UTILITY OF FISHERY HIGH SCHOOL DATA IN EXAMINING SPATIAL AND TEMPORAL CATCH AND EFFORT TRENDS IN THE INDONESIAN LONGLINE TUNA FISHERY

Lilis Sadiyah[1], Natalie Dowling[2], Budi Iskandar Prisantoso[1], Retno Andamari[3] and Craig Proctor[2]

[1]Center for Fisheries Management and Conservation, Jakarta (CFMC)
[2]CSIRO Oceans and Atmosphere Flagship, Hobart, Tasmania, Australia
[3]Institute for Mariculture Research and Development, Agency for Marine and Fisheries Research, Ministry of Marine Affairs and Fisheries, Gondol, Bali (IMRD)
Received; June 12-2015 Received in revised from December 01-2015; Accepted December 02-2015
email: lilis_sadiyah@yahoo.com

ABSTRACT

One of the endeavours to address the shortage of catch per unit effort (CPUE) information from the Indonesian Indian Ocean tuna fishery is the collation of a large amount of catch and effort data collected by Indonesian Fisheries High School students ("FHS data"). This paper attempts to investigate spatial-temporal patterns of catch and effort of the FHS data for the main tuna species caught by the fishery: bigeye tuna (*Thunnus obesus* - BET), yellowfin tuna (*T. albacares* - YFT), albacore (*T. alalunga* - ALB) and southern bluefin tuna (*T.maccoyii* - SBT). Reported sets occurred in the Eastern Indian Ocean, north and south of 20°S. Recorded effort from the FHS data set was concentrated within the only known SBT spawning ground. However, within this data set, SBT were recorded in the lowest catch proportion relative to BET, YFT and ALB. The catch composition data suggested that YFT and ALB were predominantly targeted by the fishery, with ALB and SBT most predominantly recorded south of 20°S, whereas BET and YFT were mostly recorded north of 20°S. Unfortunately, there was no strong information on targeting practices reported by this data set, limiting any attempts to understand the factors that influenced those results. As the sampling predominantly occurred in between July and December, the data are not representative of fishing activities throughout the entire year, and any seasonal patterns from the FHS data set are biased. In addition, the FHS data set is prone to observation error and uncertainty in terms of fish identification and fishing location. Therefore, the FHS data set needs to be interpreted with caution.

KEYWORDS: Indonesian Fisheries High School Students Data, longline, Indian Ocean

INTRODUCTION

There have been some endeavours to address the shortage of catch-per-unit-effort, or CPUE, information from the Indonesian Indian Ocean longline tuna fishery. This includes the collation of a large amount of catch and effort data that has been collected by Indonesian Fisheries High School students ("FHS data"). The FHS training program was organised by WASKI ("Unit Pengawas Kapal Ikan" = Office for Control and Surveillance of Fisheries Vessels), a government office in the Benoa Fishing Port that is under the Directorate General of Marine Resources and Fisheries Control since 1995 (Basson *et al*., 2005; Basson *et al*., 2007). Since 2000 Indonesia's Research Institute of Marine Fisheries (RIMF) and WASKI have been collaborating on the documentation of the FHS data. In 2004, Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) began to collaborate with these organisations, and with Indonesia's Research Centre for Fisheries Management and Conservation (RCFMC)[1] and Directorate General of Capture Fisheries (DGCF) (Basson *et al*., 2005; Basson *et al*., 2007). Students are placed on the Indonesian Indian Ocean tuna longline vessels based at Benoa Fishing Port and are required to undertake one (full) trip to sea as an observer as a requirement for their graduation (Bachelor's Degree) (Basson *et al*., 2005; Basson *et al*., 2007). This enables them to gain experience on vessels and to observe and learn fishing techniques. However, in some cases students do not fulfil the requirement of completing a full trip due to seasickness.

It should be noted that the FHS data collection does not equate to a rigorous survey. As trainees, students are likely to make more mistakes in fish identification than a trained observer. In addition, the students relied on information from the captain or crew for fishing positions, as they were not equipped with Global Positioning Systems (GPS). Furthermore, data were only collected within a restricted time of the year, mostly after the students' examination period (i.e. after June). However, a large amount of catch and effort data (2514 trips recorded from 2000 - 2007) have been collected by the Fisheries High School students, which provides a time series of spatial and seasonal patterns of catch and effort, and includes bait type information.

[1]Previously called as Research Centre for Capture Fisheries (RCCF).

Corresponding author:
Center for Fisheries Management and Conservation
Jl. Pasir Putih II, Ancol Timur, Jakarta Utara-14430

Therefore, to begin to address the lack of catch and effort information, the data gathered by the Indonesian Fisheries High School students were used to gain some insight into Indonesia's tuna fisheries.

A preliminary investigation of the FHS data (up to June, 2005) had been done previously by Don Bromhead (Bureau of Rural Sciences, Australia) in collaboration with the CSIRO Pelagic Fisheries and Ecosystems Group (PFE) (Basson *et al*., 2005). The results of some of those investigations were reported to the 2005 Commission for the Conservation of Southern Bluefin Tuna (CCSBT) Scientific Meeting (Basson *et al*., 2005). However, the filtering (cleaning) of the data during those preliminary analyses was considered to be relatively coarse (Basson *et al*., 2007). This paper attempts to investigate spatial-temporal patterns of catch and effort of the FHS data for the main tuna species caught by the fishery: bigeye tuna (*Thunnus obesus* - BET), yellowfin tuna (*T. albacares* - YFT), albacore (*T. alalunga* - ALB) and southern bluefin tuna (*T. maccoyii* - SBT).

MATERIAL AND METHODS

The FHS data examined were obtained between October 2000 and June 2007 (Table 1). Students generally commenced on-board training after their examination period, i.e. after June. The number of Fisheries High Schools offering this training showed a steady increase from 13 schools in 2000 to 19 schools in 2006 (Table 1).

