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Update on the length and age distribution of SBT in the Indonesian longline catch

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Executive summary

This paper updates previous analyses of SBT length and age data from the Indonesian longline fishery operating out of the port of Benoa, Bali. Length-frequency data are presented for 22 spawning seasons (1993/94 to 2014/15) and age frequencies for 20 seasons (1993/94 to 2013/14, but excluding 1995/96). As noted in previous reports to CCSBT-ESC, considerable change has occurred in the size and age distribution of SBT landed by the Indonesian longline fleet since monitoring began. In summary:

- There was a change in the size and age distribution of SBT caught in the early 2000s when the proportion of small/young fish (155-165 cm/10-15 years) increased markedly. The young fish can be tracked through the age distribution of subsequent years suggesting a pulse of recruitment to the spawning population. A second recruitment pulse of fish is apparent in the mid-2000s.
- In the last three spawning seasons (2012/13 to 2014/15), the length and age frequencies showed a new mode of very small/young fish in the catch (140-155 cm/7-10 years). The proportion of fish aged <10 years increased from 5.8% in 2011/12 to 37.0% in 2012/13 and 22.5% in 2013/14 (the last year we have direct age data for). It is not known whether the small/young SBT landed in recent years were caught on or south of the SBT spawning ground, and whether they can be considered part of the SBT spawning population.
- It is important that we understand where the small fish are being caught because of how these data are used in the SBT operating model. The Indonesian age frequency (from direct ageing) are used in the SBT operating model and the fishery selectivity estimates from the operating models are used in projections and used to test the management procedure. Substantial changes in selectivity in a fishery could trigger exceptional circumstances under the SBT Management Procedure (MP) meta-rules process, because the MP has not been tested under these conditions. If the small fish are coming from further south, then these data may need to be assigned to a different fishery within the SBT OM fishery definitions. Information from the Catch Documentation Scheme may be able to provide information on fishing location.
- The Indonesian monitoring data are also used in the current close-kin (CK) estimation framework. It is assumed that all catches come from the spawning grounds. Hence, these recent changes will influence how these data can be used in the future in the CK abundance estimation.

1 Introduction

Southern bluefin tuna spawn from September to April in an area between Indonesia and the northwest coast of Australia (Farley and Davis, 1998). An Indonesian-based longline fishery operates on this spawning ground year-round targeting yellowfin and bigeye tuna, with a bycatch of SBT. Obtaining an accurate estimate of the size and age composition of SBT landed by the Indonesian longline fishery is vital for population modelling and stock assessments, and to monitor changes in the spawning population over time.

Since the early 1990s, the size and age structure of the SBT spawning population has been monitored through a series of collaborative research programs between CSIRO, Indonesia's Research Centre for Capture Fisheries (RCCF) and Research Institute for Marine Fisheries (RIMF), the Indian Ocean Tuna Commission (IOTC), and Japan's Overseas Fishery Cooperation Foundation (OFCF). The program monitors the catch of SBT by Indonesia's longline fleet operating on the SBT spawning ground in the north-east Indian Ocean. Initially, the program collected data on SBT landed at the port of Benoa in Bali, but in 2002 this was expanded to include the ports of Muara Baru (Jakarta) and Cilacap (south coast Central Java), and to comply with IOTC protocols. The majority of targeted SBT sampling, however, still occurs at Benoa, as this is the port where the bulk of SBT are landed.

The collection of such large quantities of length frequency data, and the development of validated methods to directly age SBT using the otoliths sampled, have allowed us to accurately estimate the age composition of the Indonesian catch. These data have shown that the parental stock of SBT has undergone substantial changes since monitoring began; the greatest change being a shift in the mode of SBT caught from 18-22 years in the mid-1990s to 12-15 years in the early-2000s.

In the mid-2000s, at least one Benoa-based fishing company (Processor A) was identified as having shifted their operations to target SBT south of the SBT spawning ground (Andamari et al., 2005; Proctor et al., 2006; Farley et al., 2007). A greater proportion of the catch landed at Processor A comprised small (<165 cm FL) fish compared to the other processors. SBT of these sizes are consistent with historic Japanese catch data for vessels operating on the staging ('Oki') fishing ground to the south of the spawning ground (Shingu, 1978).

