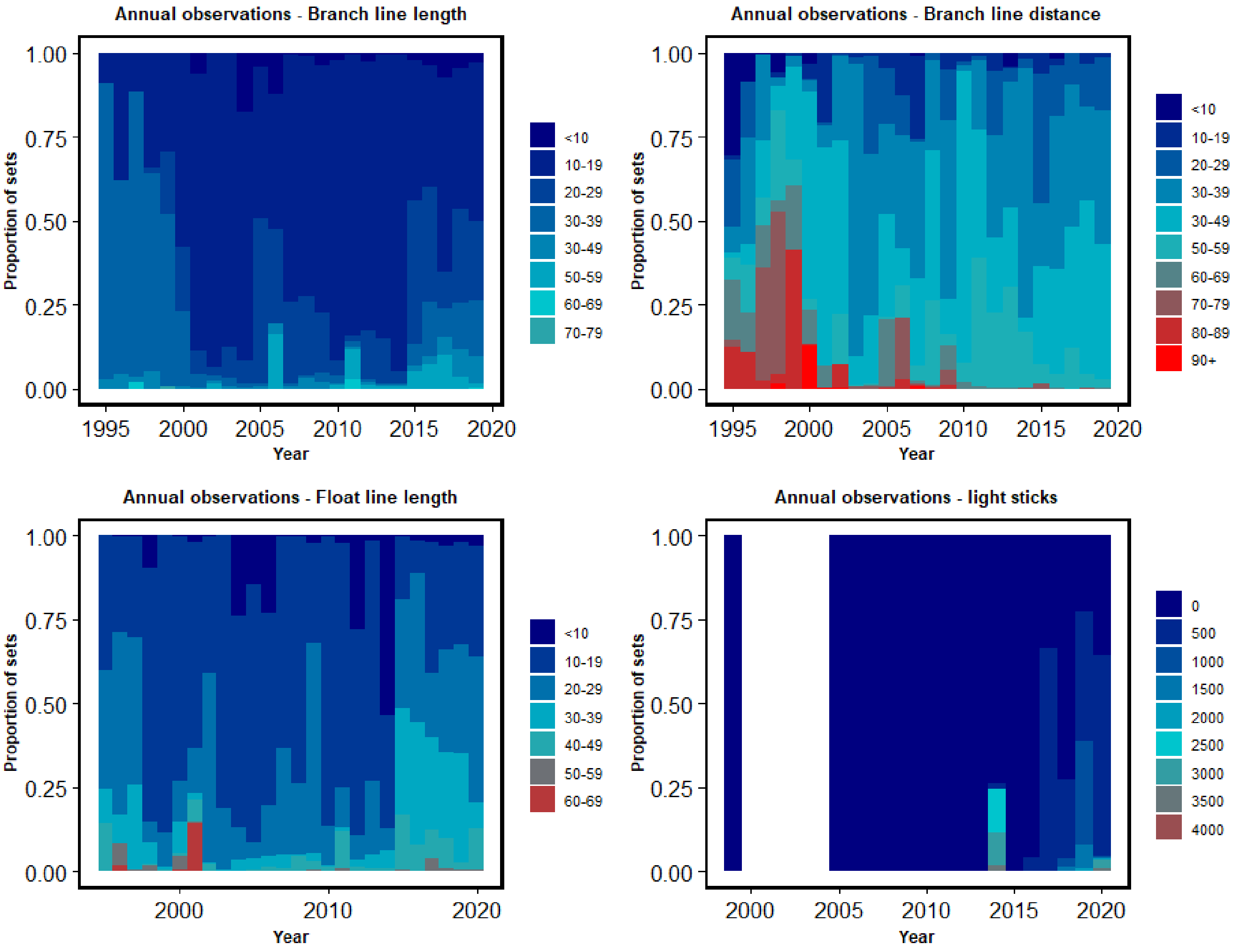


Figure 29: Observed branchline length, branchline distance, float line length and lightstick use on longline sets, in the WCPFC between 1990 - 2022.