Student data collection included detailed trip and setting information including: a unique trip identification number ("trip ID"), vessel name, company name, vessel size (GT), a unique set identification number ("set ID"), setting date, species caught and retained (recorded as numbers of fish), fishing position, total number of hooks per set, type of bait used, and water temperature. Unfortunately, length and weight information of fish caught, and environmental information other than temperature were not recorded. Catch data were recorded by number for both tuna and bycatch species. Catch information covers the four tuna species BET, YFT, ALB and BET, and bycatch species: black marlin (*Makaira indica*), blue marlin (*M. nigricans*), striped marlin (*Kajikia audax*), white marlin (*Makaira* spp.*)*, broadbill swordfish (*Xiphias gladius*), Atlantic sailfish (*Istiophorus albicans*), longbill spearfish (*Tetrapturus Pfluegeri*) and other marlin species (*Makaira* spp.). However, as many other species are caught as bycatch by the fishery, as recorded by the Observer Program[2] (analysis on this data set is given in Sadiyah *et al*., 2014), the FHS data set is not fully representative of the bycatch occurring in the fishery.

Of the total 2,514 trips recorded, vessel size was reported for ~70% (1,775 trips). Students were only allowed by WASKI to carry out training on vessels with size ed 30 GT (*pers comm. with WASKI*, 2006). However, 247 trips which were reported to have occurred on vessels with size < 30 GT, and it was assumed these trips were incorrectly recorded by the students, in terms of the vessel size.

In some cases, there was a time lag between the registration process and the commencement of training (Table 1 and Table 2). The data consist of a total of 81,741 sets with the number of sets observed per trip ranging from 2 to 161 sets. Smaller numbers of observed sets per trip were most likely recorded when students did not record vessel activities for the entire duration of the trip (e.g. due to seasickness). On average, each set's duration was one day.

Number of hooks between floats (number of hooks per basket) were not available to indicate targeting practices (where a greater number of hooks per basket equates to a deeper set), but the number of hooks per blong and the number of blong per set were recorded. A blong is a traditional system used by Indonesia's fishers as a unit to indicate the number of hooks. One blong might consist of several baskets or one large basket, but the number of baskets in one blong was not defined. Since information on number of hooks between floats data were not available within the data set, total number of hooks per set was calculated by multiplying the number of hooks per blong by the number of blongs.

The data were cleaned by eliminating obvious errors including incorrect position information on fishing grounds of the vessels (i.e. where positions overlapped with mainland or islands), duplicate trip IDs (where different trip IDs had the same vessel name, and same departure and return date., and obvious erroneous set IDs (where the date associated with a set was outside of the date range associated with the trip ID). The FHS data presented in this paper were restricted to the area between longitude 70° and 150°E, and between latitude 0° and 40°S, which covers the

[2] A trial Observer Program for the industrial tuna longline fishery based at Benoa Fishing Port, Bali, commenced in mid 2005.This program was a collaboration between Indonesia's Ministry of Marine Affairs and Fisheries (MMAF) through the RCCF, and CSIRO Marine and Atmospheric Research (Australia), and was 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) (ACIAR, 2002).

spawning ground of tropical tuna (Nishikawa *et al*., 1985) and southern bluefin tuna (Collette & Nauen, 1983; Nishikawa *et al*., 1985; Safina, 2001). This area limitation was imposed because Indonesia's longline vessels based at Benoa (Bali), were unlikely to fish outside of that area. Three percent of the total recorded sets were outside of the core tuna fishery and so were excluded from analysis.

Table 1. Number of registered students at WASKI by month prior to their trips to sea

Year	Number of registered students at WASKI by month												Number of Students	Number of Schools
	1	2	3	4	5	6	7	8	9	10	11	12		
2000	0	0	0	0	0	112	210	40	103	0	0	0	465	13
2001	0	0	0	0	0	173	114	171	187	56	0	0	701	15
2002	57	20	0	0	0	94	206	128	44	72	22	33	676	16
2003	0	23	0	0	0	44	62	130	66	158	45	21	549	18
2004	29	20	27	55	45	50	89	80	61	0	0	62	518	18
2005	25	44	21	19	73	69	18	73	44	6	36	26	454	19
2006	38	61	0	20	57	20	57	15	40	14	59	0	381	19
2007	30	56	22	17	57	33							215	9

Source: WASKI (2003), WASKI (2004), WASKI (2005), WASKI (2006), WASKI (2007) and WASKI (2008) (Note: sometimes there was a time lag between the registration process and the commencement of training)

Table 2. Summary of the catch (for BET, YFT, ALB and SBT) and effort data recorded by the Fisheries High School students within the core area, together with the actual number of landings occurring at Benoa Fishing Port

Year	Number of Sets Recorded by Month												Effort			Average no. of sets per trip	No. of trips recorded	No. of Landing recorded	No. of vessels landing at Benoa Fishing Port *)	Coverage (%)
	1	2	3	4	5	6	7	8	9	10	11	12	Days= Sets	Total hooks	1-degree Squares					
2000										716	269	16	1,001	1,114,955	106	21	47	47		
2001					14	281	2,068	2,632	2,552	3,002	1,466	125	12,140	13,768,741	344	20	603	603		
2002	435	190	310	58	17	44	1,575	2,877	2,445	2,177	1,469	906	12,503	14,369,475	376	22	561	516	3,347**)	15.41
2003	808	450	215	35		19	1,337	2,320	2,583	2,336	2,152	1,509	13,764	16,603,737	547	28	485	433	3,445	12.57
2004	880	542	415	488	751	893	1,449	1,949	1,801	1,998	1,102	979	13,247	16,908,113	532	37	354	316	2,922	10.81
2005	1,013	980	1,030	870	819	997	1,389	1,572	1,690	2,022	997	642	14,021	15,499,464	680	40	350	331	2,439	13.57
2006	441	726	738	677	926	820	806	1,089	749	458	370	675	8,475	9,378,512	548	34	247	230	1,664	13.82
2007	349	123	181	247	96	31							1,027	1,168,945	138	27	38	38	1,011	3.76

Notes:

Data available (shaded)

Data not available (blank)

* Source: Benoa Port-based Catch Monitoring Program

** Number of vessels landing in 2002 was only available from July to December (i.e. 2039 vessels landing), thus number of vessels landing from January to June of 2002 was estimated by an average number of vessels landing in the period between January and June of 2003-2007.

