CCSBT-ESC/2308/10
(ESC Agenda item 7.1)

Australia's National
Science Agency

Update on the length and age distribution of southern bluefin tuna (SBT) in the Indonesian longline catch

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CCSBT-ESC/2308/10

Prepared for the CCSBT Extended Scientific Committee for the Twenty Eighth Meeting of the Scientific Committee

28 August – 2 September 2023

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Acknowledgments

The success of the SBT monitoring program in Indonesia has only been possible due to the dedicated efforts of all participating scientists at Research Institute for Tuna Fisheries (Bali), and in particular that of Mr Kiroan Siregar and Mr Rusjas Mashar and other staff involved in measuring SBT and collecting otoliths and tissue samples in Indonesia. We also thank Mr Enjah Rahmat (RIMF) for earlier years of data entry into the SBT biological database and to Mr Budi Iskandar Prisantoso (RCFMC) and Ms Retno Andamari (Gondol Mariculture Research Institute) in their former roles as database manager and monitoring program manager respectively. We also acknowledge Ms Paige Eveson for providing the R script in this report and Mr I Gede Bayu Sedana for his assistance in fixing the R bugs. The cooperation of the longline tuna industry (coordinated through Asosiasi Tuna Longline Indonesia), and the individual processing companies in providing access and facilities to carry out the sampling is much appreciated. We also acknowledge the support of all other agencies within Ministry of Marine Affairs and Fisheries (Indonesia) for the research activities.

Abstract

This paper updates previous analyses of southern bluefin tuna (SBT) length and age data from the Indonesian longline fishery operating out of the port of Benoa, Bali. In 2022, otolith samples collected during the 2019/20 and 2020/21 spawning seasons, which were unable to be transported from Indonesia to Australia were delivered to CSIRO laboratories in Hobart. From each season's collection of 1,500 otoliths, a subsample of 500 were selected and sent to Fish Ageing Services (FAS) for age estimation. An age-length key (ALK) was developed for each season using this sub-sample of aged fish. As discussed in Farley et al. (2021), determining suitable length data to apply the age-length key continues to present a challenge as data from two sources (catch monitoring by enumerators in port and CDS) provided different age composition results for the five years compared. This year, we used length data obtained from the otolith sampling program as the fish were landed fresh and more likely to have been caught in CCSBT statistical Area 1 (close to Indonesia and includes the spawning ground) rather than in Area 2 (south of Area 1). The update length and age distribution data were provided to CCSBT and are used in the 2023 stock assessment. The data showed that the mean size/age of SBT monitored has fluctuated around 160-165 cm FL / 12-15 years for the last 9 seasons. However, it is unclear if a higher proportion of small fish may be classed as "reject" (and available for sampling), skewing the size frequency data used in the ALK analyses over this period. Further work is needed to examine the uncertainties identified in Farley et al. (2021) and to refine and improve the quality control of the monitoring program.

Otolith samples were not collected in Indonesia in the 2021/22 season due to disruptions caused by institutional changes in Indonesia during this period. Otolith sampling recommenced in February 2023 and 148 samples were collected for the 2022/23 season. As we will have no (or very little) age data for these two seasons, it will not be possible to build annual age-length-keys for this period. To estimate the age distribution of the catch, we can develop an ALK using the direct age data for the two preceding seasons (2019/20 and 2020/21) and apply it to the 2021/22 and 2022/23 length frequency data, when and if it is available.

Introduction

The southern bluefin tuna (SBT) spawning ground lies between Indonesia and the northwest coast of Australia, where spawning occurs during September to April each year (Farley and Davis 1998). SBT caught in the Indonesian fishery on the spawning ground is categorized as a by-product of the longline vessels, which mainly target bigeye and yellowfin tuna. Obtaining an accurate estimate of the size and age composition of SBT landed by the Indonesian longline fishery is central to population modelling and stock assessments and close-kin mark recapture (CKMR), which are used by CCSBT to monitor changes in the spawning population over time.

The 30-year program of monitoring the size and age structure of the SBT spawning population was first established in 1993 through a series of collaborative projects between Indonesia's marine fisheries research institutes[4] within the Ministry of Marine Affairs and Fisheries (MMAF) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Farley et al. 2017). The main location monitored for SBT was the Benoa Fishing Port in Bali. In 2002, the scope of research collaboration expanded to include more tuna species (yellowfin, bigeye and albacore) and related species (billfish and other bycatch species) landed by the longline fleet. This occurred with the addition of new partners to the collaboration: the Indian Ocean Tuna Commission (IOTC) and Japan's Overseas Fishery Cooperation Foundation (OFCF) (Farley et al. 2014). The monitoring locations expanded to three fishing ports: Muara Baru (Jakarta) and Cilacap (south coast Central Java), in addition to Benoa (Farley et al. 2007). The majority of targeted SBT sampling, however, still occurs at Benoa, as this is the port where the majority of Indonesian caught SBT are landed. The monitoring program samples otoliths from the 'reject' quality SBT (graded as non-export quality) (Farley et al. 2007).