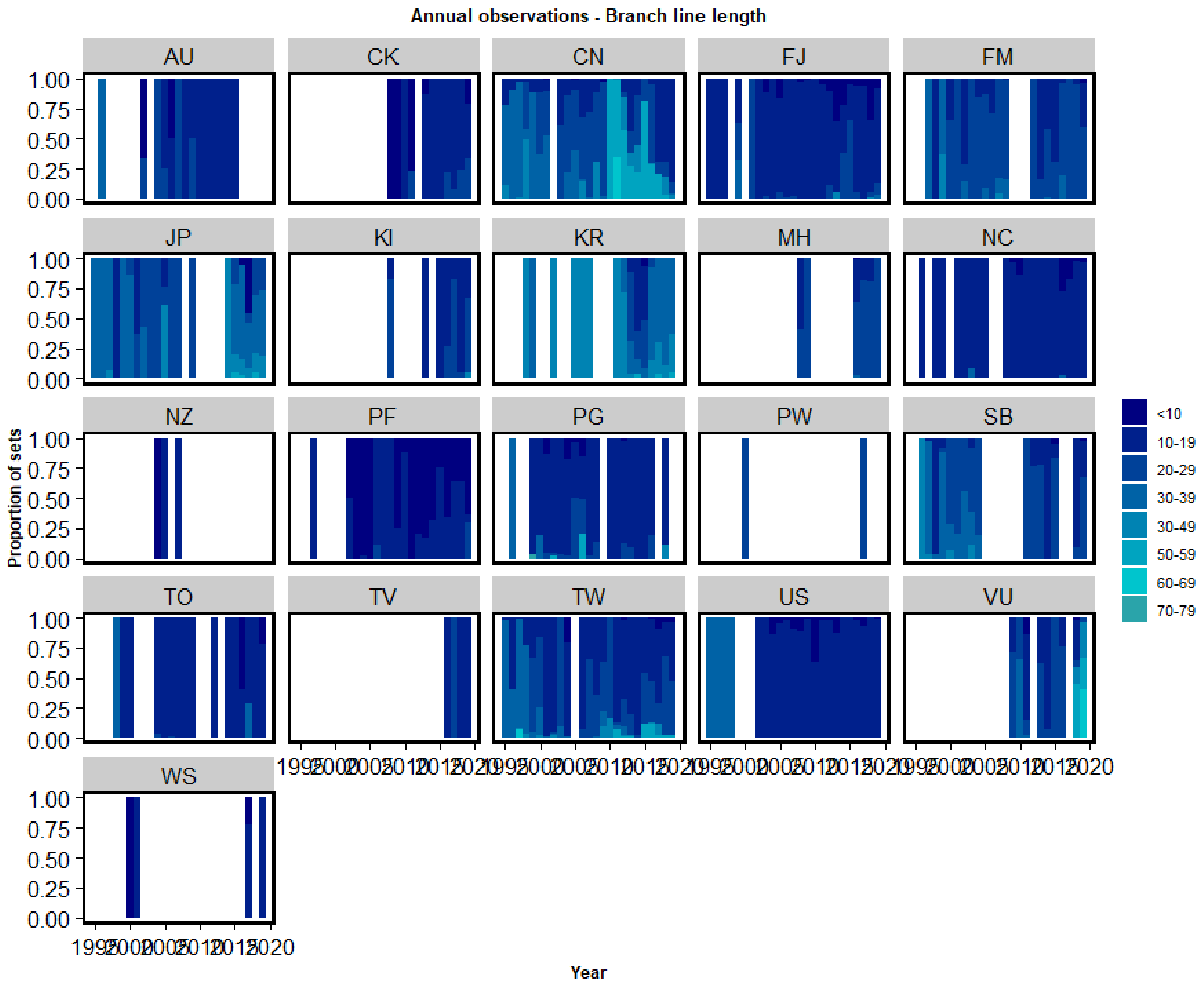


Figure 30: Observed branchline length, used on longline sets, by flag in the WCPFC between 1990 - 2021.