Records with fishing positions corresponding entirely to land were excluded from the data set, but if a set had a fishing position located in a 1-degree square straddling water and land, then the set was included in analyses. The cause of the errors may have been clerical (students incorrectly recording positions) or due to misinformation by the crew/captain. In addition, the cleaned data set was limited only to sets for which the total number of hooks per set recorded did not exceed 3,000 hooks (as it was unlikely the number of hooks per set exceeded 3000 hooks (*pers comm. with observers, 2006*). As a consequence, 3.85% of sets within the core tuna fishery were excluded.

RESULTS AND DISCUSSION

Results

In 2004 the recorded total catches by species (including tunas and bycatch species) and the recorded catch of tuna (BET, YFT, ALB and SBT combined) decreased by 4.97% and 18.64% relative to that in 2001, respectively (Figure 1a). This occurred even though the number of hooks recorded increased between 2001 and 2004 from around 14 million to approximately 17 million hooks (Figure 1b). The decrease in the 2004 tuna catch was mostly due to a decline in the catch of the three main tuna species (BET, YFT and ALB); the SBT catch in 2004 increased by about 34% compared to that in 2001. The closeness between tuna and total catch in 2001 is because the students only recorded tuna catches in that year; although bycatch species may have been caught, these were not recorded.

Of the four tuna species, the total number of YFT recorded showed the most decline over the time period (the number of YFT recorded in 2006 was less than half that in 2001) (Figure 1a). ALB was consistently the dominant tuna species caught (comprising more than 40% of the tuna catch) from 2002 to 2006, whilst SBT was caught in the lowest proportion (less than 20% of tuna catch) over the studied period (Figure 1a). The recorded BET catch ranged from around 12,900 to more than 20,000 fish between 2001 and 2006 (Figure 1a). On average, recorded bycatch comprised 18% of the total recorded catch, and ranged between 3% and 27% of the total recorded catch per year. The annual catch trends for tuna species from the FHS data (Figure 1a) differed from those suggested by the Benoa Port-based Catch Monitoring Program[3] (Appendix 1). It should be noted that the FHS data total catches are based on numbers of fish, whereas the Benoa monitoring program data is species by weight (tonnes).

In 2005, the number of hooks recorded in that year dropped by around 8% and 27% respectively, relative to the 2004 effort (Figure 1b). This was most likely due to the fuel price rise in August 2005. This had no noticeable effect on the catch recorded for 2005: on the contrary, the total catch increased by 46% of that in 2004 and reached its highest level in 2005 and the recorded total tuna catch increased by around 28% relative to the 2004 catch (Figure 1a). This trend continued in 2006, with a further decrease of recorded effort (number of hooks), to less than the 10 million recorded hooks (Figure 1b). Commensurate with the lower effort recorded in 2006, recorded catch across all species declined in that year to its minimum level between the period 2001 to 2006, after rising in 2005. The low catch numbers in 2000 and 2007 were due to a lack of data, with students going to sea in only 3 and 6 months, respectively (Table 2).

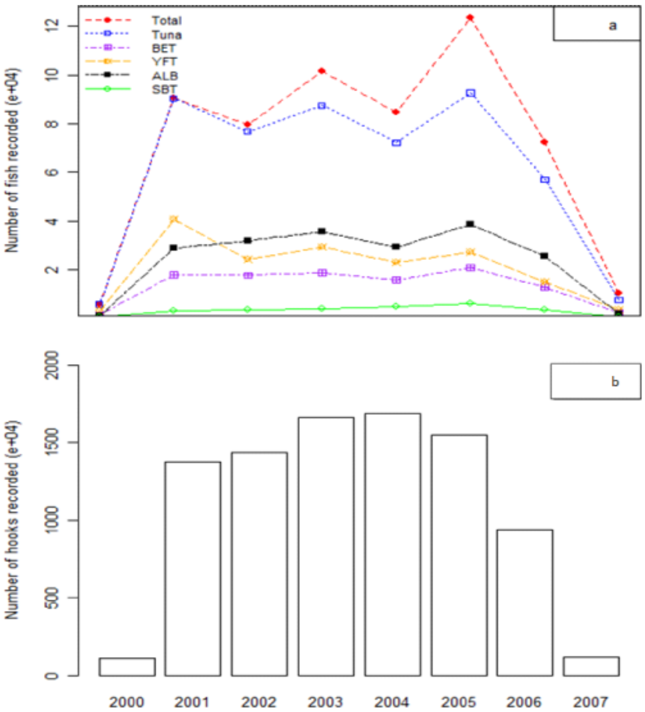


Figure 1. Number of fish (for the four tuna species, the combined tuna catch and total catch) (a) and total effort (number of hooks) (b) recorded by year in the FHS program.

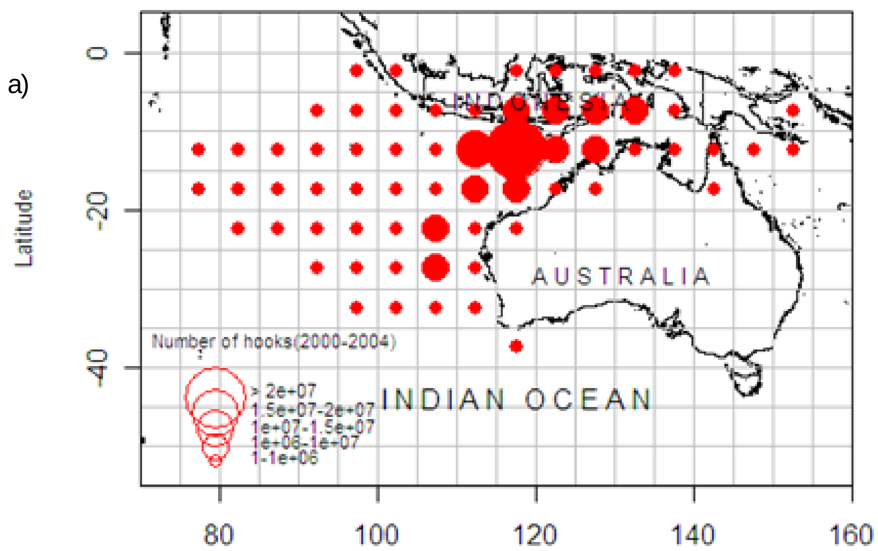
[3]A monitoring program established by Indonesia in 2002, in collaboration with Indian Ocean Tuna Commission, Japan and Australia, to collect data on daily landings of tunas and bycatch species from Indonesian longline vessels.

