# A preliminary report on Indonesia's Indian Ocean tuna and bycatch longline fisheries, based on historical and newly established sources of CPUE information: a project overview

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# Abstract

Indonesia has the largest longline fleet operating in Eastern Indian Ocean, with the number of active vessels now estimated at approximately one thousand. The Indonesian longline fleet is globally important from both an economic and environmental perspective: it is one of the main suppliers of fresh tuna for the Japanese market and it fishes the only known spawning ground for southern bluefin tuna. However, there is a shortage of detailed catch and effort information from Indonesia's Indian Ocean tuna fisheries. The port-based monitoring is not able to provide the type of CPUE information that is required for a full understanding of the impacts of fishing, the factors that influence trends in the catch over time, and the reasons behind changes in 'behaviours' of the fishing fleet. An understanding of all these is, in turn, required for conducting scientific stock assessments for all key species within the fishery.

The first author is undertaking a Ph.D. that includes a preliminary report on the available data from Indonesia's Indian Ocean tuna longline fishery. The main aim of the project is to provide an improved understanding of Indonesia's Indian Ocean tuna longline fishing activities. This paper presents a broad overview of the data and briefly mentions some of the main findings to date pertaining to SBT, from exploratory analyses undertaken on two of the available data sets. The remainder of the thesis plan is also outlined. In general, the data provide some history of the fishery and information on target species by location and gear type, and support previous suggestions that Southern Bluefin Tuna are a minor component of the fishery. Otherwise, few discernable or strong seasonal, spatial and/or temporally consistent patterns in catch and/or fishing behaviour are apparent, and no clear patterns have emerged in attempting to relate catches and/or fishing patterns to environmental variables or targeting behaviours. The question remains as to whether this is an accurate reflection of the fishery, or whether is due to the observation and/or clerical errors in the data, the extent of the coverage (both in terms of the proportion of fishing activity reported, and to what extent the reported data is representative of the fleet), or the lack of an appreciable time series.

# Overview

Indonesian commercial tuna longline operations commenced in 1965 with one state-owned company and two vessels. The fleet gradually grew to 18 vessels in 1976 and 36 vessels in 1986. By 1991, there were 536 longline vessels, many of which were foreign vessels operating under the Indonesian flag. Indonesia currently has the largest longline fleet operating in the Eastern Indian Ocean. In 2003 there were an estimated 1500-1800 active vessels (Proctor et al. 2003) in the fleet, but with impacts from fuel price rises in 2005 and 2008, the number of active vessels is now estimated at around 1000 (Miguel Herrera's (IOTC) presentation at Steering Committee Meeting for Monitoring of Indonesia's Tuna Fisheries, Jakarta, 27-28 May 2008).

The Indonesian longline fleet is one of the main suppliers of fresh tuna for the Japanese market (http://www.chasque.net/frontpage/suns/trade/process/followup/1998/10300698.htm), and it fishes spawning grounds for many of the commercial tuna and tuna-like species (Nishikawa et al., 1985 in Proctor et al., 2003), including the only known spawning ground for southern bluefin tuna (Caton 1991, Fonteneau and Soubrier 1995). Thus, global tuna management will be substantially improved with increased involvement and cooperation from Indonesia. Currently, there is a shortage of detailed catch and effort information from Indonesia's Indian Ocean tuna fisheries. Port-based monitoring provides valuable data on the

amount of southern bluefin tuna (SBT) and other species landed by the Indonesian longline fleet but it does not provide the type of CPUE information that is required for an understanding of the effects of fishing, the factors that influence trends in the catch over time, and potential reasons behind changes in 'behaviours' of the fishing fleet. An understanding of all these is, in turn, necessary for conducting scientific stock assessments for all key species within the fishery.

To date no comprehensive analyses have been undertaken on existing data. As part of a capacity-building project funded by the Australian Centre for International Agricultural Research (ACIAR), a Ph.D. project will undertake a preliminary evaluation of the available data from Indonesia's Indian Ocean tuna longline fishery. The main aim of the project is to provide an improved understanding of Indonesia's Indian Ocean tuna longline fishing activities. Specifically the project seeks to

1. Undertake exploratory analyses and examine trends in the activities of the Indonesian Indian Ocean industrial tuna longline fishery based at Benoa Port, focusing on the main tuna species caught, including SBT, and the bycatch/byproduct species, using i) data from the fisheries high school on board training program, ii) data obtained from the PT. Perikanan Samodra Besar (PSB) fishing company, and iii) data from the trial observer program that commenced in 2005

2. To develop an understanding of factors that may influence the Indonesian Indian Ocean industrial tuna fishery trends.

3. To standardize catch-per-unit-effort (CPUE)

4. To develop a spatial-temporal simulation to determine optimal monitoring strategies of longline fishing activity, in order to ultimately obtain robust CPUE estimates via adequate coverage of the fleet.

5. To make recommendations to improve the quality of the data collected from various sources.

This paper provides a broad overview of the data and briefly mentions some of the main findings to date pertaining to SBT, from exploratory analyses undertaken on the Fisheries High School and PSB sets. (Sadiyah et al. 2008 CCSBT-ESC/0809/20 discusses pertinent results to date from exploratory analyses undertaken on the trial observer data). Finally, the remainder of the thesis plan is outlined.


## Available Data

Table 1 summarises the three available data sets for the Indonesian longline fishery that form the basis of this Ph.D. project. Note that there are two additional data sources: Data collection as part of the National System of Fisheries Statistics of Indonesia dates back to 1976, and the Indonesia – Australia port-based tuna monitoring program that commenced in Bali in 1992. As these data sets do not include CPUE information, they are not considered as part of the project.

**Table 1. Summary of available data for the Indonesian tuna longline fishery**

| | PSB Data | Fisheries High School Data | Observer Program Data |
|---|---|---|---|
| Collected by | Vessel skippers | Students (little training in tuna identification, no GPS) | 6 trained observers (trained in fish identification, GPS) |
| Project aim | Company reporting | Degree requirement (first on-board experience) | Trial program, as preliminary step to broader observer program |
| Data | Catch (number fish) Effort (number hooks; hooks per basket) Fishing position | Catch (number fish) Effort (number hooks) Fishing position Some environmental data and bait information | Catch (number fish; length-frequency) Effort (number hooks; hooks per basket) Detailed trip, setting and hauling information Environmental data |
| Period | 1978-1995* | 2000-2007 | 2005-2008 |
| Number of recorded sets | 35 687 | 81 741 | 793 |

*Data is available from PSB for period 1996 – present, but not yet processed

Fisheries High School Data

Across the Indonesian archipelago there are over 20 Fisheries High Schools (FHS) that provide training to students wishing to become fishers, skippers, and fishing masters. As part of their final year of training and as a prerequisite for graduation, the students must successfully complete a full fishing trip at sea aboard a longline vessel. The average length of the trips is 30 – 40 days. This FHS 'observer' program was an initiative of WASKI ("Unit Pengawas Kapal Ikan" = Office for control and surveillance of fisheries vessels), a government office in the Port of Benoa that is under the Directorate General of Marine Resources and Fisheries Control. The potential to use these data to try to address the lack of information on catch rates and to gain a better understanding of the fishery on the spawning grounds was recognised, and with the excellent cooperation and assistance from WASKI a collaborative project commenced in 2005.

WASKI has managed the placement of students on longline fishing vessels and also the archiving of the data collected by them. The students are provided with data sheets on which they record daily catch of the main tuna species, as well as information such as, setting position, gear details and number of hooks used. The Manager of WASKI at Benoa, Mr Nengah Nesa, has emphasised that the FHS Program was not designed for, nor ever intended to provide operational fisheries data, but simply to fulfill a training requirement for the students. However, through the program, an enormous amount of information has been accumulated on daily fishing operations of the Benoa-based longline fleet with specific fishing locations, and catch and effort data from 1995 to the present. Unfortunately, pre-2000 data was unavailable. As each trip involves a different student recording catch and gear details, and with only limited training on observer skills provided to the students before they go to sea, there is wide variation in quality and quantity of data recorded.