In 2012/13 and 2013/14, the size distribution of SBT landed in Bali also showed a greater proportion of small fish (<150 cm FL) in the landed catch compared to previous seasons (Farley et al., 2014), suggesting that some vessels may have operated south of the spawning ground. Unfortunately, the catch locations of the sampled fish are unknown.

In this paper we update the information given in Farley et al. (2014) by including the most recent length and age data available for the Indonesian fishery. Length frequency data are presented up to the 2014/15 season and age frequency data up to the 2013/14 season.

2 Methods

As in previous years, targeted sampling of SBT occurred at the Port of Benoa using the existing monitoring system (e.g. see Proctor et al., 2006). Length measurements were obtained for 3433 SBT in the 2014/15 spawning season and otoliths were collected from 1346 fish (Table 1).

Direct ageing of a subsample of 500 otoliths was undertaken for fish sampled in the 2013/14 spawning seasons (Table 1). Otoliths were selected based on size of fish (length stratified sampling scheme rather than random sampling) to obtain as many age estimates from length classes where sample sizes were small. Length stratified sampling is the best way of obtaining sufficient age estimates from length classes where sample sizes are small, while providing enough estimates for each season. Otoliths were sent to Fish Ageing Services Pty Ltd (FAS) for sectioning and reading using the techniques described in Anon. (2002). The otolith reader has at least 10 years experience reading SBT otoliths.

Each otolith was read twice by the primary otolith reader (FAS) and then a final age estimate was given to 473 fish. All readings were conducted without reference to the size of the fish, date of capture, or to previous readings. The precision of readings was assessed using the coefficient of variation (CV) (Chang, 1982; Campana et al., 1995).

To determine the age structure of the Indonesian catch of SBT in the 2013/14 season, an age-length key was developed using the sample of aged fish. The age-length-key gives the proportion of fish at age in each 5-cm length class, which enabled us to infer the age-frequency distribution of the catch from the length-frequency distribution obtained through the monitoring. 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 for the two preceding spawning seasons and applied to the 2011/12 length frequency data.

3 Results

3.1 Length distribution

Figure 1 shows the length frequency distributions for SBT caught by the Indonesian longline fishery by spawning season (note that 8 fish between 100 and 129 cm FL were also sampled in 2013/14 but are not shown). The data are separated into those caught on and those caught just south of the spawning ground in the 2003/04 to 2006/07 seasons (see Farley et al., 2007) as SBT caught south of the spawning ground are not considered part of the spawning population.

As noted in previous reports to CCSBT-ESC, considerable change has occurred in the size distribution of SBT caught on the spawning ground since monitoring began. In the mid- and late-1990s, the majority of SBT caught were between 165 and 190 cm FL with a median length of ~180 cm (Figure 1). In the early-2000s, the relative proportion of small SBT (155-165 cm FL) in the catch increased (Figure 2). The mean size of SBT caught declined from 188.1 to 166.8 cm between 1993/94 and 2002/03, and remained between 168.3 and 171.0 cm until 2011/12 (Table 1).

In the last three spawning seasons (2012/13 to 2014/15), the length frequencies indicate a new mode of very small fish between 140 and 155 cm FL in the catch. In these seasons, the relative abundance of fish <155 cm was between 32.9% and 35.3% compared to much lower levels of 0 to 12.4% in the previous seasons (Figure 2). This change in the size distribution is reflected in a decrease in the mean size of SBT in the catch to ~162 cm FL (Table 1; Figure 3).

Investigations were initiated to determine whether the small SBT sampled recently were caught on or off the SBT spawning ground. In early May 2014, tuna fishing industry in Benoa participated in a workshop[3] at which a presentation was given highlighting the importance of catch location information to enable a better understanding of the increase in smaller fish in the landings. Follow-up discussions at the Benoa office[4] with responsibility for monitoring of fishing vessel activity revealed that VMS is available for some of the Benoa longline fleet and may provide validation of catch location information for the smaller SBT, should such information be provided by individual fishing companies.