Across both periods, the total hooks recorded were concentrated in waters between Indonesia and Australia, northeast of the Indian Ocean, and southeast of Java (i.e. between 110º-120ºE and 10º-15ºS) (Figures 2a and 2b). The highest number of recorded hooks deployed (more than 20 million hooks, 32.48% of total hooks recorded over the period) occurred between 115º-120ºE and 10º-15ºS (Figure 2a). Since 2005 several new 5-degree squares were recorded as being fished within the areas 75°-90°E and 0°-10°S, 70°-75°E and 10°-20°S and several new 5-degree squares below 20°S, whilst several 5-degree squares were recorded as being fished in 2004 but not fished in 2005 (Figures 2a and 2b). But overall, there was no evidence of spatial contraction of the fleet in response to decreasing effort.

The spatial distribution of recorded tuna catch across all years was similar to the spatial distribution of effort (Figure 2c), in that the peaks in recorded catch occurred in the same areas as the peak recorded effort (i.e. within 110º-120ºE and 10º-15ºS, where more than 140,000 fish were recorded). The higher catches in these areas thus apparently reflect the effort recorded and as such are not necessarily indicative of abundance patterns. YFT formed the majority of the catch recorded between 0° and 15°S, while the predominant species recorded in the 5-degree squares below 15ºS was ALB (the maximum proportion of ALB recorded was more than 90% of the total recorded tuna catch). Within the study period, there was only one fished 5-degree square with no tuna recorded (within area 70º-75ºE and 10º-15ºS), and this effort was from only one set. Relative SBT recorded catch was higher within the areas 100º-105ºE and 30º-35ºS and 135º - 140ºE and 0º-5ºS. Recorded SBT catch in these areas comprised ~37% and ~60% of the total tuna catch recorded, respectively. As the latter 5-degree area is in the Banda Sea, outside of the known geographic range of SBT, the high SBT catch recorded in this area was most likely due to erroneous reporting of position and /or species identification.

The majority of recorded fishing effort occurred in the area between 115°-120°E and 10°-15°S, with most sets recorded by the FHS students in this area between July and November across the eight years examined (Figure 3). However, this is confounded by the fact that the majority of trips done by the students to sea occurred between July and November. The total number of hooks recorded in the other months never exceeded 2 million hooks across all years. The recorded effort was almost evenly distributed between March and August, with the maximum recorded in July.

The highest monthly SBT nominal CPUE occurred in April, May and October over the time period, while for other months SBT CPUE never exceeded 0.03 fish/100 hooks (Figure 4). Recall that the number of catches recorded by students was relatively low in April and May. The lowest SBT CPUE occurred in August (less than 0.02 fish/100 hooks) (Figure 4).



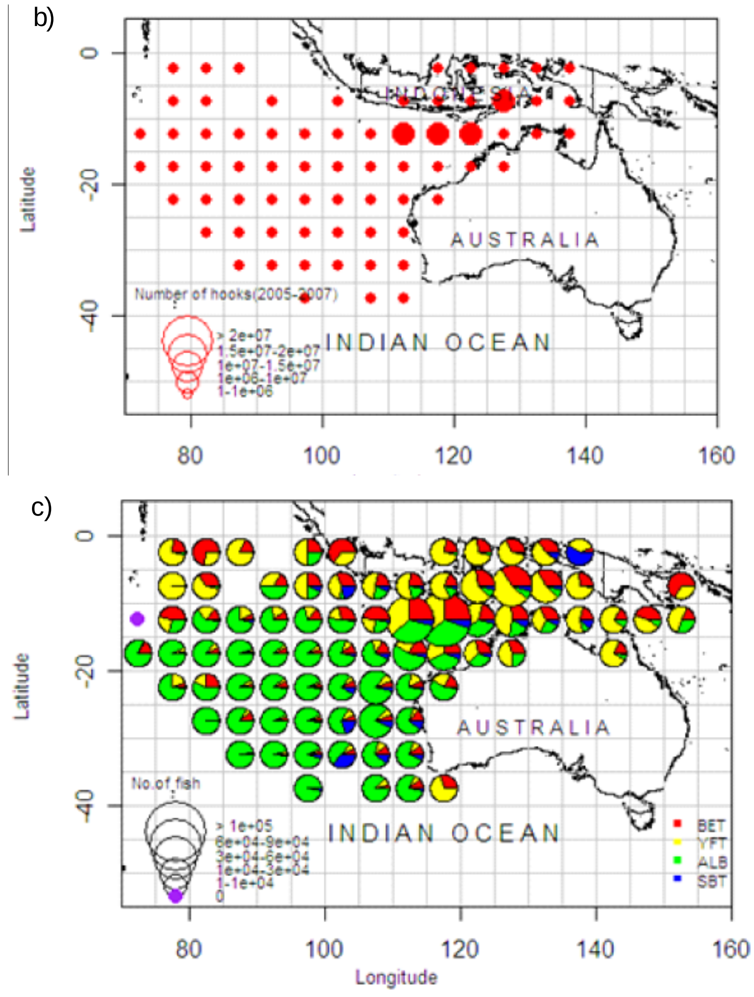


Figure 2. Spatial distribution of recorded effort (number of hooks) from 2000-2007 (a) and recorded catch (of the four tuna species) (b), expressed as total numbers of fish, from 2000-2007.