During the past three years, copies of the FHS logsheets (year 2000 – present) have been provided by WASKI to the project, and with the support of funding provided by Department of Agriculture, Fisheries and Forestry (Australia), the basic information needed to determine

CPUE for the key tuna species by location have been entered on a database by staff at Research Institute for Mariculture, Gondol, in north Bali.

PSB Data

PT. Perikanan Samodra Besar, an Indonesian tuna fishing company that commenced its first fishing operation in 1972 (Proctor et al. 2003, Marcille 1984), has been collecting records of catch and effort information of its vessels since 1973 (Marcille et al. 1984). This company recently merged with three other Indonesian State-owned companies and now operates under the name PT. Perikanan Nusantara, however in this report it will continue to be referred to as "PSB". The PSB data is the longest time series catch and effort data available from the Indonesian industrial longline fishery, as PSB is the oldest tuna fishing company that is currently active and the only fishing company, to our knowledge, that has kept a long-term records of catch and operational data. Therefore, to understand the historical catch and effort trends of Indonesian commercial tuna longline fishery, the PSB data is a valuable data source. However, it should be emphasised that the PSB data is not representative of the entire longline fishery. There are 13 other tuna companies based in Benoa Fishing Port (Proctor et al. 2003), and we know from results of the port-based monitoring program and from the trial observer program (Sadiyah et al. 2008 CCSBT-ESC/0809/20) that there are significant differences among some companies in terms of which species they target, areas of operation, and gear setting practices.

The PSB data for period 1978 – 1995 have previously been entered into the Research Centre for Capture Fisheries (RCCF) database. It should be noted that no PSB data for 1986 in the database. This does not necessarily mean that PSB longliners were inactive in 1986, but simply reflects a lack of information for that year. PSB data beyond 1995 have yet to be processed, as some of the symbols (i.e. codes) used by PSB skippers still require translation. The dataset includes information on catch (number of fish), effort (including number of hooks per basket, number of basket and setting position) and water temperature for each longline set. Catch information were reported by species, including the four tuna species (BET, ALB, YFT and SBT), and bycatch species (i.e. black marlin (BLM), blue marlin (BUM), striped marlin (MLS), swordfish (SWO), atlantic sailfish (SAI), longbill spearfish (SPF), white marlin (WM) and moro (MR)). No information is available on bait type or gear configuration (such as the number of hooks per basket) other than that relating to the total numbers of hooks and baskets.

Observer data

In an effort to address the shortage of CPUE information, and as a preliminary step to a broader observer program, Indonesia began to develop a trial observer program for the industrial tuna longline fishery based at Benoa Fishing Port, Bali, in late 2005 (see Sadiyah et al. 2007 CCSBT-ESC/0709/Info 04). This program is a collaboration between Indonesia's Ministry of Marine Affairs and Fisheries (MMAF) through the Research Centre for Capture Fisheries (RCCF), and CSIRO Marine and Atmospheric Research (Australia), and is funded by the Australian Centre for International Agricultural Research (ACIAR) (project FIS/2002/074: Capacity development to monitor, analyse and report on Indonesian tuna fisheries) (http://www.aciar.gov.au/project/FIS/2002/074).

The trial observer program was designed to provide detailed catch and effort data from Indonesia's Indian Ocean industrial tuna longline fishery based at Benoa, and also to provide

detailed information in terms of fishing activities and environmental conditions (Sadiyah et al. 2008 CCSBT-ESC/0809/20). This program is an extension of the port-based tuna catch monitoring program in Benoa which was initially established in 1992 for monitoring the SBT catch of Indonesia's longline fleet (Davis & Andamari 2003, Davis et al. 2003) and then expanded in 2002 to monitor tuna catches (all species) landed at Benoa, Jakarta, and Cilacap (Proctor et al. 2006; Davis et al. 2003). Although the port-based monitoring programs have provided good quality data in terms of catch numbers, catch composition and length frequency information, these programs do not provide effort information.

The trial observer program dataset is important for several reasons. This dataset is currently the most detailed data available from the fishery, in providing catch and effort data that should ultimately allow an improved understanding of fishery and form the basis for a stock assessment by enabling CPUE standardisation. It includes detailed information on catch, including length information, fishing techniques (including targeting practices), and environmental factors. Whereas the other sources of data provide a longer time series, the Fisheries High School data is observation prone to error and uncertainty, and the PSB data is not sufficiently detailed and nor is it representative of the whole fleet. Currently the observer data spans only three years, but as the time series develops, it will be the best source of data for recent fishing activity. However, it should be noted that that the observer data are not yet representative of all industrial tuna fishing companies based at Benoa port as only a few fishing companies are currently participating in the program. Also, the observed vessels were not chosen randomly, but were largely determined on the basis of the voluntary participation of companies (i.e. their willingness to carry an observer on their vessels) and on vessel safety (i.e. the observers only go to sea on vessels that meet certain safety requirements). With only three years of data to date, it is currently difficult to discern trends, but the exploratory analyses undertaken will hopefully provide a sound basis for future analysis.

## Approach

Data cleaning

Exploratory analyses were undertaken on each individual set of data. Prior to this, each set of data was examined and "cleaned". This in itself was a significant challenge, particularly for the Fisheries High School (FHS) data. Errors in the other data sets were mostly clerical and required a general screening to detect obvious outliers such as land-based or implausible locations, or extremely low or high numbers of hooks or numbers of fish caught, and naming inconsistencies of vessels, species and bait types. Additionally, the length data recorded by the observers needed to be standardized to a common measuring system. Other errors in the observer data were corrected by direct cross checking with the relevant observer. However, the FHS data was obtained by students who were not equipped with GPS and were not trained in species identification.

WASKI has always made it clear that the FHS data should be treated 'with caution' in any scientific analyses as the program was not originally designed to provide robust observer data. The students are provided with some training on how to collect data at sea, but it appears many of the students rely heavily on information provided to them by vessel personnel. During very busy periods during fishing operations, such as hauling, it is likely the information provided by the vessel personnel to the students is not always accurate, as the vessel personnel would not be aware of any need for provision of accurate data i.e. their impression may be that any data will suit the training needs of the student.

There are three primary areas of concern with respect to the FHS dataset:

1. Highly questionable catch locations (e.g. ~1% of sets entered were recorded with Lat & Long positions that correspond to locations on land).

2. Records of SBT having been caught in areas where there have been no previous confirmed records of SBT ever having occurred. This includes records from the Java Sea (north of Java), Banda Sea (bordered by Sulawesi, Timor Leste, and Arafura Sea), Timor and Arafura Seas. Longline vessels from Benoa do sometimes fish in the Banda Sea but there are no previous confirmed records of SBT having occurred there.

3. Records of significant numbers of SBT having been caught on the SBT spawning ground during the non-spawning season – May to August. This does not agree with what we know of Indonesia's SBT catch by longline vessels based at Benoa - from both the port-based monitoring program and the trial scientific observer program.

While cleaning can remove the more obviously erroneous records, much uncertainty remains about the remaining records in terms of location (point 1) and species identification (points 2 and 3).

An additional problem with the FHS data is the within-year bias in the sampling, with most coverage occurring in the last 6 months of each year, less in the first 6 months of the year. This renders it difficult to infer any seasonal patterns within this data or to infer seasonal availability of different species. This is particularly relevant when examining fishing activity during the SBT spawning season, as this period does not correspond with the highest student recording activity.

Thus, although the FHS data provides the most information in terms of number of sets recorded, it is also the more uncertain. The PSB data provides the longest time series, but lacks some details, and is not representative of the whole fleet. The observer data is the most reliable source of data but a long time series has yet to be established.

Exploratory analyses

Exploratory analyses aimed to examine each set of data in graphical and tabular form in order to yield a rigorous preliminary investigation and discern any spatial, temporal and/or seasonal patterns in catch, effort, catch composition and CPUE, and any potential effects of environmental variables (such as sea surface temperature) or of reported targeting behaviour (such as hooks per basket or bait type). Analyses were generally undertaken for data within both the broader fishing ground, and within a spatial subset corresponding to the SBT spawning zone in the northeast Indian Ocean, south-east of Java (Caton 1991, Fonteneau and Soubrier 1995): between 100º and 130ºE and 5º and 20ºS.