3.2 Direct age estimation and age distribution

A final age was available for 473 of the 500 otoliths selected from the 2014/15 spawning season. Fish ranged in size from 135-211 cm LCF and age estimates ranged from 6 to 36 years. The coefficient of variation between readings was 2.99%. When successive readings of otoliths differed, 95.3% were only by ±2 (n=463), again indicating a good level of precision.

[3] Workshop “Monitoring and Evaluation of Enumerator and Observer Acitivties in Port of Benoa, Bali”, 5 May 2014, held at office of Asosiasi Tuna Longline Indonesia, Benoa.

[4] Pelabuhan Perikanan Nusantara Pengambengan – Benoa Office, a regional office under Directorate General of Capture Fisheries.

Figure 4 shows the estimated age structure of the Indonesian catch by spawning season. As reported previously, the age composition of the catch has also changed over time. There was a change in the age distribution of SBT caught in the early 2000s when the proportion of young fish aged 10-15 years increased markedly. These young fish can be tracked through the age distribution of subsequent years suggesting a pulse of recruitment to the spawning population. A second recruitment pulse of young fish occurred in the mid-2000s (see Farley et al. 2014).

In 2012/13 and 2013-14, however, there was a substantial increase in the catch of very young SBT (7-10 years) (Fig. 4). The proportion of fish aged <10 years increased from 5.8% in 2011/12 to 37.0% in 2012/13 and 22.5% in 2013/14 (Fig. 5). As expected, the mean age of SBT sampled decreased from 15-16 to 13-14 years (Table 1; Fig. 6). The mean age of SBT >20 years has also decreased since the mid-2000s.

Table 1. Number of length measurements and age estimates for SBT by spawning season.

SPAWNING SEASON	FORK LENGTH (CM)			OTOLITHS	AGE (YEARS)	
	N	MEAN	RANGE	*N*	*N*[1]	MEAN
1993/94	676	188.1	161-207	0	0	NA
1994/95	1610	180.7	147-221	549	486	21.2
1995/96	1107	178.9	149-216	225	50	NA
1996/97	1615	179.6	146-218	602	475	20.8
1997/98	1577	176.4	143-214	519	485	19.8
1998/99	936	179.9	145-210	660	474	20.7
1999/00	786	177.4	150-216	533	498	19.5
2000/01	762	174.2	140-210	720	481	16.9
2001/02	821	169.5	147-223	715	489	14.8
2002/03	1385	166.8	134-229	1502	488	14.5
2003/04	1279	168.5	145-215	1283	494	15.2
2004/05	1580	170.1	89-205	1523	493	15.3
2005/06	1182	169.2	122-201	1180	486	14.4
2006/07	1586	168.3	134-202	1586	491	15.1
2007/08	1693	169.5	145-203	1709	485	16.7
2008/09	1704	171.0	143-219	1697	479	15.6
2009/10	1583	168.5	141-204	1538	488	15.3
2010/11	1015	170.4	142-198	1009	481	16.8
2011/12	565	169.4	136-212	543	*NA*	16.0
2012/13	1381	162.1	135-211	1373	474	13.2
2013/14	1810	161.8	100-204	1637	473	13.9
2014/15	3443	161.4	95-225	1346	NA	NA
Total	30096			22449	8770	*Total*

[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.