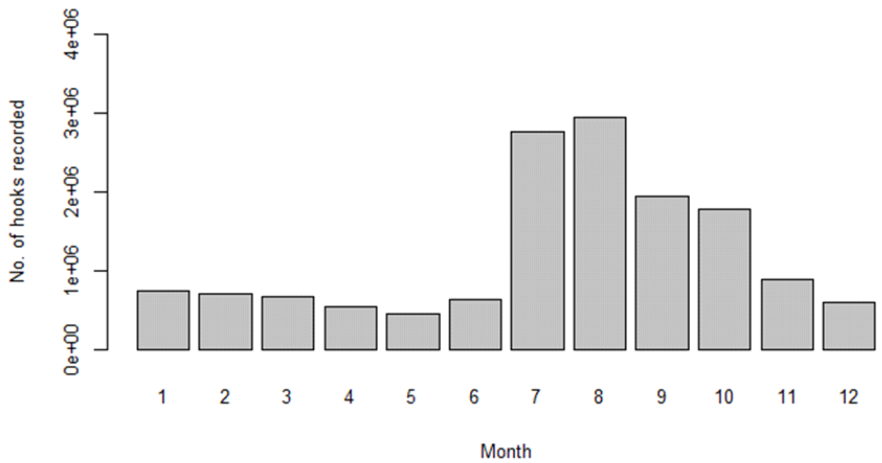


Figure 3. Number of hooks recorded by month in the area between 115° and 120°E, and between 10° and 15°S, aggregated from 2000-2007.

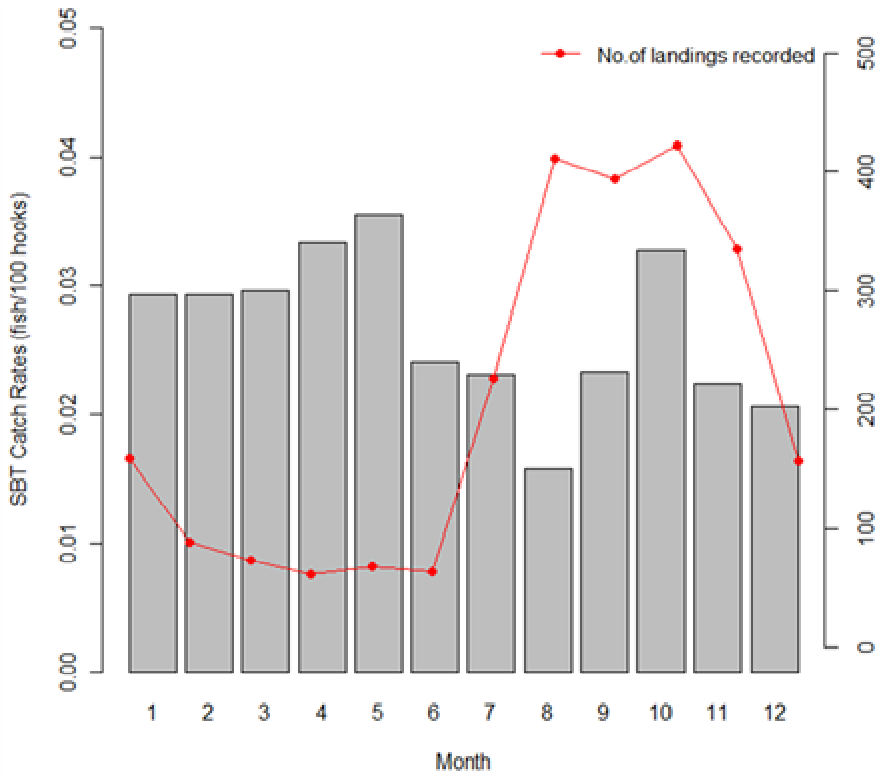


Figure 4. Nominal SBT catch rates (fish/100 hooks) by month, aggregated across all years, and the aggregated monthly recorded landings.

Discussion

Confounding Factors

The Fisheries High School students generally carried out training at sea between July and December (Table 2). As a result, the total recorded effort mostly occurred between July and November. As such, the quarterly effort pattern was largely influenced by the timing of the student activities as opposed to being a direct representation of the total effort distribution of the fleet. This was verified by examining the actual number of landings by vessels operating out of Benoa Fishing Port (Appendix 2), which showed the number of landings was relatively constant by quarter (except in 2002 where landings largely occurred in quarters 3 and 4). The higher recorded catch in quarters 3 and 4 also reflects the student coverage and the hooks recorded, and, as such, is not necessarily indicative of fish availability. This is in contrast to Japanese longline catch in the Western Australian Fishing Zone (from 1980 – 1996) where the majority of catch occurred in the first or fourth quarters of the year (Dowling & Campbell, 2001).

The interannual effort pattern was also influenced by the interannual pattern of student trips as opposed to being representative of the annual Benoa effort trend. Although the number of active vessels at Benoa Fishing Port was the main factor considered in determining the number of students undertaking training, the level of coverage was not consistent interannually. As an example, in 2005, when the fuel prices rose to more than double those in former years (following a lowering of Indonesian Government subsidies), which caused vessels of many fishing companies to become less active (Appendix 2), the number of students going to sea only decreased by about 14% relative to 2004 (Table 1). As a result, the landing coverage at sea by the students in 2005 was higher relative to 2004 (Table 2). The interannual variation in landing coverage, 10%-15% (between 2002 and 2006) of the total Benoa landings (i.e. catches landed in port) is not a high variability, but it does show that landing coverage is not absolutely consistent interannually.

Validation - Are Recorded Trends Reliable?

The FHS data suggested that ALB was the most dominant species (by numbers of fish) recorded between 2002 and 2006 (except in 2001 where YFT was recorded in the highest proportion) (Figures 1a and 1b). On the other hand, the Benoa Port-based Catch Monitoring Program suggested that both YFT and BET catches (in weight) were higher relative to ALB between 2002 and 2005 (Appendix 1). Either YFT or BET (in total weight) was generally suggested to be the dominant species caught by Indonesian tuna longline operating in the Indian Ocean (Campbell, 2004; Irianto *et al*., 2014). In contrast, Taiwanese longliners operating in the Indian Ocean caught mainly YFT during the late 1960s and early 1970s, but shifted to ALB during the mid 1970s, and then to BET in the 1980s, and since 1992, SWO became one of the main target species (Wang & Wang, 2002). Furthermore, the SBT catch pattern recorded by students showed a continuous increase in recorded numbers between 2002 and 2005 (Figure 1a), whereas the total weight of SBT landed in Benoa Fishing Port fluctuated between ~556 and ~1690 tonnes (Appendix 1). This may suggest that the size composition of SBT was variable (noting that the FHS data, however is not a representative coverage of the fleet). Unfortunately, information on weight and length of fish caught was unavailable, so it is difficult to resolve this issue using this data set.