## Some key findings pertaining to SBT

Fisheries High School data

Due to the persistent intra-annual bias in the sampling, seasonal patterns will not be discussed here. The issues of SBT being recorded on the spawning grounds outside of the spawning season, and the lower data coverage during the spawning season have been mentioned above, as has the issue of records of SBT having been caught in areas where there have been no previous confirmed records of SBT occurring.

The FHS data suggested that, in general, the Indonesian industrial longline fleet catch predominantly albacore south of 15°S, and yellowfin tuna north of 15°S (Figure 1). The fishing area appears to be concentrated between 110°-130° East and 10°-15° South (Figure 1). This area overlaps the only known SBT spawning ground (i.e. between 103ºE and 128º E, and 7ºS and 17ºS), but SBT were caught as byproduct in this fishery (Sadiyah et al. 2007 CCSBT-ESC/0709/Info 04) i.e. the spatial distribution of effort was not associated with higher relative catches of SBT. The spatial effort distribution may be related to the area's proximity to the home port, where fishers undertake fishing trials on their way to their target fishing areas. Alternatively, fishers may be aiming to sell their tuna catch as fresh product and thus undertake shorter trips, i.e. closer to the home port. As the highest catches (total and tuna) within these areas reflected the highest effort deployed, they are not necessarily indicative of any abundance pattern.

Southern Bluefin Tuna comprised a minor part of the overall catch, even within the SBT spawning ground (Table 2). There was no consistent seasonal pattern in nominal CPUE in this area (Figure 2), although the highest CPUE occurred in the second quarter of the year for 3 of the years.

The fuel price increase in 2005 resulted in a reduction in fishing activity (in 2005 the number of vessels operating from Benoa port in decreased by about 32 vessels (ATLI presentation in Tuna Monitoring workshop on 12 July 2006, Bali)), but not in the SBT CPUEs derived from the FHS data (Figure 2).

The FHS data showed that SBT catches and effort, in terms of numbers of hooks, showed slight decreases since 2005. SBT catches were highest when using four of 17 specific bait types examined (Figure 4). Only 2529 sets or about 3.32 % of total sets deployed in the core area of tuna fishery were accompanied by information on sea surface temperature (SST), and there was no significant difference between sea surface temperature and species-specific catch, although surprisingly a slightly lower median temperature was associated with yellowfin tuna (Figure 5).
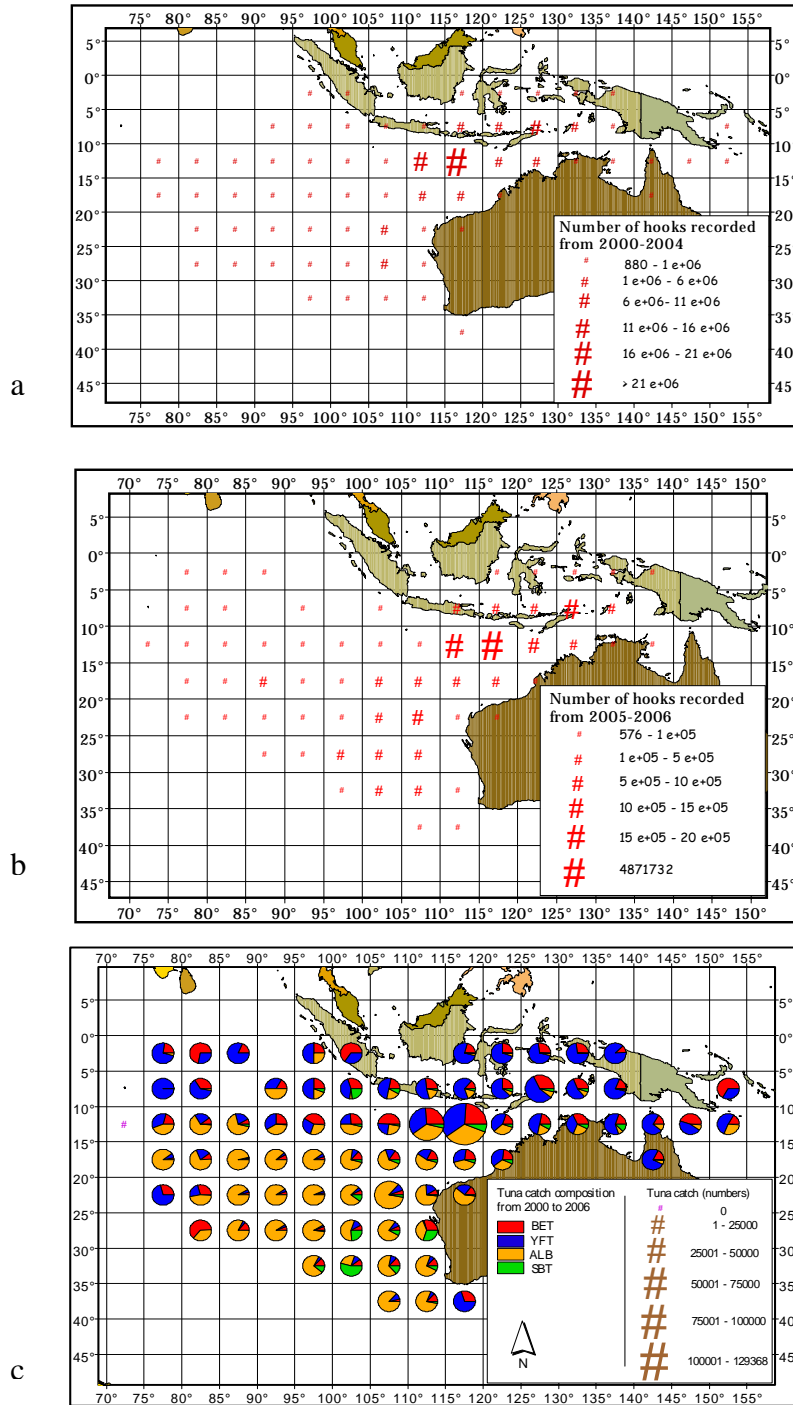
**Figure 1:** Spatial distribution of effort (numbers of hooks) from 2000-2004 (a) and 2005-2006 (b) and catch of the four main tuna species expressed as total number from 2000-2006 (c), from the Fisheries High School data set.