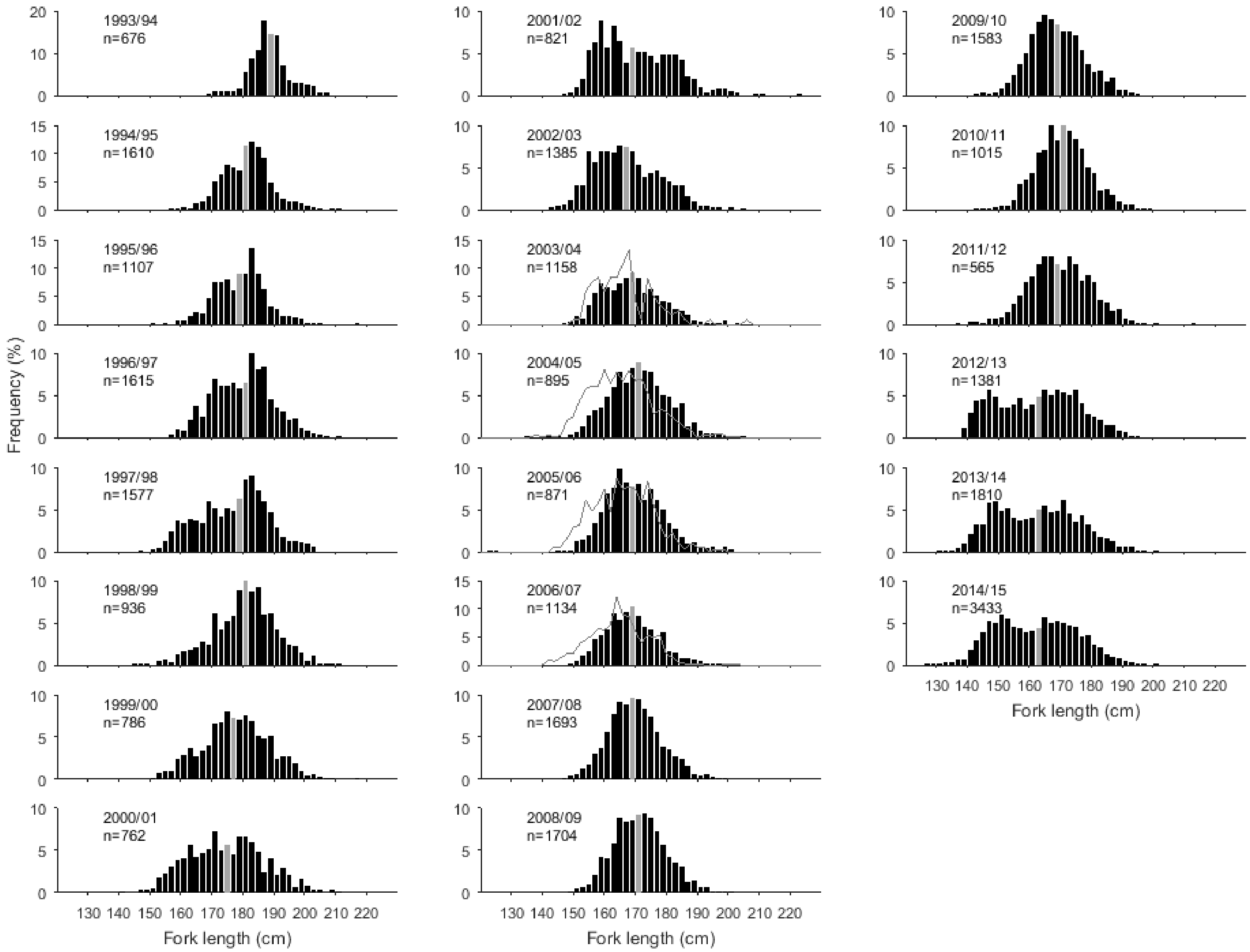

Figure 1. Length frequency (2 cm intervals) of SBT caught by the Indonesian longline fishery (bars) by spawning season. The grey bar shows the median size class. For comparison, the length distribution of SBT thought to be caught south of the spawning ground (Processor A) is shown for the 2003/04 (n=121), 2004/05 (n=685), 2005/06 (n=311) and 2006/07 (n=452) seasons (grey line) (see Farley et al., 2007).