The higher ALB catch recorded by the students relative to YFT is likely to be biased by the fact that the student activities mostly occurred at the latter half of the year. Without additional information on targeting, the high catches of ALB alone do not necessarily imply that this was the main target species. Availability of ALB may simply have been higher than YFT during the fishing period. Taiwanese data show that between October and November, ALB CPUEs are lower than in other months and in contrast, YFT shows a higher abundance in April and May (Lee *et al*., 1999). Given that the effort recorded by the students mostly occurred between July and December, the higher ALB CPUEs and lower YFT CPUEs are consistent with this observation.

Within the FHS data set, it was found that the increase in total hooks recorded between 2000 and 2004 was accompanied by an increase in the recorded bycatch proportion (total tuna recorded decreased while total catch recorded increased). More than 30 bycatch species were recorded within the Observer Program data, while only 8 bycatch species were recorded here. The level of bycatch or non-target species is often related to the fishing gear (i.e. longline) selectivity. As cited on the FAO website, a key definition of selective fishing refers to a fishing method's ability to target and capture organisms by size and species during the fishing operation. As such, the increase in bycatch recorded may indicate a decrease in gear selectivity during that period. However, the fact that the students were required to record more bycatch over time, is most likely to be the main factor responsible for the increase in recorded bycatch.

The fishing area was strongly localised between 115°-120°E and 10°-15°S (Figure 2). This area overlaps with the only known SBT spawning ground (i.e. between 103º and 128ºE, and 7º and 17ºS). However, effort was mostly recorded in this area between July and August (Figure 3), which does not coincide with the SBT spawning season, i.e. between September and April (Farley & Davis, 1998; Davis *et al*., 2003c) or from September to March (Caton, 1993) (SBT are distributed in the area below 30ºS between July and August (Anon, 2008). In addition, fishers experienced high catches for all tuna species in the SBT spawning areas. This may suggest that the effort localisation is more likely a result of this area being in close proximity to the home port, where fishers would fish and undertake fishing trials en route to their target fishing areas. Fishing close to port may be desirable if the aim is to sell the catch as fresh product for export to other countries, mainly to Japan (Proctor *et al*., 2003). To do so limits the trip duration to 15 fishing days (ATLI presentation to Tuna Monitoring Workshop, Bali, 12 July 2006).

Although the annual recorded effort, in terms of hooks deployed, was 18% lower in 2005 compared to 2004, the 2005 recorded tuna catch increased by about 12% over the 2004 tuna catch, and total recorded catch peaked in 2005. This was accompanied by an increase in nominal tuna CPUE in 2005, while the nominal total CPUE was at the highest level observed during the studied period. If vessels fished in the same area, used the same gear configuration, same fishing technique in the same season under consistent environmental conditions, then the higher 2005 CPUE than other years may indicate higher fish availability in 2005. However, conditions are almost never constant; for example, the fishing area in 2005 was different compared with that in former years. Thus standardisation of the nominal CPUE in order to statistically eliminate the influence of confounding factors on the relationship between CPUE and abundance is typically undertaken to yield a CPUE abundance proxy. Unfortunately other supplementary information was not recorded in the FHS data set, precluding CPUE standardisation.

The four tuna species are known to have different biological characteristics in terms of (but not limited to) their spawning behaviour, spawning ground and general habitat. This was reflected in the different observed spatial distributions in the recorded catch of the four tuna species, and furthermore by the spatial-temporal distribution of the species-specific recorded catch. Nominal CPUE for BET and YFT was higher in any 5-degree square within the tropical latitudes, consistent with the catch patterns of the

Japanese longline fleet operating in the whole Indian Ocean in 2000 (Dai *et al*., 2002), whereby the nominal Japanese CPUE of these species was higher in tropical than in temperate latitudes.

In the absence of information on number of hooks between floats, information on dominant tuna species caught from tuna catch composition can be used to infer gear type and targeting behaviour. The annual recorded tuna catch composition suggests that in 2001 the most dominant species caught was YFT, and for subsequent years the predominant species was ALB. YFT mostly occur above the thermocline (Campbell *et al*., 2002). The Benoa-based fishing company, PT Perikanan Samudra Besar[4], experienced tuna catches comprising more than 50% YFT per year when they used surface longline from 1978-1982 (Marcille *et al*., 1984), which may suggest that in 2001 most fishers used surface longline. It was stated by Lee *et al*. (2005) that ALB are targeted by Taiwanese longline vessels using surface longline (with number of hooks between floats ranged from 6 to 10) and ALB are the main target species for Taiwanese longliners (Yeh *et al*., 1995). As such, the gear type used from 2002 to 2005 was likely to have been predominantly surface longline.

Validity of Data

There are some issues that have been raised by the FHS data set regarding the accuracy of location information and species identification. A lot of sets recorded incorrect positions, as the coordinates corresponded to locations on land. Although those sets were excluded from the analyses, this position issue confers uncertainty on position information across the whole data set. This uncertainty is compounded by the fact that the students were not equipped with GPS during their trips, but gained location information from vessel skippers. As information on fishing ground is highly confidential, there is the possibility that skippers may have deliberately provided erroneous coordinates.

The issue of inaccurate species identification is predominantly highlighted by records where SBT have been recorded in locations known to be their only known spawning area, but outside of their spawning season, and also records of SBT caught outside their known geographic range (e.g. in the Banda Sea). SBT are distributed south of 30°S (south of their spawning area) outside of their spawning season (Collette & Nauen, 1983; Caton, 1993). Within the FHS data, it was noted that species recorded as SBT were caught in their spawning area between May and August over the studied period (i.e. outside of the SBT spawning season), and moreover, within the SBT sub-area, the nominal SBT CPUE by month was highest in May (Figure 4), yet the spawning season is between September and March/April. If this was caused by inaccuracy in species identification, then there is the potential for species misidentification across all species within the data set. However, it is also possible that the species identification was correct, but that the fishing location was wrongly recorded. A significant number of smaller SBT are known to be caught by some Benoa-based tuna longline vessels in seas south of the SBT spawning ground (Farley *et al*., 2007).