The Extended Scientific Committee (ESC) developed a new Scientific Research Plan (SRP) for SBT in 2013. Specific priorities and projects to be included in the new SRP were reviewed in 2014 and again in 2015. Several items were identified as high priority in the subsequent 2016 work plan including the ageing of Indonesian SBT otoliths and continued collection and archiving of SBT tissue samples for close-kin genetics (see paper CCSBT-ESC/1708/09). This paper provides an update on the length and age distribution (Sulistyaningsih et al. 2020; Farley et al. 2021) of SBT in the Indonesian longline catch, which is a deliverable for one of these SRP projects (Attachment 12, Anon 2019).

Methods

Otolith collection 2021/22 and 2022/23

Otolith samples were not collected from the Indonesian longline fishery in 2021/22 due to disruptions caused by institutional changes in Indonesia. A training workshop was held in January 2023 for DGCF Enumerators in Benoa on how to collect SBT muscle tissue and otolith samples, to enable the SBT monitoring and sampling in Benoa to recommence. Sampling recommenced in February 2023 and 148 otolith samples were collected (the 2022/23 season). We anticipate sampling will recommence in September for the 2023/24 spawning season.

SBT ageing 2019/20 and 2020/21

Otolith samples collected in the 2019/20 and 2020/21 spawning seasons (n = 3,000) were transported to Australia in August 2022 (Table 1). A total of 500 otoliths were selected for ageing from each season based on size of fish (length stratified sampling scheme rather than random sampling) to obtain as many age estimates as possible from length classes where sample sizes were small.

[4] Indonesian collaborating institutions, in chronological order: Central Research Institute for Fisheries Indonesia (CRIFI), Research Institute for Marine Fisheries (RIMF), Research Centre for Capture Fisheries (RCCF), Research Centre for Fisheries Management and Conservation (RCFMC), and currently Centre for Fisheries Research (CFR) in Jakarta, and Research Institute for Tuna Fisheries (RITF) in Bali.

The SBT otolith ageing process (sectioning and reading) was undertaken by Fish Ageing Services Pty Ltd (FAS) in Australia, using the techniques described in Anonymous (2002). The otoliths were read by two readers at FAS and a final age estimate was determined for each fish (Table 1). The otolith readings are completed without referring to the fish size information, the date of capture, or previous readings. The precision of the readings (inter-reader consistency) was assessed using the index of average percent error (Beamish & Fournier, 1981). Age-bias and age difference plots were used to detect any systematic disagreement between age estimates made by the two readers (Campana et al., 1995).

Age-length-keys and length frequency data

To determine the age structure of the Indonesian catch of SBT in each spawning season, an age-length-key (ALK) was developed using the sub-sample of aged fish. The ALK gives the proportion of fish at age in each 5-cm length class, which is then used to estimate the age-frequency distribution of the catch from the length-frequency distribution of the catch from the port monitoring data. A previous study found that annual ALKs are more appropriate for tracking cohorts than a combined ALK (Rodriguez-Marin et al., 2009), noting that “annual” in this case is equivalent to the Indonesian SBT spawning season, usually September to April. This method has been used to estimate the age distribution of the Indonesian catch since the mid-1990s, apart from 2011/12 when no direct age estimates were available. For that season, an ALK was developed using direct age data from the two preceding spawning seasons (i.e., 2009/10 and 2010/11) and applied to the 2011/12 length frequency data.

Determining suitable length data to which the annual age-length keys are applied has presented a challenge in recent years (see review by Farley et al. 2021). This year we used length data obtained from the otolith sampling program to ensure the fish were more likely caught in CCSBT statistical area 1. Only fresh fish are available for sampling in Benoa, and it assumed these fish are more likely to have been caught in Area 1 (close to Indonesia) rather than in Area 2 (directly south of Area 1)

Results and Discussion

SBT ageing 2019/20 and 2020/21

A final age was obtained for 484 of the 500 otoliths selected from both the 2019/20 and 2020/21 spawning seasons. Fish ranged in size from 133-208 cm fork length (FL) and age estimates ranged from 6 to 30 years. A systematic age bias was not evident between readers, apart from for the very youngest ages (5 and 6) where the reader 2 age was higher on average than reader 1 (Figure 1; Figure 2). The average percent error between the two otolith readers was 2.69%. When successive readings of otoliths differed, 97.5% were by ±2 years, indicating a good level of precision.