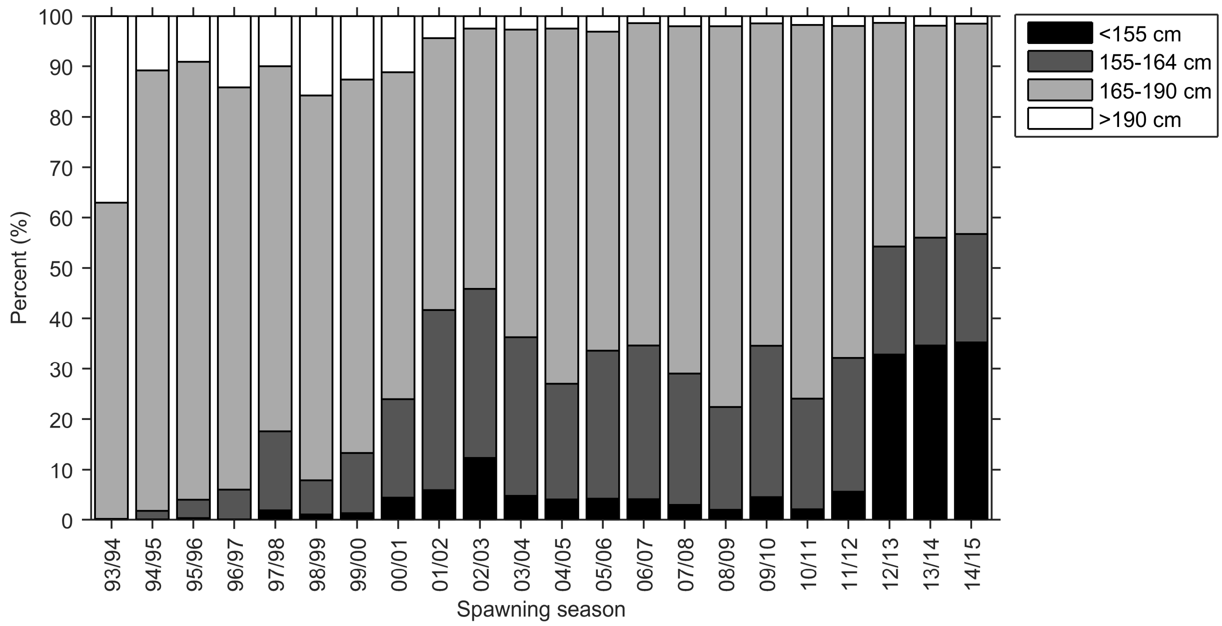

Figure 2. Proportion of SBT caught by the Indonesian longline fishery by size class. Data from Processor A in 2003/04 to 2006/07 are excluded.

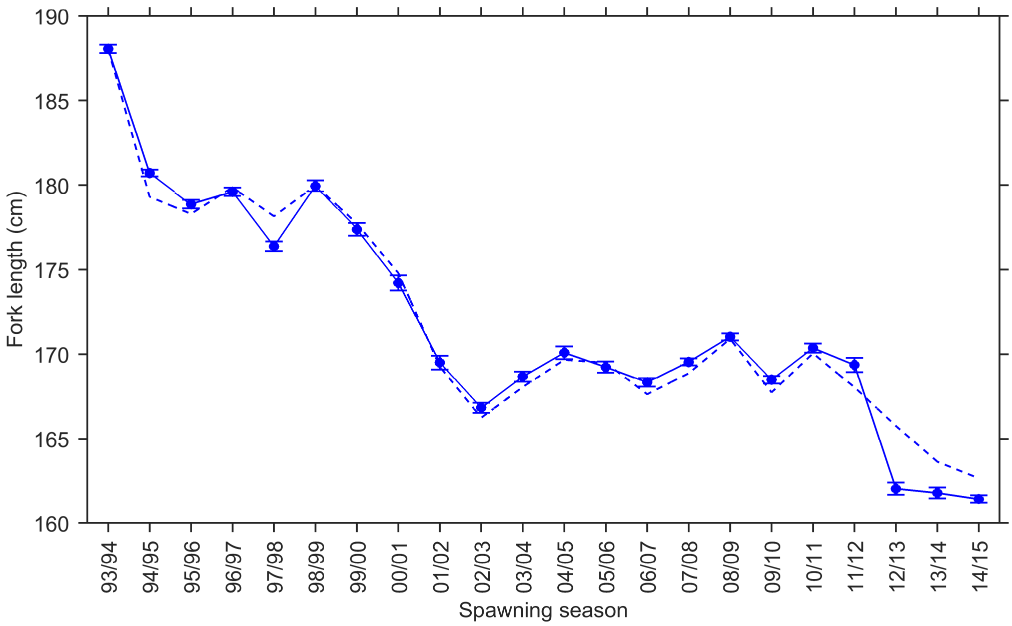

Figure 3. Mean length (+/- 95% CI) of SBT landed by the Indonesian longline fishery by season. Data from Processor A in 2003/04 to 2006/07 are excluded. Dashed line is the mean length of SBT caught in December to May only.