**Table 2:** Summary of catch and effort information from the Fisheries High School SBT spawning ground data subset

| Year | Number Sets Recorded by Month | | | | | | | | | | | | Effort | | | Tuna Catches | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total hooks | Days=Sets | 1-degree Squares | BET | YFT | ALB | SBT |
| 2000 | | | | | | | | | | 716 | 269 | 16 | 1114955 | 1001 | 106 | 1312 | 2998 | 760 | 488 |
| 2001 | | | | | 14 | 281 | 2037 | 2576 | 2526 | 2965 | 1451 | 124 | 13575725 | 11974 | 297 | 17556 | 39511 | 28388 | 3085 |
| 2002 | 431 | 190 | 309 | 58 | 17 | 44 | 1515 | 2687 | 2122 | 2044 | 1413 | 878 | 13412539 | 11708 | 292 | 16876 | 22255 | 23622 | 3140 |
| 2003 | 801 | 415 | 195 | 35 | | 19 | 1251 | 1858 | 1991 | 1931 | 1948 | 1318 | 14106691 | 11762 | 310 | 16962 | 25396 | 20108 | 3641 |
| 2004 | 773 | 471 | 393 | 486 | 723 | 879 | 1348 | 1620 | 1358 | 1519 | 843 | 790 | 13969369 | 11203 | 309 | 14410 | 20950 | 18485 | 3138 |
| 2005 | 798 | 763 | 932 | 847 | 778 | 826 | 1075 | 1159 | 1248 | 1411 | 680 | 564 | 11945988 | 11081 | 279 | 17607 | 23310 | 17896 | 2823 |
| 2006 | 391 | 673 | 663 | 622 | 870 | 754 | 691 | 824 | 510 | 309 | 270 | 563 | 7495681 | 7140 | 260 | 11613 | 13561 | 8273 | 2511 |
| 2007 | 343 | 115 | 181 | 239 | 96 | 31 | | | | | | | 1132285 | 1005 | 128 | 2005 | 3269 | 1709 | 367 |
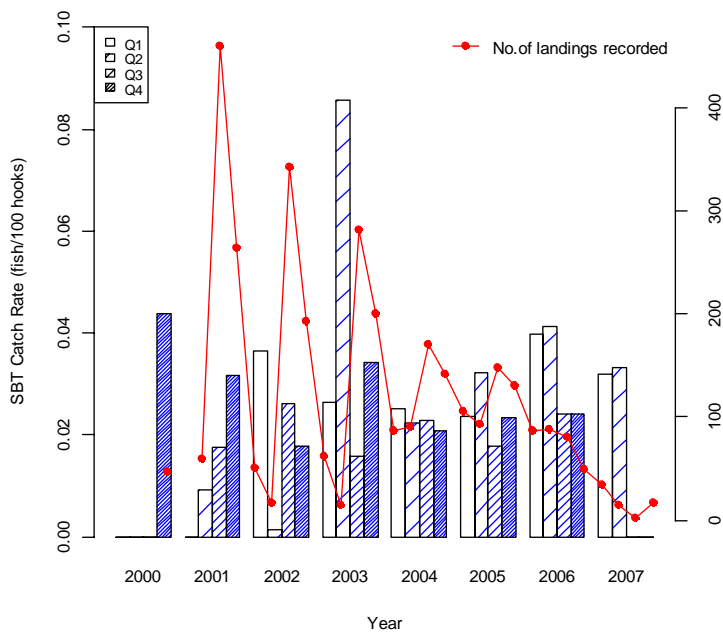


**Figure 2:** Southern Bluefin Tuna catch rate (fish per 100 hooks) by quarter for each year, from the Fisheries High School SBT spawning ground data subset
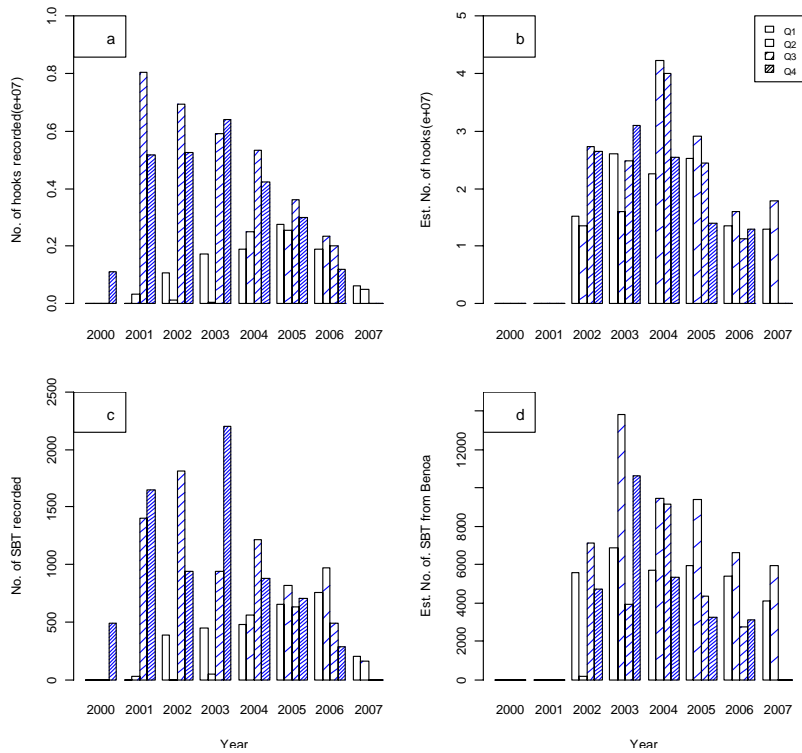
**Figure 3:** Number of hooks and SBT catch both as raw recorded values (panels a and c) and rescaled according to the sampling coverage ratio (panels b and d) for the Fisheries High School SBT spawning ground data subset.
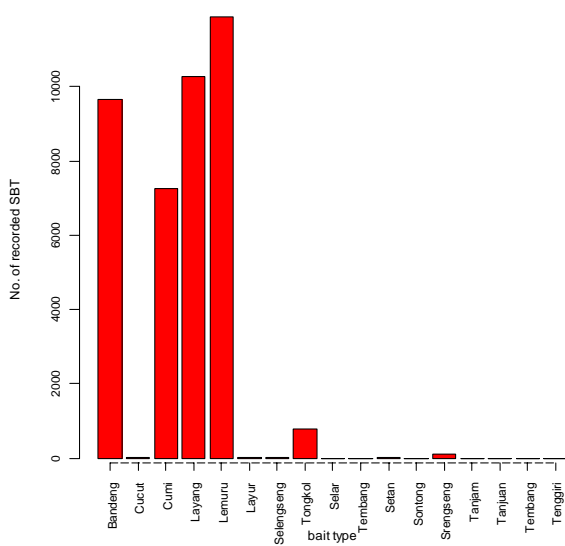


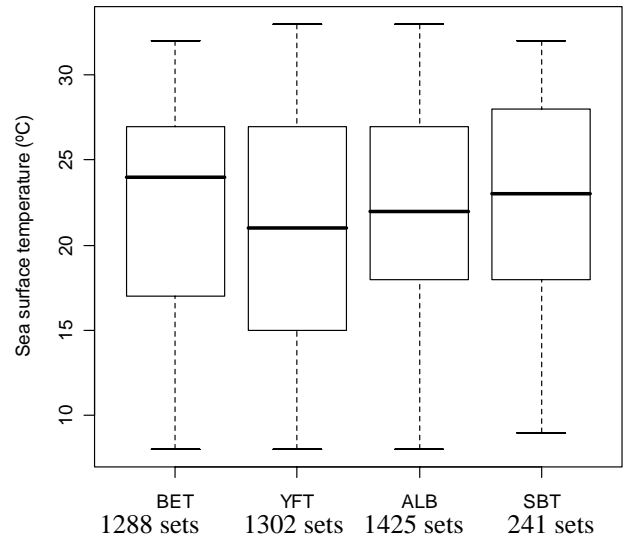**Figure 4:** Number of recorded SBT by bait type from the Fisheries High School SBT spawning ground tuna data subset.

**Figure 5:** Box-whisker plots of sea surface temperature by species recorded from the Fisheries High School data set.

<u>PSB data</u>

The earlier period covered by the PSB data shows that, as with the fisheries school data in later years, SBT comprised a minor fraction of the longline catch (Figure 6). As opposed to the overall tuna, yellowfin and albacore catches, that show declines since 1987, SBT catch showed an overall increase between 1990 and 1995.

The PSB data was more localised than that from the fisheries school (Figure 7). In the late 1970s and early 1980s, the PBS company appeared to mainly catch yellowfin tuna, with occasional high catches of albacore south of the equator and west of 120°E. During the late 1980s, bigeye tuna began to comprise a larger relative proportion of the catch (Figure 7), such that this subsequently became the predominant species in the catch south of 10°S (Figure 8). However, the overall number of bigeye tuna caught did not show an increase (Figure 6a), reflecting the corresponding spatial contraction of the fishery (Figure 7).

The shift in catch composition from predominantly yellowfin to bigeye tuna may have corresponded to a change in targeting practice whereby the number of hooks per basket was increased from 6 to approximately 11 (Figure 9). This was done to fish deeper waters that corresponding to the swimming layer of bigeye tuna (Marcille et al. 1984). However, there was not a strong association of a greater proportion of bigeye tuna catch with a higher number of hooks per basket, with the possible exception of 1991 and 1993 (Figure 10).