Length frequency distribution

The length frequency distribution of SBT captured by the Indonesian tuna longline fleet by spawning season, based on the length data from the otolith sampling data is presented in Figure 3. As reported previously, there has been a major change in the size distribution of SBT caught in the spawning area. The SBT captured in the mid and late 1990s was dominated by size classes between 165 and 190 cm FL with an average length of ~ 180 cm (Figure 3). The average size of SBT then decreased in the early 2000s as fish 155-165 cm FL increased in relative abundance (Figure 4). The average size of captured SBT decreased from 188.1 to 166.8 cm between 1993/94 and 2002/03 and remained between 168.3 and 171.0 cm through 2011/12 (Table 1; Figure 5).

In the 2012/13 spawning season, the length frequency indicates a new mode of unusually small fish (relative to the historical distribution) between 140 and 155 cm FL in the catch, in addition to the "usual" mode around 160-180 cm FL (Figure 3). The mode of small fish seems to progress through the fishery moving from ~146 cm in 2012/13 to ~155 cm in 2016/17. The mode is at ~160 cm for the last two seasons that have been monitored. The mean size of SBT caught has fluctuated around 160-165 cm FL for the last 9 seasons for which data is available.

As noted above, the monitoring program samples otoliths from the 'reject' quality SBT; it is unclear if a higher proportion of small fish may be classed as "reject" (and available for sampling), skewing the size frequency data used in the ALK analyses over this period. As noted in Sulistyaningsih et al. (2020), the otolith sampling in Benoa is complicated by factors such as different processing practices and rules for accessing fish at the different processors. The enumerator must consider this when deciding where to sample to reach the targeted number per month. Note that skewed sampling for otoliths will not affect the ALK itself, if there is enough age data obtained for each length class.

Age frequency distribution

Figure 6 shows the estimated age structure of the Indonesian catch by spawning season. As expected, given the change in the length distribution of the catch, the proportion of young fish aged 10-15 years has increased markedly in the early 2000s. These young fish can be tracked through the age distribution of subsequent years, suggesting a pulse of recruitment to the spawning population. A second pulse of higher recruitment of young fish occurred in the mid-2000s (Farley et al. 2014). The mean age of SBT >20 years has decreased since the mid-2000s although it has increased slightly in the last 5 years (Figure 8).

In 2012/13 there was a substantial increase in the catch of young SBT (<10 years) and the mean age of SBT sampled decreased (Figures 6-8). The mode of young fish in the catch has persisted each year since that time, and there is some indication that the mode has moved through the fishery on an annual time step until ~2016/17. The mean age of captured SBT has fluctuated around 12-15 years for the last 9 seasons monitored (Figure 8).

Summary

This year we successfully completed the ageing of SBT caught in the 2019/20 and 2020/21 spawning seasons and completed the CCSBT data exchange as planned. Otolith were not collected in the 2021/22 season due to disruptions caused by Institutional changes in Indonesia, and otolith sampling recommenced in February 2023 with 148 otolith samples collected for the season. As we will have no (or very little) age data for two seasons (2021/22 and 2022/23), it will not be possible to build age-length-keys for those seasons. To estimate the age distribution of the catch, we can develop ALKs using the direct age data for the two preceding spawning seasons (2019/20 and 2020/21) and apply it to the 2021/22 and 2022/23 length frequency data, if available.

Farley et al. (2021) conducted a preliminary review of the data used to estimate the length and age distribution of the SBT longline catch in Indonesia, which showed that the size data from the two sources (catch monitoring and CDS) provided different age composition results for the five years compared. Given the importance of the SBT size and age data to the monitoring and assessment of the SBT spawning stock, further work to examine the historical uncertainties identified by Farley et al. (2021) and to refine and improve the quality control of the monitoring program is a high priority.

Table and Figures

Table 1. Number of length measurements and age estimates for SBT by spawning season used in the age-length-key analyses this year.