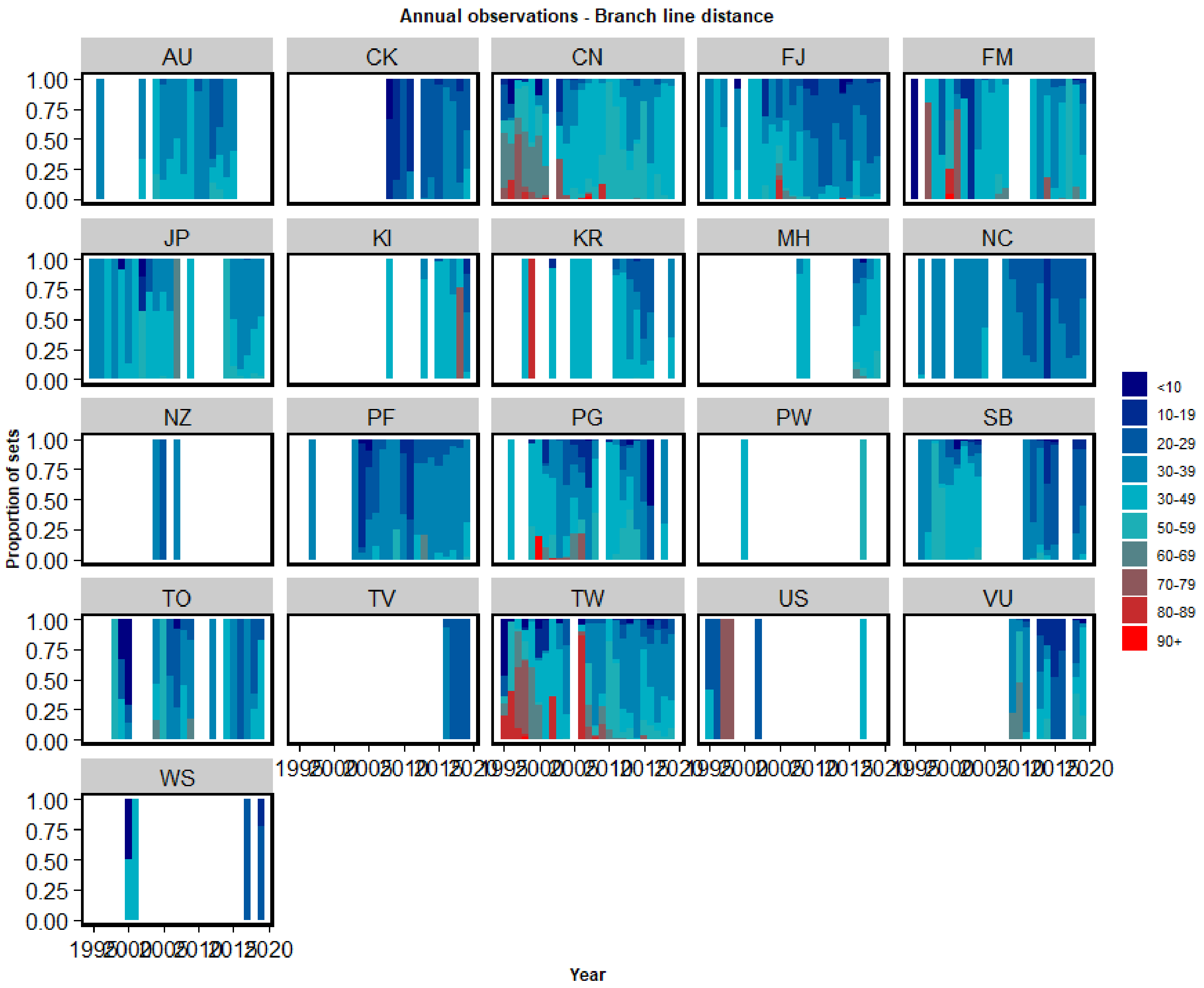


Figure 31: Observed branchline distance, used on longline sets, by flag in the WCPFC between 1990 - 2021.