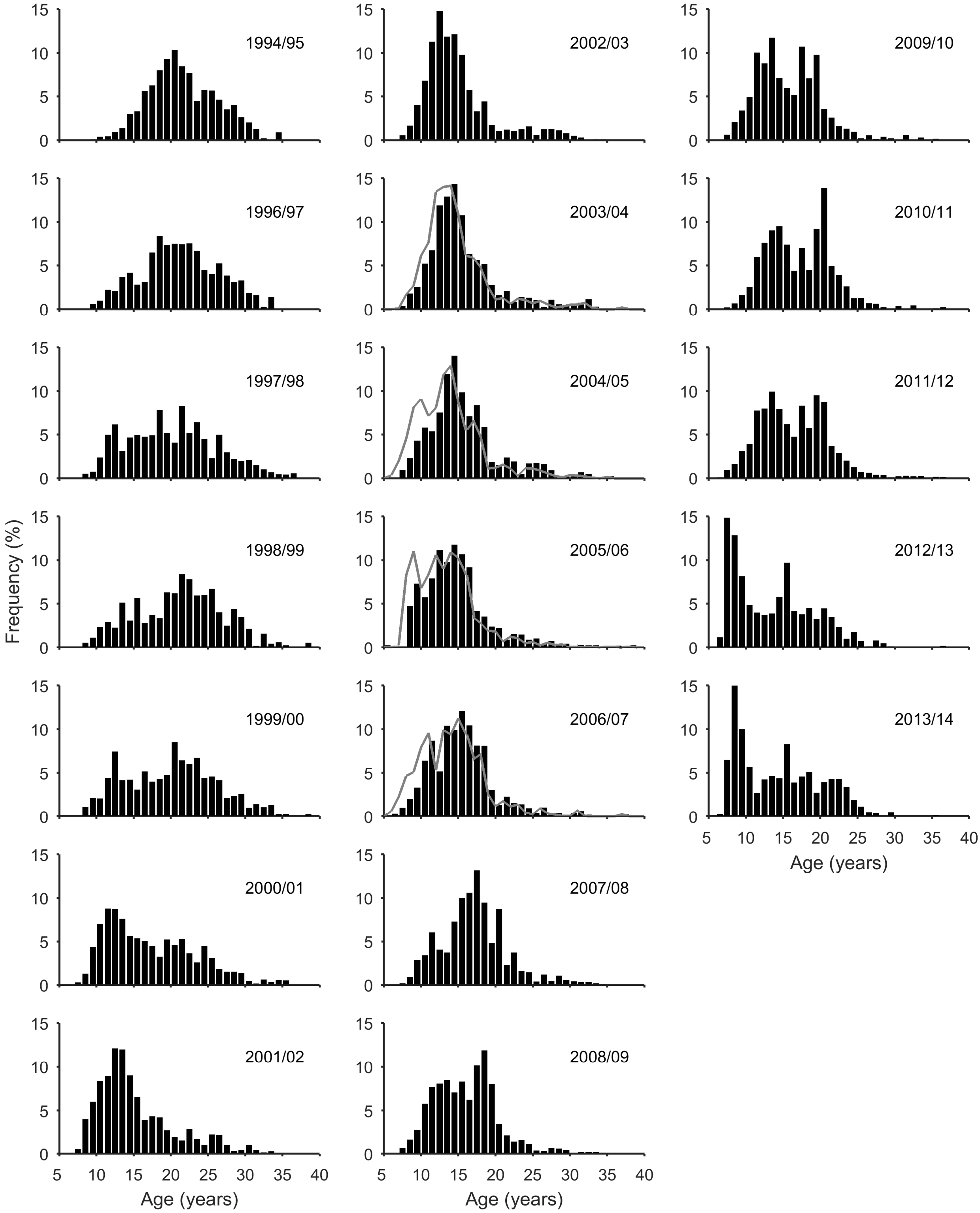

Figure 4. Age frequency distribution of SBT in the Indonesian catch on the spawning ground by spawning season estimated using age-length keys from our sub-samples of aged fish and length frequency data obtained through the Indonesian monitoring program. There was no direct ageing of the 2012–13 otoliths; age frequency is based on the age-length key from the previous two seasons and 