Spawning season	Fork length (cm)			Otoliths	
	N	*Mean*	*Range*	*N*	*Age estimates*[1]
1993/94	676	188.1	161-207	0	0
1994/95	1610	180.7	147-221	549	486
1995/96	1107	178.9	149-216	225	50
1996/97	1615	179.6	146-218	602	475
1997/98	1577	176.4	143-214	519	485
1998/99	936	179.9	145-210	660	474
1999/00	786	177.4	150-216	533	498
2000/01	762	174.2	140-210	720	481
2001/02	821	169.5	147-223	715	489
2002/03	1385	166.8	134-229	1502	488
2003/04	1279	168.5	145-215	1283	494
2004/05	1580	168.4	89-205	1523	493
2005/06	1182	168.5	122-201	1180	486
2006/07	1586	167.5	134-202	1586	491
2007/08	1693	169.5	145-203	1709	485
2008/09	1704	171.0	143-219	1697	479
2009/10	1583	168.5	141-204	1538	488
2010/11	1015	170.4	142-198	1009	481
2011/12	565	169.4	136-212	543	NA
2012/13	1381	162.1	131-211	1373	474
2013/14	1641	158.2	117-201	1637	473
2014/15	1609	160.7	110-201	1346	482
2015/16	2000	161.0	117-201	2000	477
2016/17	1500	163.3	134-203	1499	472
2017/18	1500	159.8	134-209	1500	486
2018/19	1500	162.0	134-205	1500	474
2019/20	1500	160.6	134-199	1500	484
2020/21	1500	161.6	133-208	1500	484
Total	37593			31948	12129

[1] A random sub-sample of 500 are selected for ageing, apart from the 2011/12 season where an ALK based on data from the previous two seasons was used.

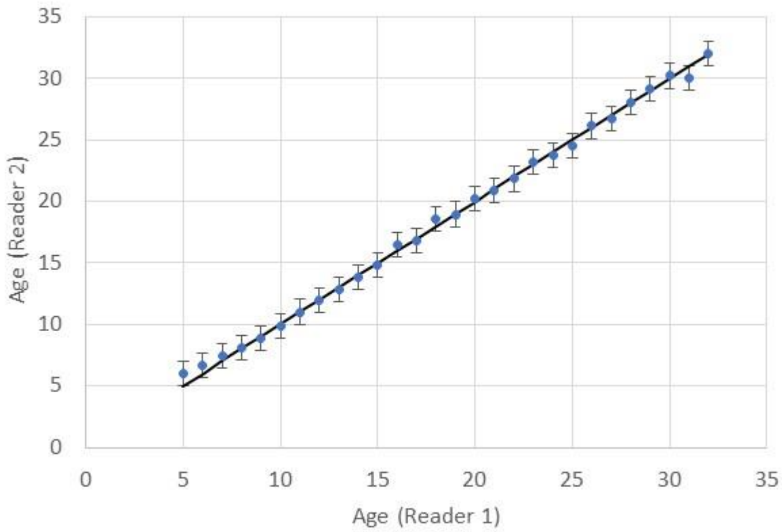

Figure 1. Age-bias (mean±s.e.) for comparisons of counts by otolith reader 1 and otolith reader 2.

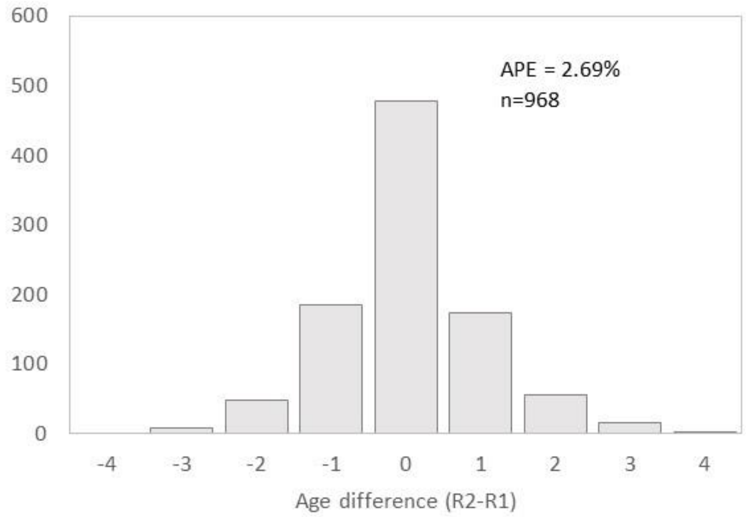

Figure 2. Age difference (right) plots for comparisons of counts by otolith reader 1 (R1) and otolith reader 2 (R2).