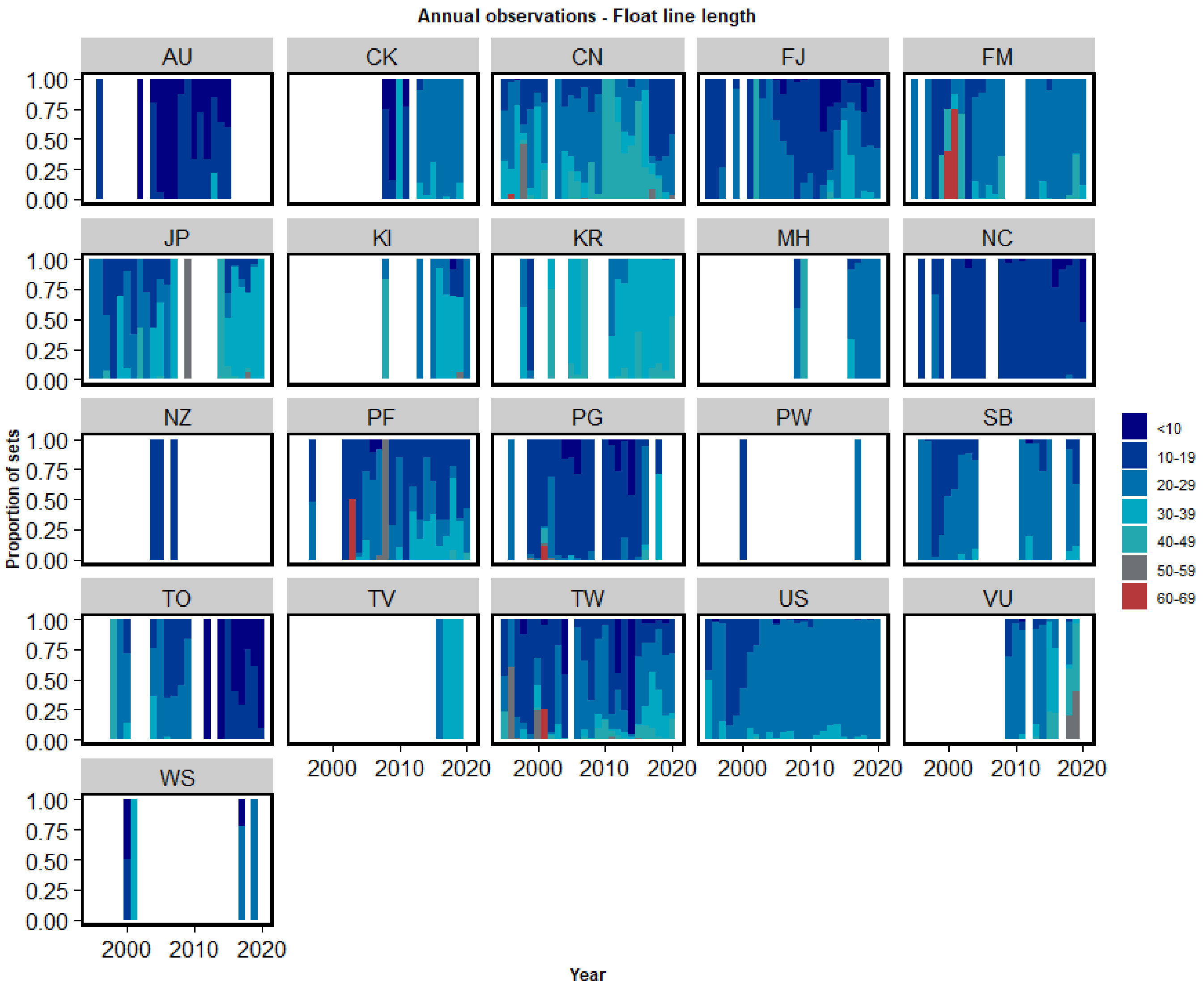


Figure 32: Observed float line length, used on longline sets, by flag in the WCPFC between 1990-2021.