Annually aggregated total (tunas + bycatch), total tuna (YFT+BET+ALB+SBT) and yellowfin tuna catches were all significantly ($r^2 > 0.7$, $p < 0.01$) positively correlated with the aggregated annual effort (number of hooks) (Figure 11). On the other hand, there was no significant linear correlation between bigeye tuna, albacore, SBT or bycatch, and effort ($p > 0.1$). As yellowfin was the only tuna species that was significantly positively correlated with effort, this may suggest that yellowfin tuna were targeted. The lack of correlation (if anything, a suggested negative correlation) between SBT and effort reflects the status of this species as a minor catch species in this data set. This is again emphasised by the low nominal SBT CPUE, although this mirrors the catch pattern in showing an increase between 1990 and 1995 (Figure 12).
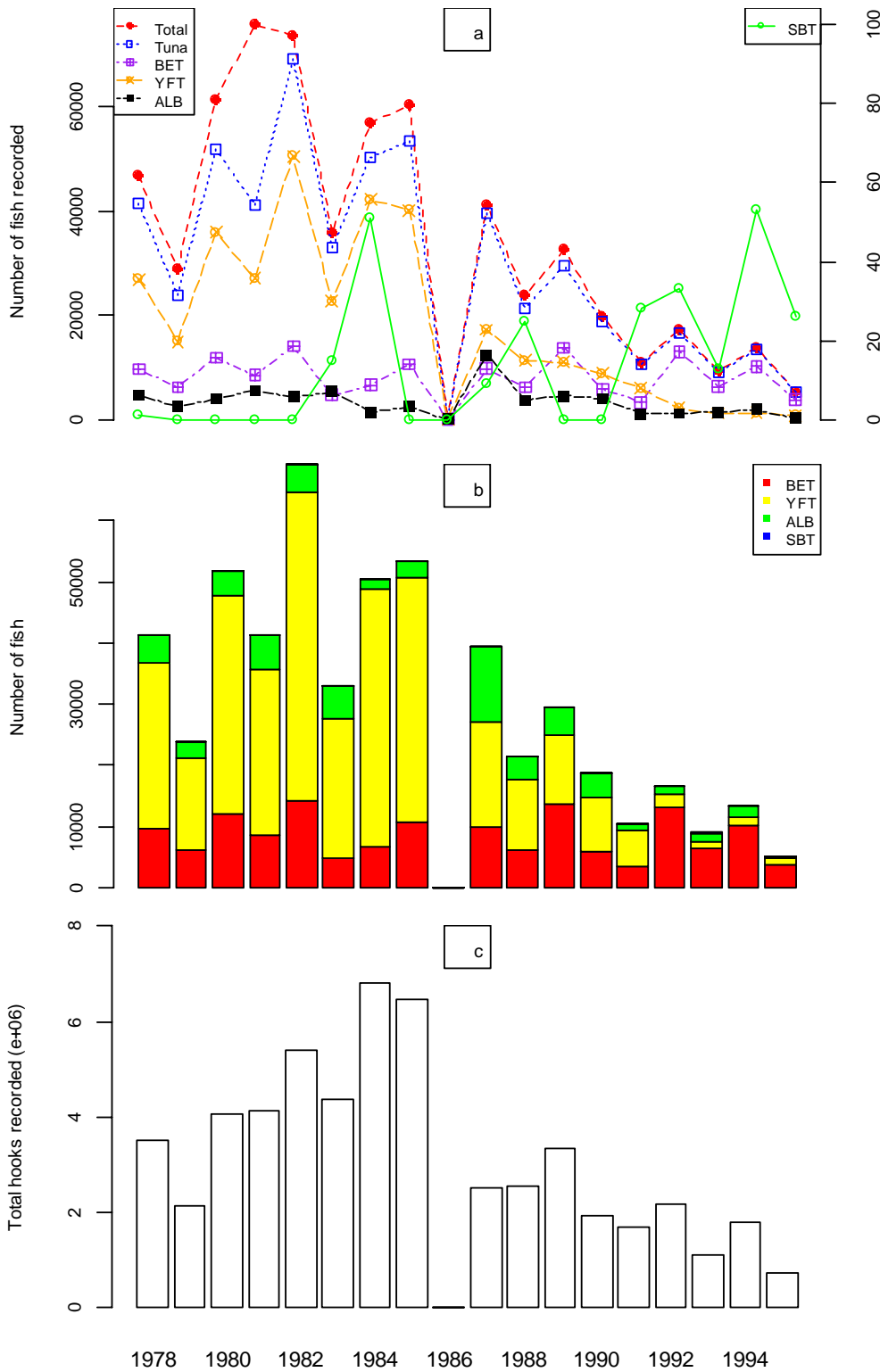
**Figure 6:** Annual catch and effort from PSB data for period 1978 – 1995: (a) number of fish caught by year (note SBT on secondary y-axis due to relatively low catches), including aggregated totals, (b) number of fish caught by year , for tuna species only, and (c) effort (number of hooks by year).
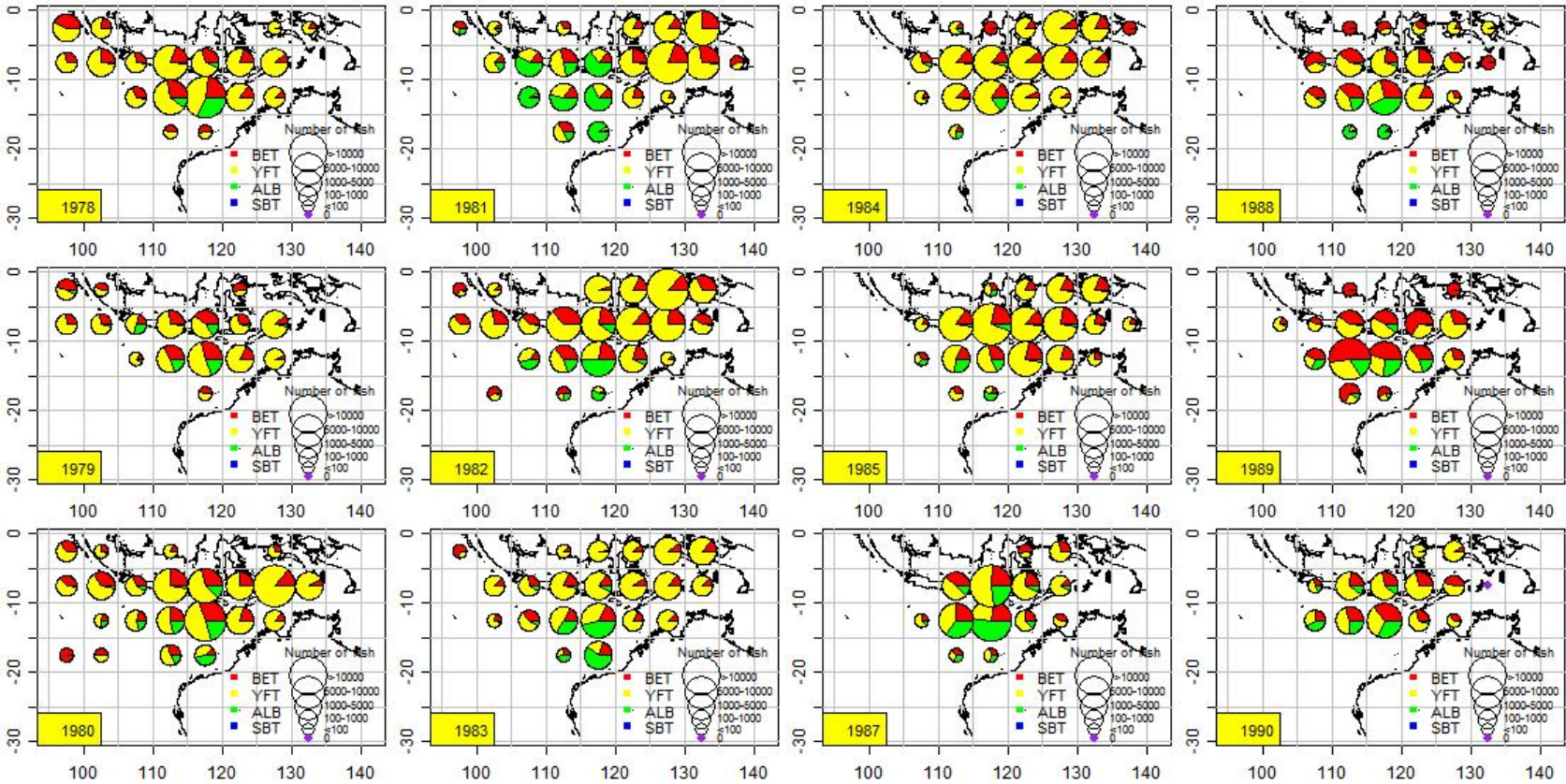
**Figure 7:** Annual spatial distributions of catch of the four main tuna species expressed as total number from, from the PSB data set.
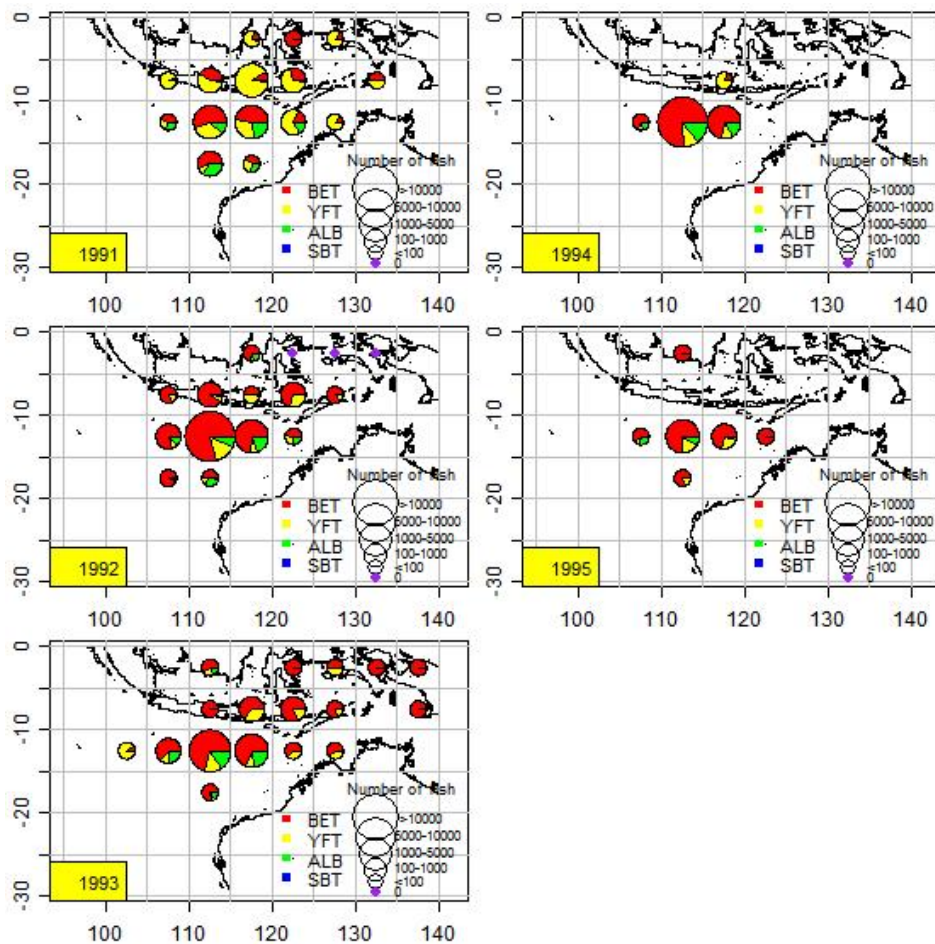
**Figure 7 cont'd:** Annual spatial distributions of catch of the four main tuna species expressed as total number from, from the PSB data set.
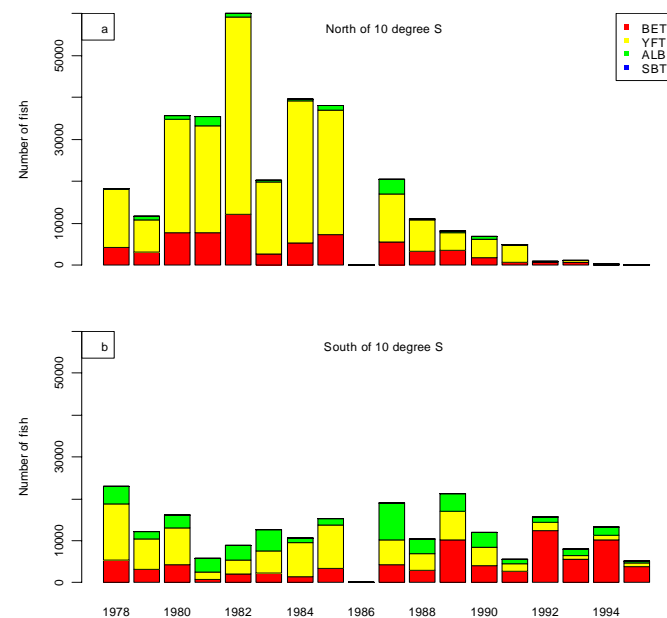