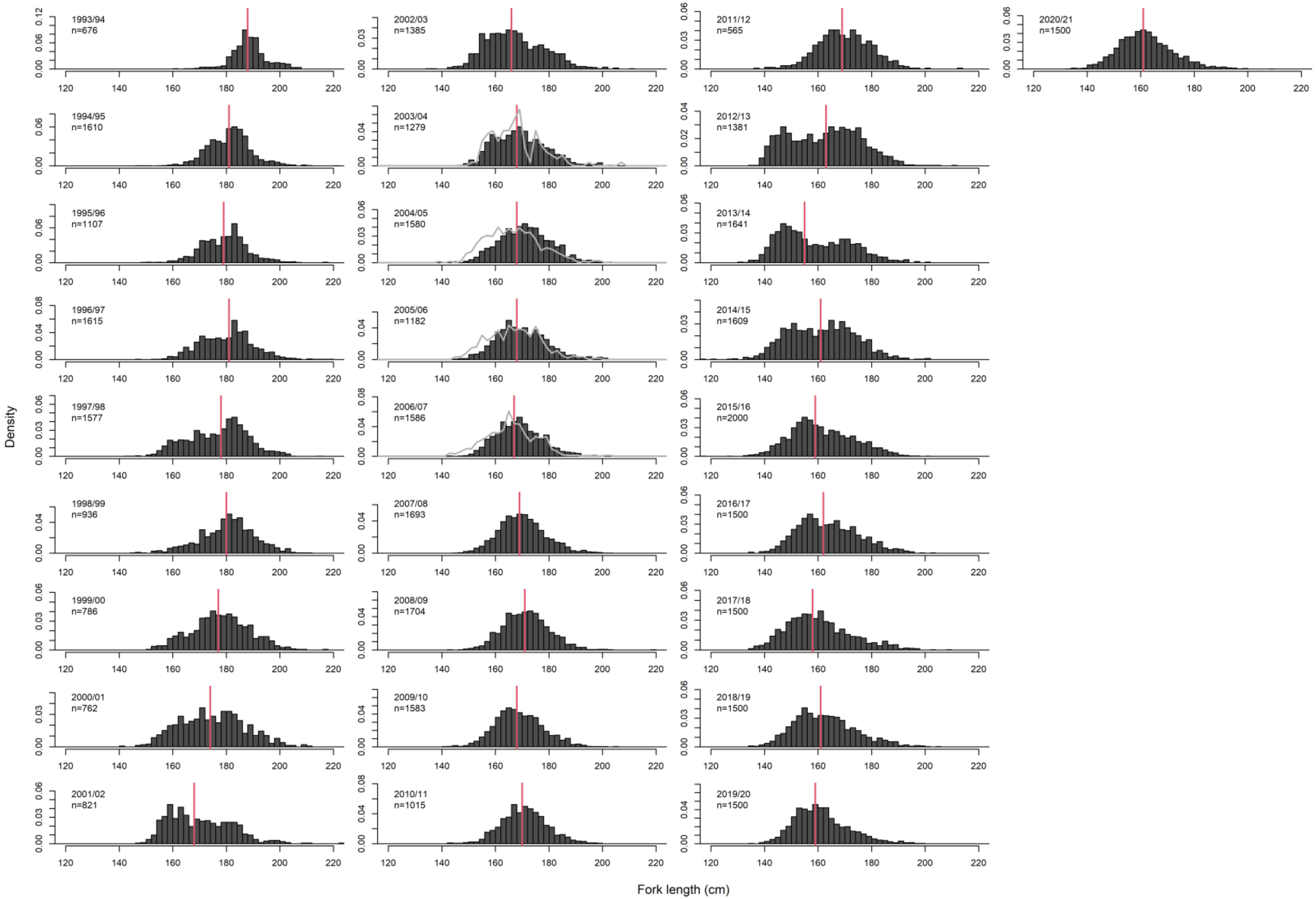

Figure 3. Length frequency (2 cm intervals) of SBT caught by the Indonesian longline fishery (bars) by spawning season. The red bar shows the median size class. For comparison, the length distribution of SBT thought to be caught south of the spawning ground (Processor A) is shown for the 2003/04 (n=121), 2004/05 (n=685), 2005/06 (n=311) and 2006/07 (n=452) seasons (grey line) (Farley et al. 2007)