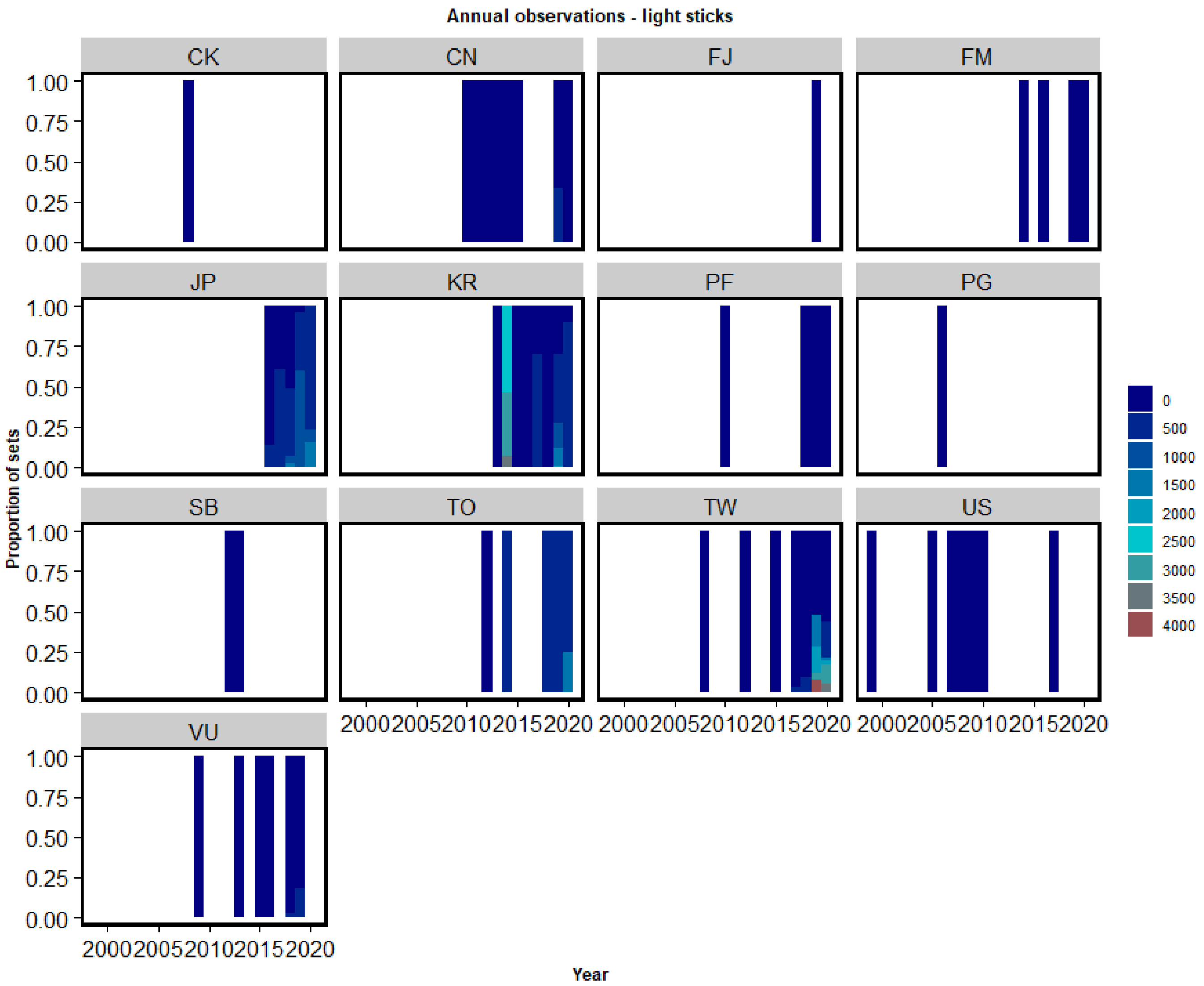


Figure 33: Observed lightstick use on longline sets, by flag in the WCPFC between 1990 - 2021.