**Figure 8:** Annual tuna catch composition (a) north and (b) south of 10°S, from the PSB data set.
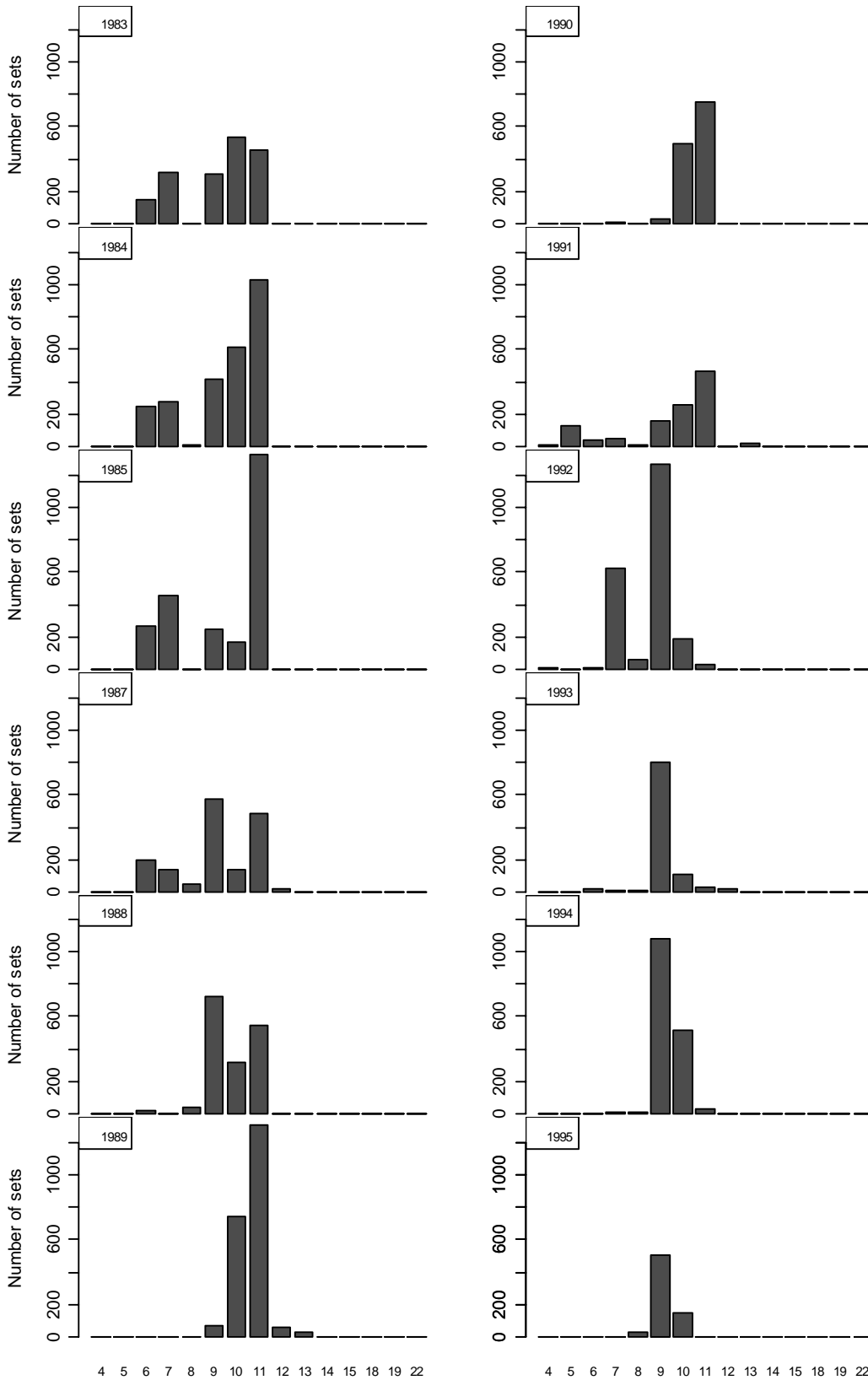
**Figure 9:** Set frequency by number of hooks per basket for each year, 1983 – 1995, from the PSB data set. Only 6 hooks per basket were used between 1978 and 1982.
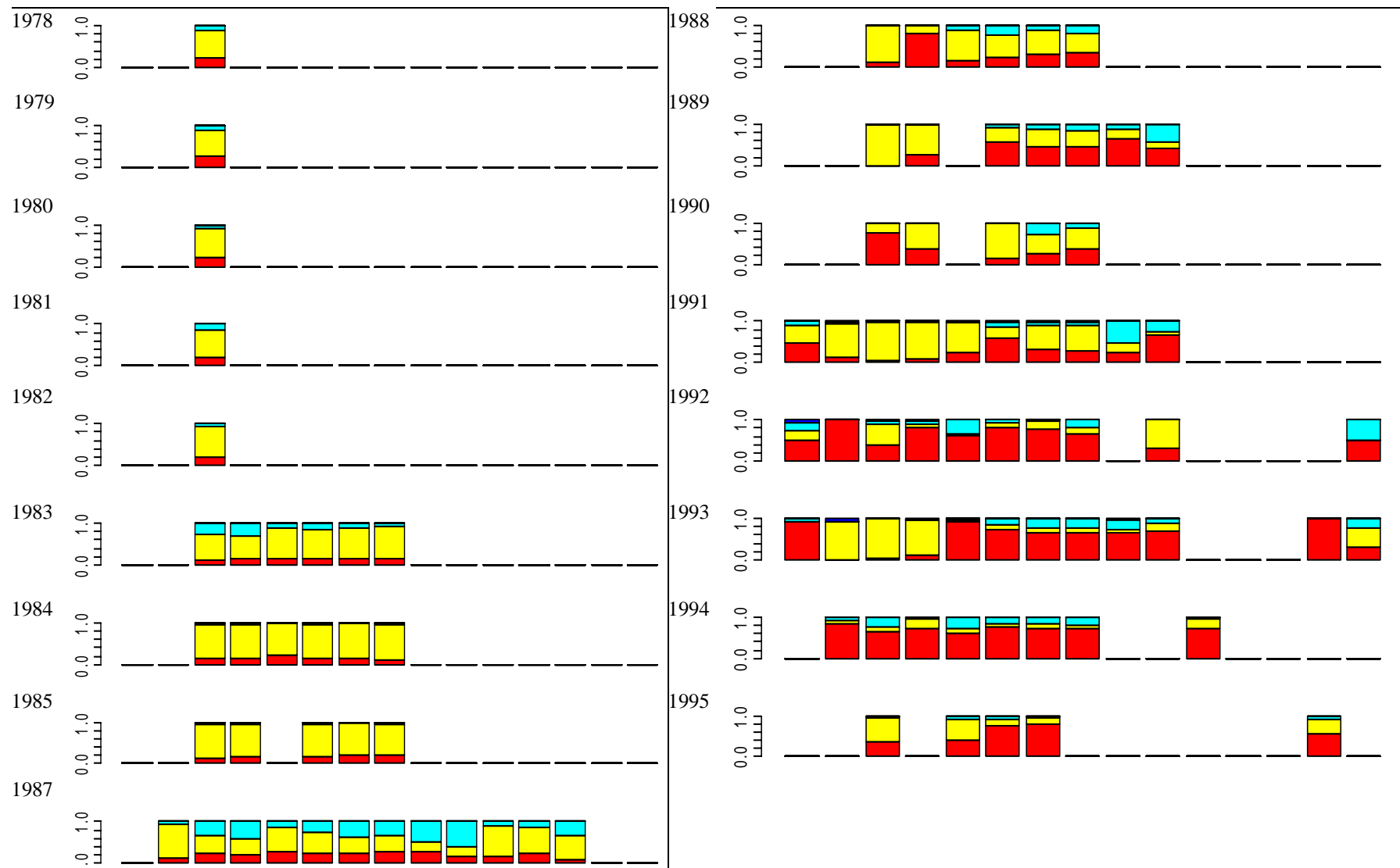
**Figure 10:** Annual tuna catch composition by hooks-per-basket, 1978 – 1995, from PSB data. Red=bigeye tuna, yellow=yellowfin tuna, blue=albacore
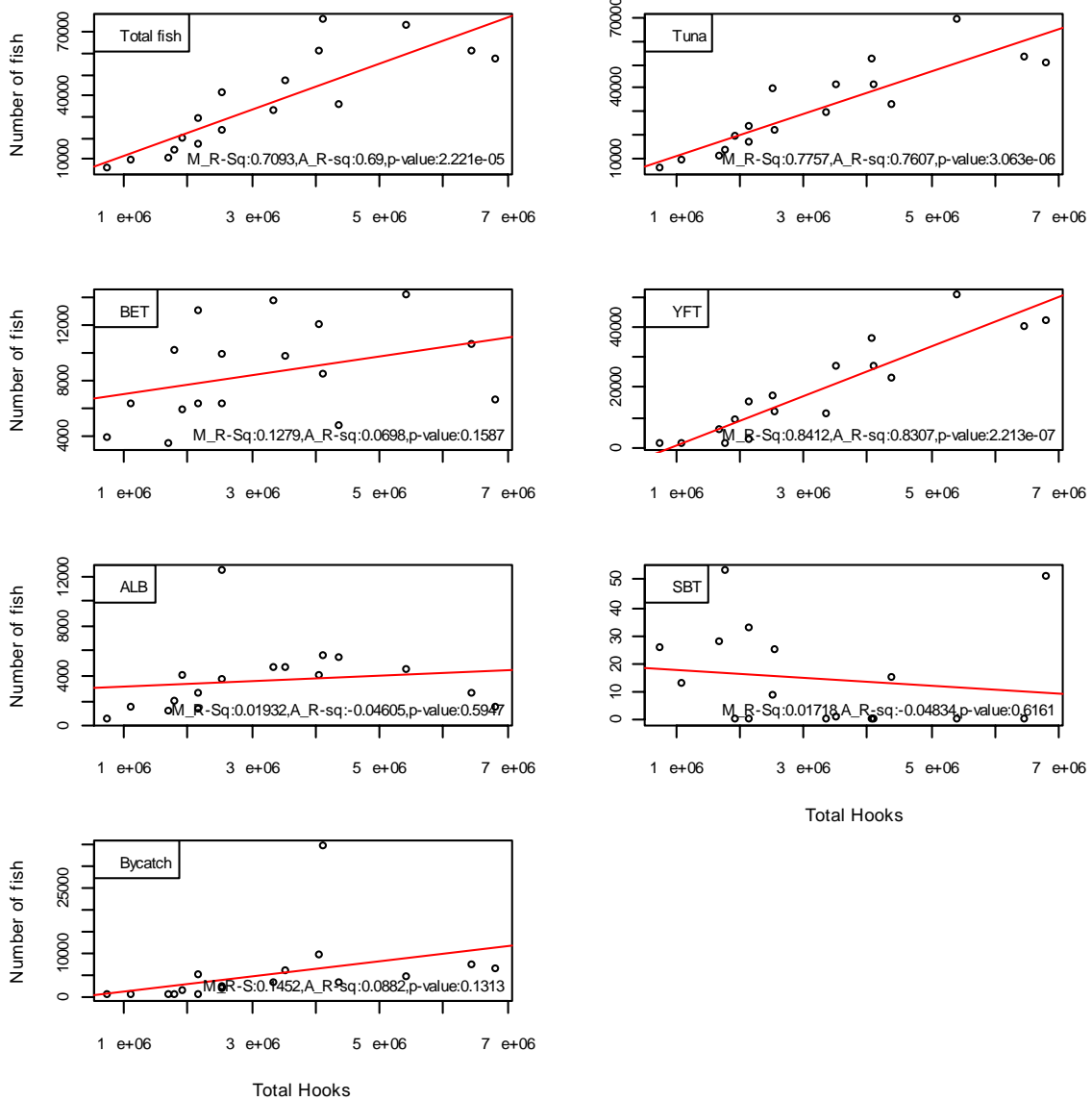