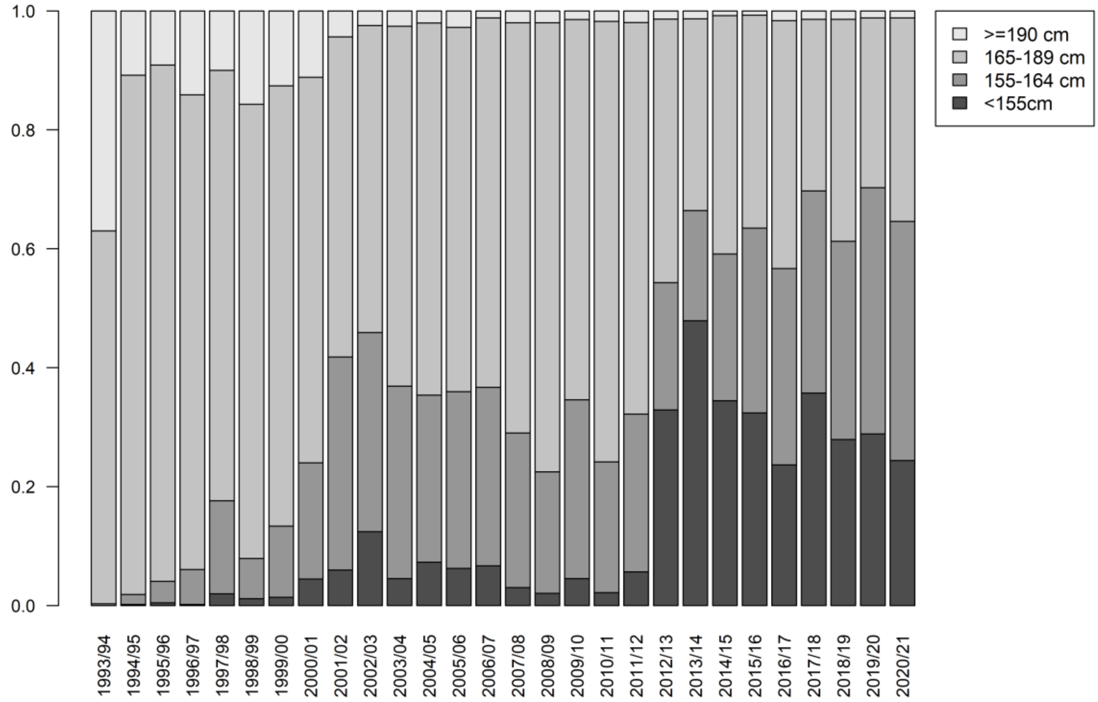

Figure 4. Proportion of SBT caught by the Indonesian longline fishery by size class. Data from Processor A in 2003/04 to 2006/07 are excluded.

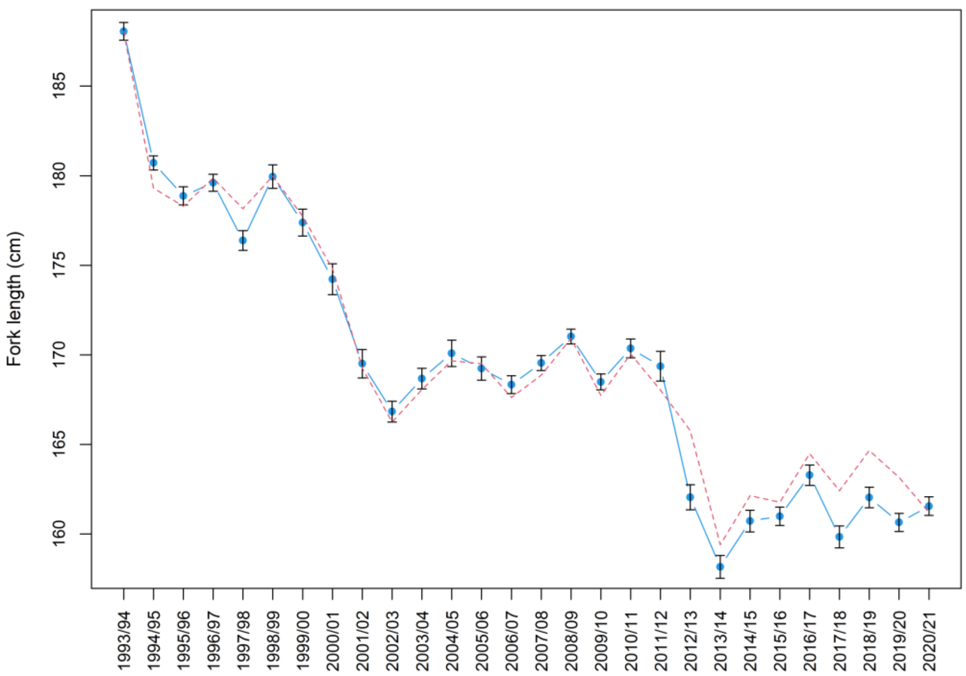

Figure 5. Mean length (+/- 95% CI) of SBT landed by the Indonesian longline fishery by spawning season. Data from Processor A in 2003/04 to 2006/07 are excluded. Dashed line is the mean length of SBT caught in December to May only.