2012–13 length frequency data. For comparison, the age distribution of SBT caught south of the spawning ground (Processor A) is shown for the 2003/04, 2004/05, 2005/06 and 2006/07 seasons (grey line).

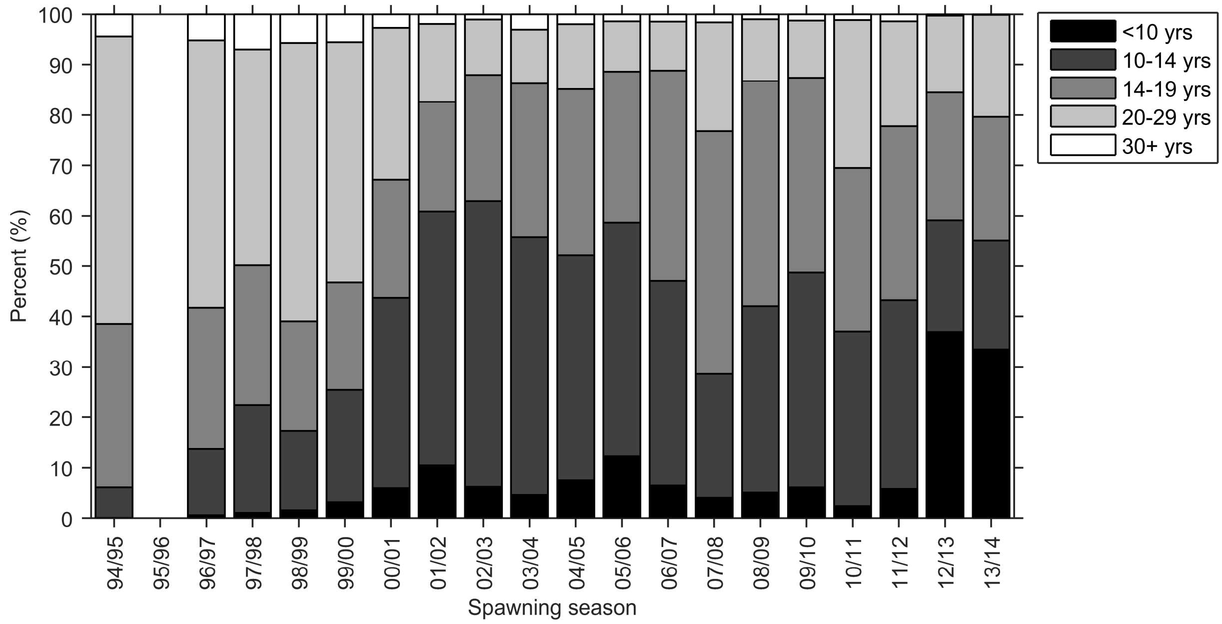

Figure 5. Estimated proportion of SBT by age class in the Indonesian catch. Data from Processor A for 2003/04 to 2006/07 are excluded. Note there are no age data for the 1995/96 season.