**Figure 11:** Scatterplots of annual total, tuna, bigeye tuna, yellowfin tuna, albacore, SBT and bycatch catch (numbers of fish) versus effort (numbers of hooks) with fitted linear regression lines, from the PSB data set.
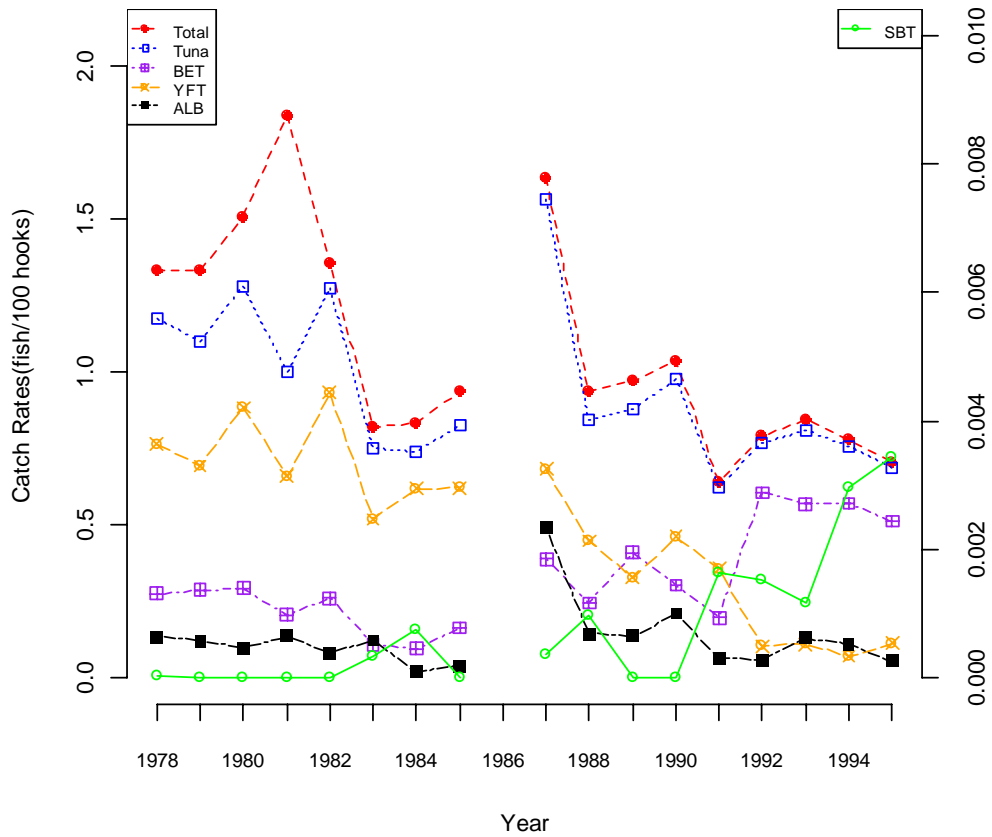
**Figure 12:** Nominal catch rates (numbers of fish per 100 hooks) for all species, all tunas, bigeye tuna, yellowfin tuna, albacore and SBT , from the PSB data set.