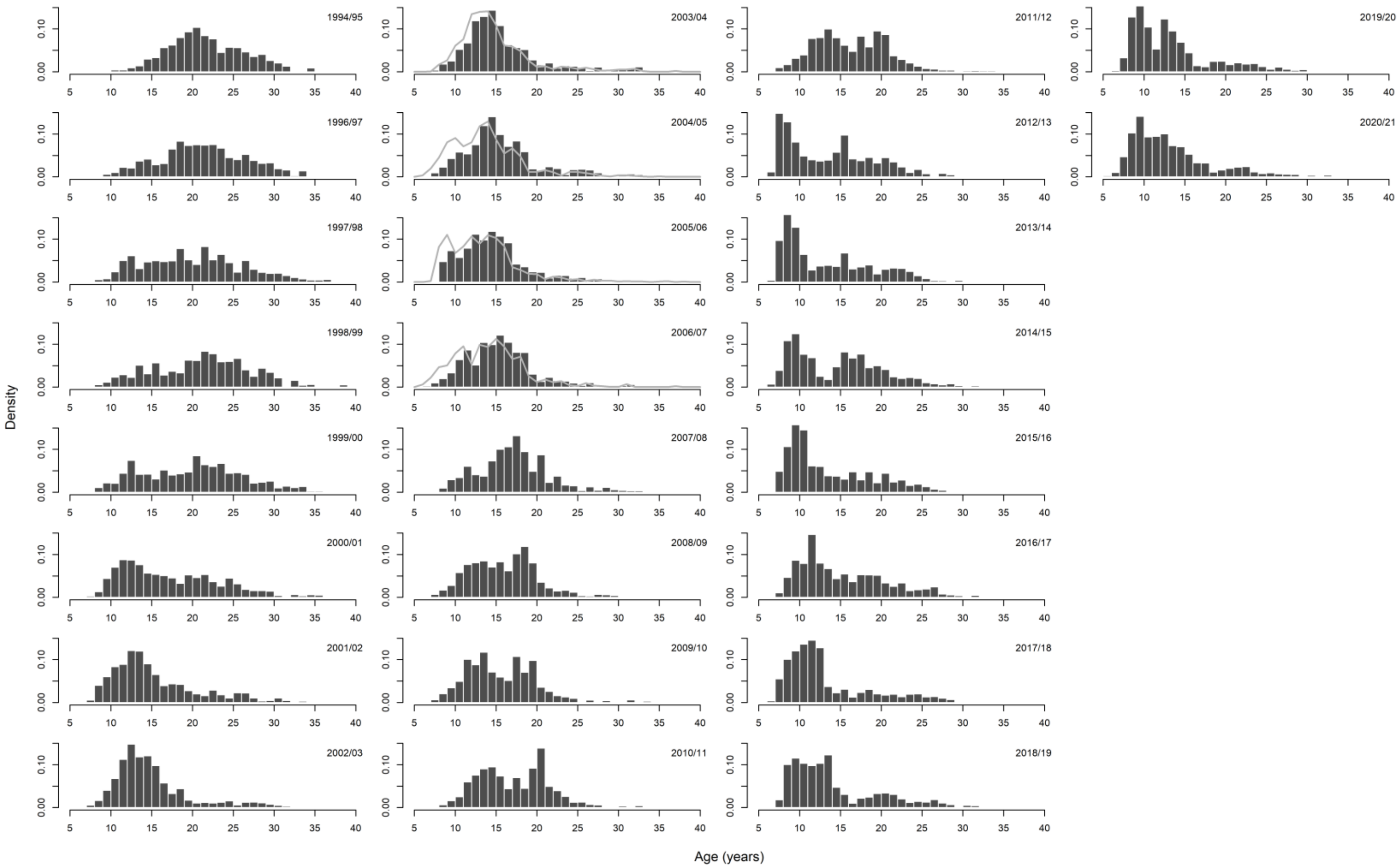

Figure 6. Age frequency distribution of SBT in the Indonesian catch on the spawning ground by spawning season estimated using age-length keys from our sub-samples of aged fish and length frequency data obtained through the Indonesian monitoring program. There was no direct ageing of the 2011–12 otoliths; age frequency is based on the age-length key from the previous two seasons and the 2011–12 length frequency data.