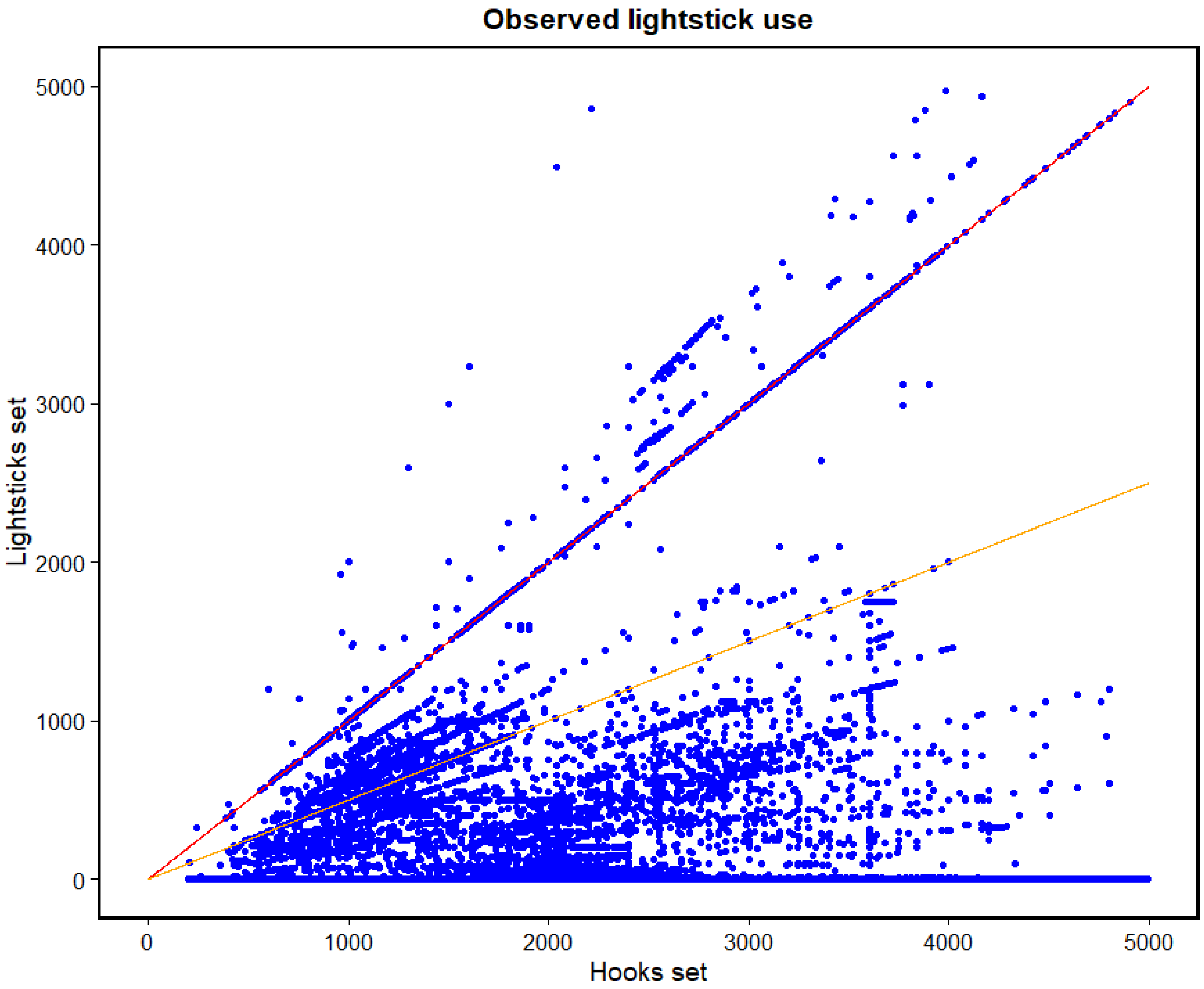


Figure 34: Comparison of the number of lightsticks to the number of hooks set. The red line represents the 1:1 ratio. The orange line represents the 1:0.5 ratio.