CONCLUSION

The FHS data set needs to be interpreted with a lot of caution due to the species identification and position information issues. Irrespective of the concerns, however, the spatial and fleet coverage recorded by this data set gives us a broad picture of the Indonesian spatial effort distribution. This extends north and south of 20°S of the Eastern Indian Ocean, with effort predominantly recorded in the area that overlaps with the SBT spawning ground. However, the FHS data set suggests that SBT were consistently recorded as the lowest catch proportion relative to BET, YFT and ALB. The nominal ALB and YFT CPUEs were higher than those for BET and SBT, suggesting that ALB and YFT were predominantly targeted by the fishery. ALB and SBT were predominantly recorded south of 20°S, whereas BET and YFT were mostly recorded north of 20°S. There was a clear decrease in YFT CPUE between 2000 and 2006. Unfortunately, there was no strong information on targeting practices reported by this data set, limiting any attempts to understand the factors that influenced those results. As the sampling predominantly occurred in between July and December, the data are not representative of fishing activities throughout the entire year, and any seasonal patterns from the FHS data set are biased.

ACKNOWLEDGEMENTS

The authors wish to thank Indonesia's tuna fishing companies and the Bali Office of WASKI for their cooperation, assistance and support, through access to the FHS data. We also thank the Fisheries High Schools students for their contribution in collecting onboard data. The core research underlying this paper was supported by the CSIRO Hobart and University of Tasmania and funded by an ACIAR John

[4]A State-owned Indonesian fishing company, which established in 1972, with financial support from Japanese Government, the first fleet of Benoa-based longline vessels and tuna processing facilities (Proctor *et al.,* 2003).

Allwright Fellowship and linked to ACIAR Project FIS/ 2002/074: *Capacity development to monitor, analyse and report on Indonesian tuna fisheries.*

REFERENCES

Anon. 2008. Report on biology, stock status and management of southern bluefin tuna: 2008. Second Session of the IOTC Working Party on Temperate Tunas, Bangkok, Thailand, 1 November, 2008. IOTC-2008-WPTe-INF02.

Bach, P., L. Dagorn & C. Misselis. 2000. The role of bait type on pelagic longline efficiency. ICES Annual Science Conference Theme Session J: Efficiency, selectivity and impacts of passive gears, Brugge, Belgium, CM 2000/J:01.

Basson, M., D. Bromhead, T.L.O. Davis, R. Andamari, I.G.S. Merta & C. Proctor. 2005. Indonesian fishery school data on southern bluefin tuna: summary and preliminary analyses. CCSBT 6th Meeting of the Stock Assessment Group and 10th Meeting of the Extended Scientific Committee, Taipei, Taiwan, 29 August - 3 September, and 5-8 September 2005. CCSBT-ESC/0509/17.

Basson, M., R. Andamari, L. Sadiyah & C. Proctor, C. H. 2007. An update on the use of the Indonesian Fishery High School dataset to obtain a standardised CPUE series for SBT on the spawning grounds. CCSBT 8th Meeting of the Stock Assessment Group and 12th Meeting of the Extended Scientific Committee, Hobart, Australia, CCSBT-ESC/0709/15.

Campbell, R.A. 2004. Overview of Longlining in the Indian Ocean. In: Long, K. J., and B. A. Schroeder (editors). Proceedings of the International Technical Expert Workshop on Marine Turtle Bycatch in Longline Fisheries. U.S. Dep. Commerce, NOAA. Technical Memorandum NMFS-F/OPR-26, 189 p.

Campbell, R.A., N. Dowling & M. Basson. 2002. Review of information pertinent to the setting of total allowable catches in the Southern and Western Tuna and Billfish Fishery. 1st TAC Setting Workshop for SWTBF, Fremantle, Perth, 17-18 June, 2002.

Caton, A.E. 1993. Review of aspects of southern bluefin tuna biology, population, and fisheries. Proceedings of the first FAO Expert Consultation on Interactions of Pacific Tuna Fisheries Noumea, New Caledonia, 3–11 December 1991. Interactions of Pacific tuna fisheries.

Collette, B.B & C.E. Nauen. 1983. Scombrids of the world: an annotated and illustrated catalogue of tunas, mackerels, bonitos, and related species known to date. Generic. Rome, United Nations Development Programme: Food and Agriculture Organization of the United Nations.

Dai, X.-J., L-X. Xu & L-M. Song. 2002. Preliminary analysis of the Nominal CPUE and fishing effort in the China longline fishery in the Indian Ocean. Fourth Session of the IOTC Working Party on Tropical Tunas, Shanghai, People's Republic of China, IOTC-2002-WPTT-14.

Davis, T.L.O., J.H. Farley, M. Bravington & R. Andamari. 2003c. Size at first maturity and recruitment into egg production of southern bluefin tuna Final Project No. 1999/106. 58 pp.

Dowling, N. & R. Campbell. 2001. Assessment of the Japanese longline fishery off Western Australia: 1980-1996. Assessment of the tuna and billfish resources within the western AFZ and the Indian Ocean: compilation of related project papers. 2003. Hobart, Tas., CSIRO Marine Research.

Farley, J. & T.L.O. Davis. 1998. Reproductive dynamics of southern bluefin tuna, *Thunnus maccoyii*. *Fishery Bulletin,* 96: 223-236.

Farley, J., R. Adamari & C. Proctor. 2007. Update on the length and age distribution of SBT in the Indonesian longline catch. CCSBT-ESC/079/10. Extended Scientific Committee Meeting of CCSBT, 10-14 September 2007, Hobart, Australia.

Irianto, H.E., Wudianto, A. Suman, K. Susanto, B. Nugraha, F. Satria& S.D. Retnowati. 2014. Indonesia National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2014. Presented to the 17th Scientific Committee Meeting, Victoria, Seychelles, 08-12 December 2014. IOTC–2014–SC17–NR10.