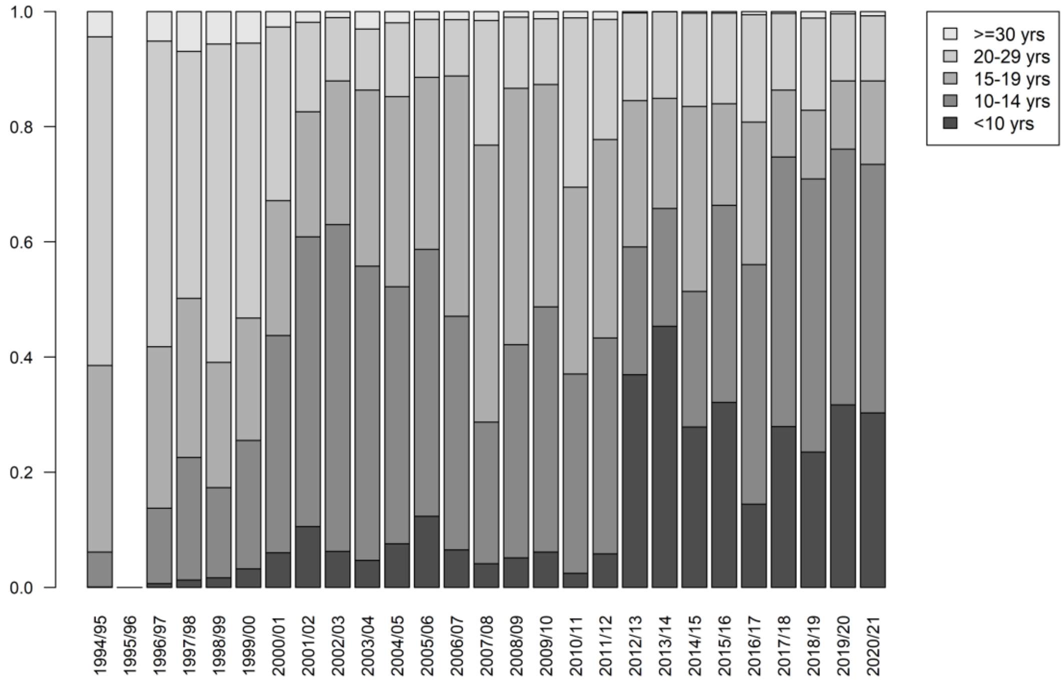

Figure 7. Estimated proportion of SBT by age category in the Indonesian catch. Data from Processor A for 2003/04 to 2006/07 are excluded. Note there are no age data for the 1995/96 season. There was no direct ageing of the 2011–12 otoliths; age frequency is based on the age-length key from the previous two seasons and the 2011–12 length frequency data.

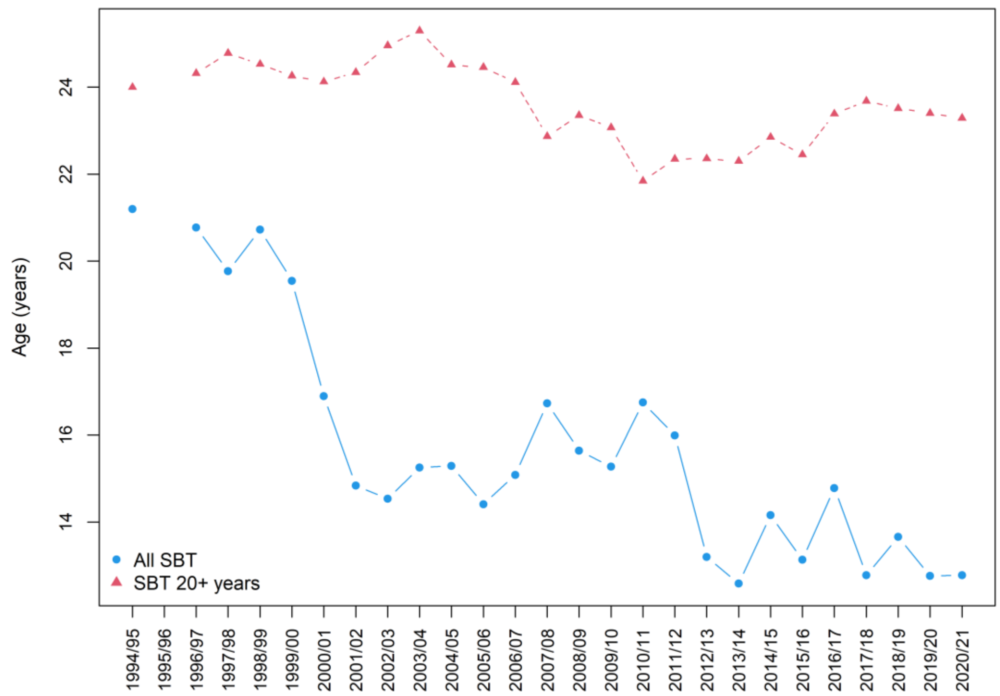

Figure 8. Estimated mean age of SBT in the Indonesian catch. Data from Processor A for 2003/04 to 2006/07 are excluded. Note there are no age data for the 1995/96 season.

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