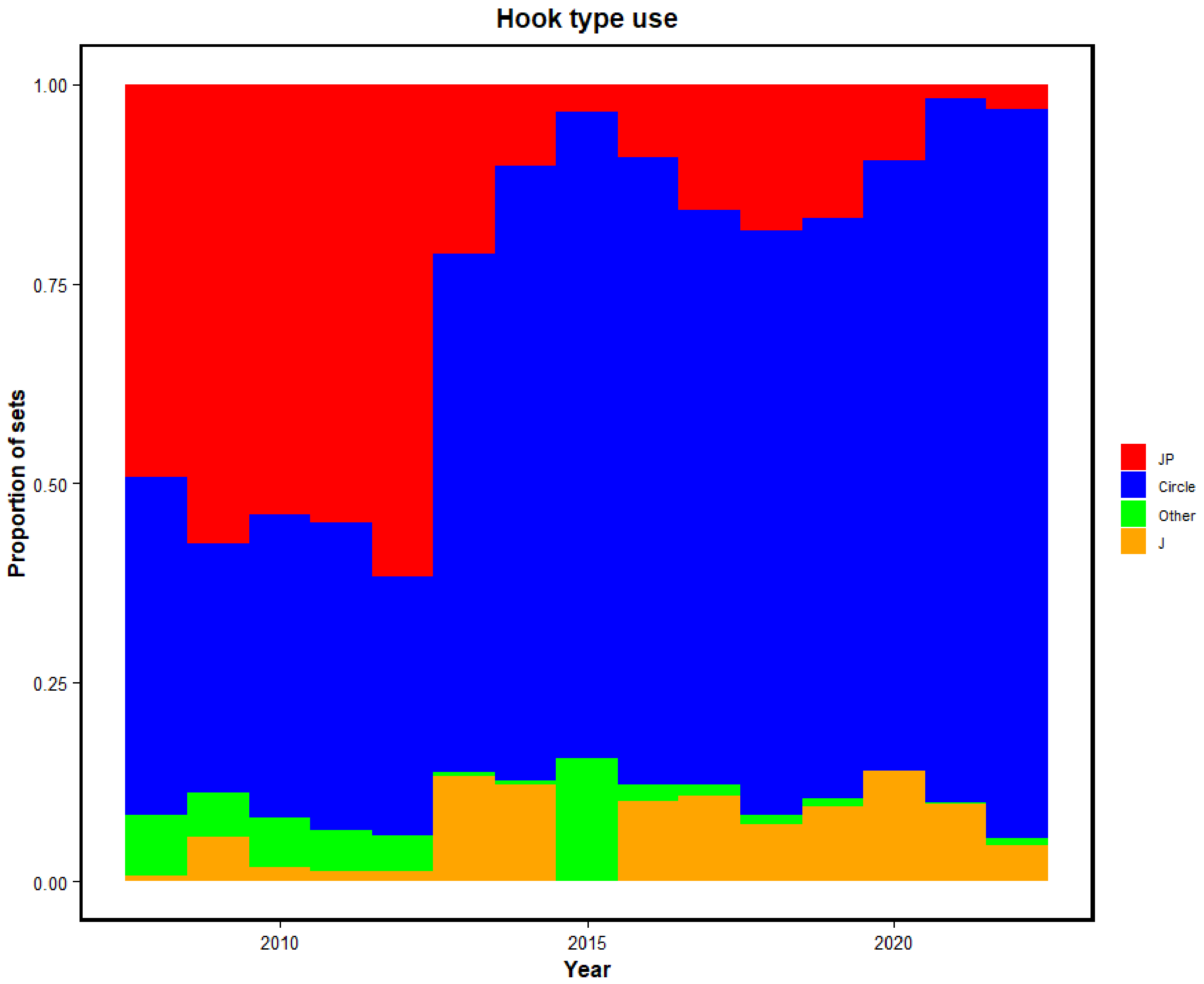


Figure 35: The use of hook types for all fleets combined in the WCPFC between 2008 - 2022.

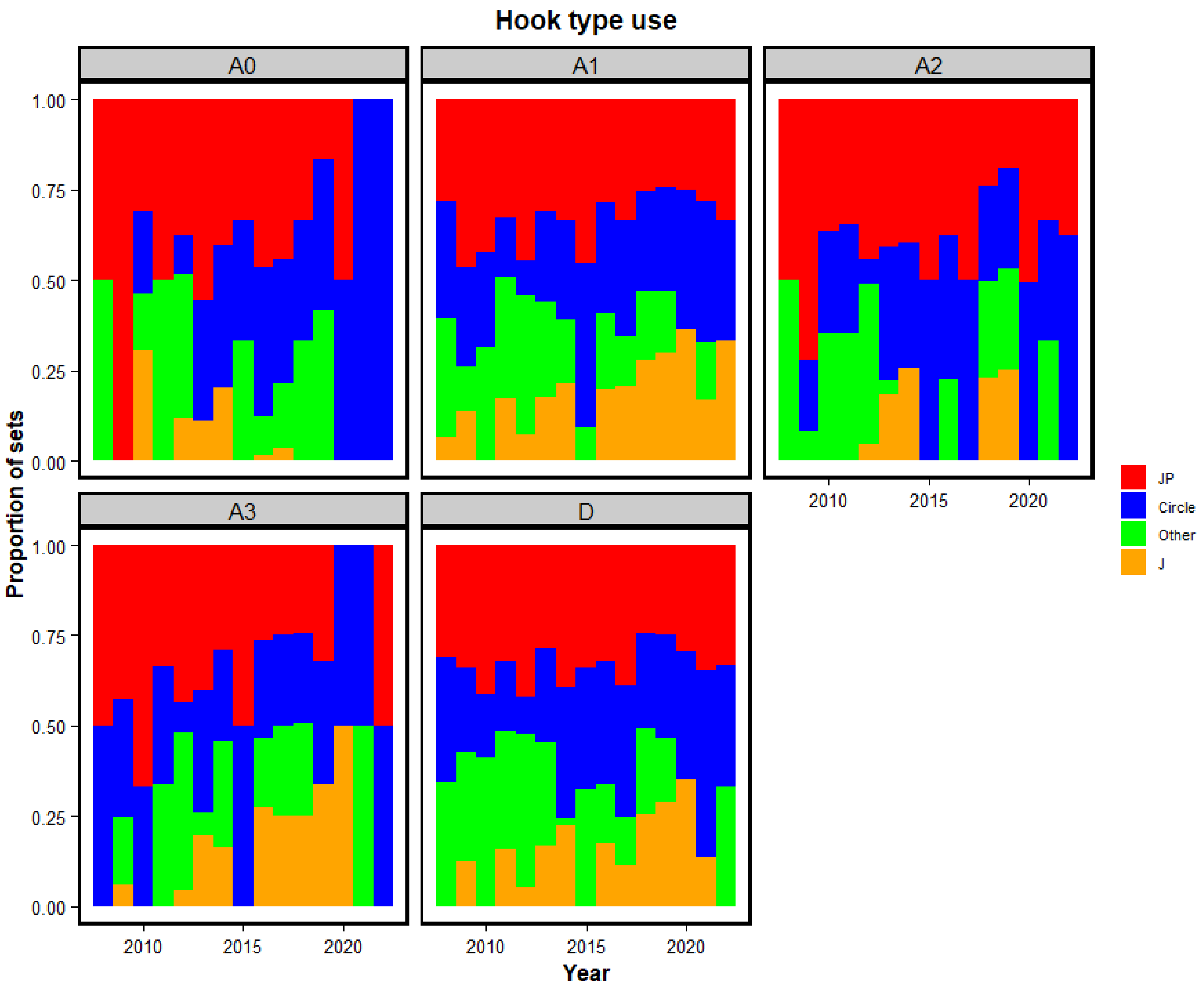


Figure 36: Silky shark condition at capture by year and hook type. Condition codes are shown in Table 2. Hook type definitions are as follows: JP = Japanese hooks; Circle = circle hook; J = J-hook.