## Work in progress

Synthesised interpretation

The next step in this Ph.D. project is to attempt to integrate the findings across the 3 data sets. The outcomes from the 3 sets of exploratory analyses will be evaluated to determine the extent of consistency in interpretation, particularly across data sets that temporally overlap (i.e. the PSB data since 2000 and the FHS data; and the FHS data and observer data since 2006). Such a synthesis will also help to evaluate the general nature of the fishery to date by providing the most complete history possible.

An immediately apparent consistent outcome is that there have generally been few discernable or strong seasonal, spatial and/or temporally consistent patterns in catch and/or fishing behaviour, and that no clear patterns have emerged in attempting to relate catches and/or fishing patterns to environmental variables or targeting behaviours. The question remains as to whether this is an accurate reflection of the fishery, or whether is due to the quality of the data, in terms of accuracy (as per the FHS data), or the extent of the coverage (both in terms of the proportion of fishing activity reported, and to what extent the reported data is representative of the fleet), or the lack of an appreciable time series (in particular, for the observer data).

CPUE standardisation

Paper CCSBT-ESC/0709/15 discussed the possibility of undertaking CPUE standardization to develop an index of SBT spawning biomass from the FHS data, pending sensitivity analyses to explore how the standardized CPUE may be affected by inaccuracies in location and species identification. However, it has since been decided not to pursue this as part of the current Ph.D. project, given that the trial observer program provides a more robust and detailed data set, and includes environmental information and information on targeting behaviours.

Currently, CPUE standardisation is being undertaken on the observer data set using generalized linear modelling. This will provide the first proxy abundance index relating to Indonesian longline fishing activity, which should provide an improved understanding of the fishery impact. Such abundance indices can also be used as an input to stock assessment.

Cluster analysis has been undertaken to allow the statistical identification of sets mostly comprising (and thus supposedly targeting) the species of interest. CPUE Standardisation can then be undertaken on this subset of data. By eliminating "non-targeted" sets, a more reliable abundance index may be obtained.

Clearly the observer data will not yet yield an insightful time series of standardised CPUE, but the protocols for CPUE standardisation developed here can be readily applied as the database grows.

Simulation model

As the final part of the project, a simple simulation model will be developed to evaluate monitoring options for delivering robust data. This simulation would evaluate the minimum monitoring requirements for delivering data that best reflects the total catch and effort and the underlying stock abundance, while considering the socio-economic consequences of the management arrangements. This simulation will addressing the deficiencies highlighted from the analysis of the existing data sets by suggesting an optimal way forward.

The simulation would be informed by the existing data and the current "Benoa monitoring model" in establishing a "mock" Indonesian longline fishery on which alternative observer programs/monitoring strategies can be imposed. This simulation framework would be spatially and temporally explicit. Using the framework, alternative monitoring strategies could be evaluated. The range of strategies tested would be pragmatic in acknowledging the socio-economic limitations of the observer program. Specifically, one could statistically design and evaluate a suite of alternative monitoring/observer strategies, to investigate the effects of:

- The number of observers
- The number of trips covered
- The relative coverage from each port
- Alternative spatial coverage by observers relative to that of the total fleet
- Alternative temporal coverage by observers relative to that of the total fleet
- IUU (illegal, unregulated and unreported) fishing
- Collecting only a subset of explanatory variables (in the context of CPUE standardization: is the standardized CPUE index compromised if the observers do not collect certain data [environmental variables/targeting information/vessel capacity/gear configuration] ? This can be evaluated via "mock" CPUE standardizations of "mock" data, and will be informed by the "real" CPUE standardizations undertaken earlier using the observer data (i.e. we have a sense of which variables are statistically significant, but how does this play out in a simulated context when these variables are omitted ?)
- Alternative fleet distributions (a higher-order effect: the interpretations associated with the above effects may play out differently in another year where the fleet dynamics are different)

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