Lee, P.-F., I-C. Chen & W-N. Tseng. 1999. Distribution patterns of three dominant tuna species in the Indian Ocean. Proceedings of the Environmental Systems Research Institute International User's Conference, 1999, San Diego, California.

Lee, Y.C., T. Nishida & M. Mohri. 2005. Separation of the Taiwanese regular and deep tuna longliners in the Indian Ocean using bigeye tuna catch ratios. *Fisheries Science,* 71: 1256-1263.

Marcille, J., T. Boely, M. Unar, I.G.S. Merta, B. Sadhotomo & J.C.B. Uktolseja. 1984. *Tuna Fishing in Indonesia,* Paris, l'ORSTOM. Institute Francais de Recherche Scientifique Pour le Developpement en Cooperation.

Nishikawa, Y., M. Honma, S. Ueyanagi & S. Kikawa, S. 1985. Average distribution of larvae of oceanic species of scombrid fishes, 1956-1981. *Far Seas Fish. Res. Lab. S Ser.,* 12, 1-99.

Prisantoso, B.I., R. Andamari & C. Proctor. 2008. The catch of SBT by the Indonesian longline fishery operating out of Benoa, Bali in 2007. CCSBT 5th Management Procedure Workshop and the 13th Meeting of the Extended Scientific Committee, Rotorua, New Zealand, 2-10 September 2008 and 5-12 September 2008.

Proctor, C.H., I.G.S. Merta, M.F.A. Sondita, R.I. Wahju, T.L.O. Davis, J.S. Gunn & R. Andamari. 2003. A review of Indonesia's Indian Ocean tuna fisheries. Country status report. Hobart, CSIRO Marine Research. 1876996498. vi, 106 p.

Proctor, C., R. Andamari, D. Retnowati, B.I. Prisantoso, F. Poisson, M. Herrera & S. Fujiwara. 2007. The catch of SBT by the Indonesian longline fishery operating out of Benoa, Bali in 2006. CCSBT 8th Meeting of the Stock Assessment Group and the 12th Meeting of the Extended Scientific Committee, Hobart, Australia, 4-8 September 2007 and 10-14 September 2007.

Sadiyah, L., N. Dowling, B.I. Prisantoso, R. Andamari & C. Proctor. 2014. CPUE trends of the Indonesia's tuna longline fishery: Lessons learned from a trial observer program. (2014). *Ind. Fish Res. J.*, 20 (1): 37-47.

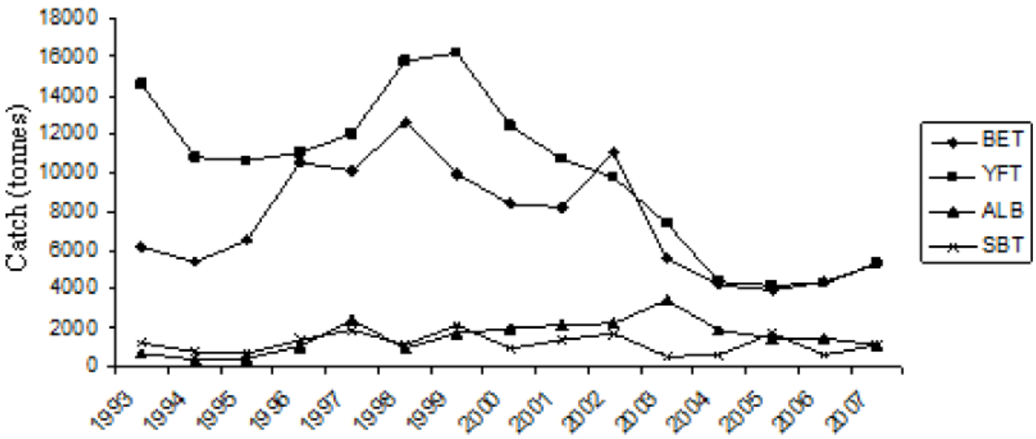
Safina, C. 2001. Tuna conservation. In Stevens, B. B. A. E. (Ed.) *Fish Physiology.* Academic Press. 413-459

Wang, S.-B. & S-H. Wang. 2002. A brief report on Taiwanese tuna longline fisheries operate in the Indian Ocean. Fourth Session of the IOTC Working Party on Tropical Tunas, Shanghai, People's Republic of China, 3-11 June, 2002. IOTC-2002-WPTT-10.

Yeh, S.-Y., C.-F. Hui, T.D. Treng & C.-L. Kuo. 1995. Indian Ocean albacore stock structure studies by morphometric and DNA sequence methods. Sixth Expert Consultation on Indian Ocean Tunas, Colombo, Sri Lanka 25-29 September, 1995. IPTP/95/EC602-25.

APPENDICES

Appendix 1. Landings (tonnes) of bigeye (BET), yellowfin (YFT), albacore (ALB) and southern bluefin (SBT) tunas from longliners from Benoa Fishing Port (modified from Davis *et al*. (2003a), Proctor *et al*. (2007) and Prisantoso *et al*. (2008).



Appendix 2. Number of landings by Benoa-based longline vessels by month, recorded by Benoa Port-based Catch Monitoring Program.

Month	2000	2001	2002	2003	2004	2005	2006	2007
January	-	-	246*)	325	320	248	193	145
February	-	-	202*)	310	206	218	111	165
March	-	-	205*)	265	274	198	130	159
April	-	-	206*)	296	234	205	129	168
May	-	-	213*)	265	234	212	157	195
June	-	-	236*)	323	273	236	170	179
July	-	-	353	292	242	218	130	
August	-	-	331	279	249	193	102	
September	-	-	348	286	231	194	119	
October	-	-	381	231	210	237	160	
November	-	-	336	305	235	113	104	
December	-	-	290	268	214	167	159	
Total	-	-	**3348**	**3445**	**2922**	**2439**	**1664**	**1011**

Source: Davis *et al*. (2004), Davis *et al*. (2005), Proctor *et al*. (2006), Proctor *et al*. (2007), Prisantoso *et al*. (2008)
* The number of vessel landings per month between January and June of 2002 was estimated as the average number of vessels landing in the same months from 2003 to 2007.