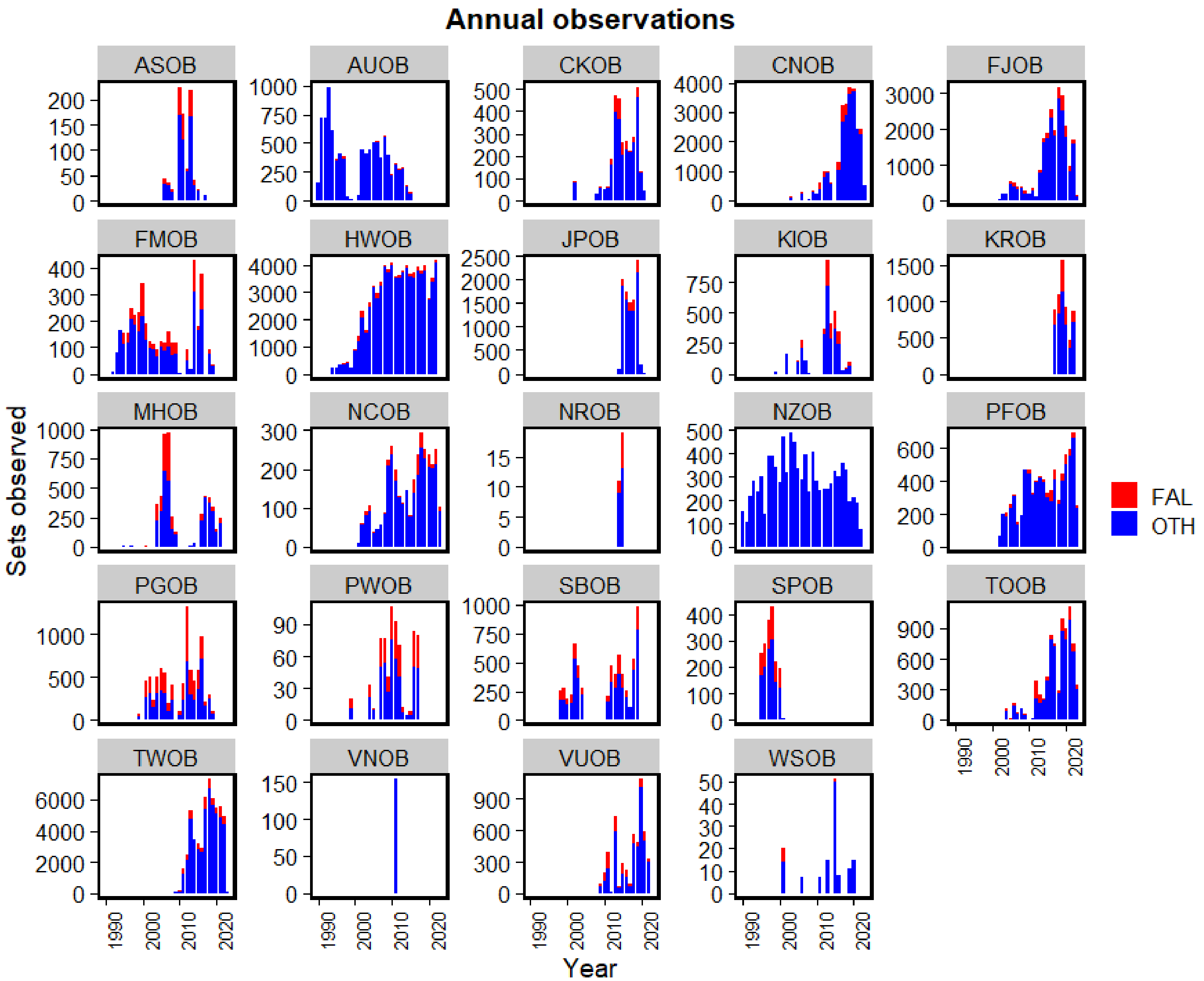


Figure 37: Sets observed by observer program and year showing all sets without silky sharks (OTH) and sets where silky sharks were observed (FAL).