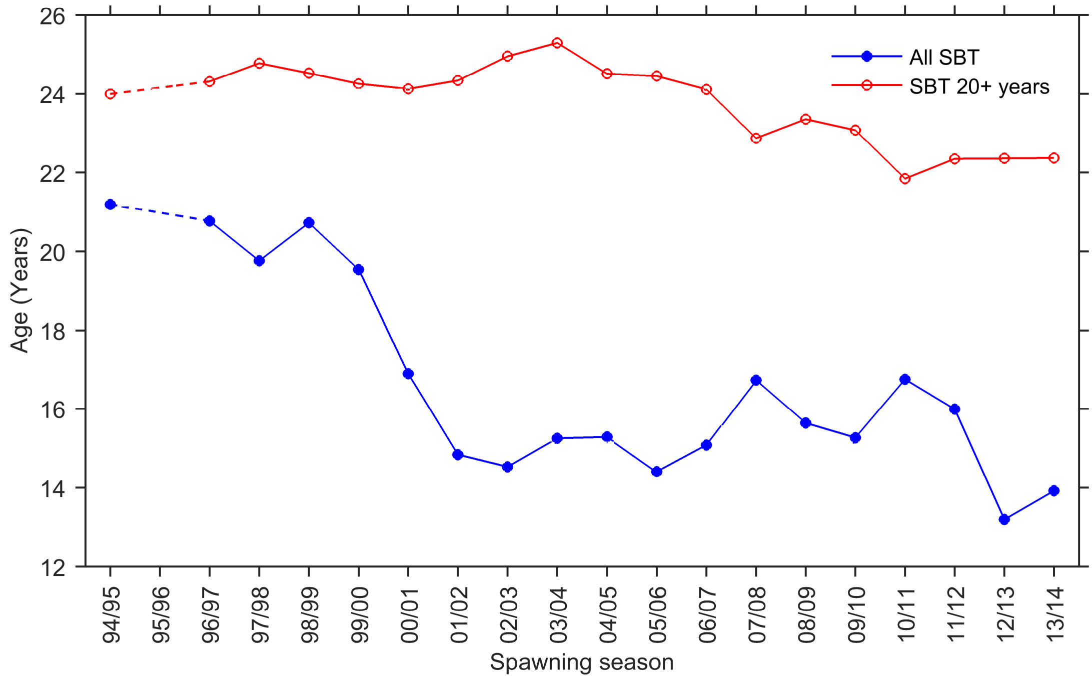

Figure 6. Estimated mean age of SBT in the Indonesian catch. Data from Processor A for 2003/04 to 2006/07 are excluded. Note there are no age data for the 1995/96 season.

4 Summary

We present the length and age distribution of the Indonesian longline catch from the mid-1990s through to the 2013/14 and 2012/13 spawning seasons respectively. In each season, apart from 2011/12, an age-length-key (ALK) was developed using age estimates obtained from that season. Length frequency data were then applied to the ALK to estimate the age distribution of the catch. In 2011/12, however, no direct age estimates were available. For that season, an ALK was developed using direct age data for the two preceding spawning seasons and applied to the 2011/12 length frequency data.

The size and age composition of the SBT in the Indonesian catch has changed over time. There was a change in the early 2000s when the proportion of young (<15 years) fish increased in the catch, which can be tracked through subsequent years (Farley et al., 2014). A second pulse of young fish is apparent in the mid-2000s.

Over the last three spawning seasons, a relatively large proportion of SBT landed were very small/young (<155 cm FL/10 years old) compared to previous seasons. Investigations have been initiated to determine whether the small SBT landed were caught on or south of the SBT spawning ground, and whether they can be considered part of the SBT spawning population. Unfortunately, the catch locations of the sampled fish are currently unknown.

It is important that we understand where the small fish are being caught because of how these data are used in the SBT operating model. The Indonesian age frequency (from direct aging) are used in the SBT operating model and the fishery selectivity estimates from the operating models are used in projections and used to test the management procedure. Substantial changes in selectivity in a fishery could trigger exceptional circumstances under the SBT MP meta-rules process, because the MP has not been tested under these conditions. If the small fish are coming from further south, then these data may need to be assigned to a different fishery within the SBT OM fishery definitions (Anon 2014). Information from the Catch Documentation Scheme may be able to provide information on fishing location.

The Indonesian monitoring data are also used in the current close-kin (CK) estimation framework. It is assumed that all catches come from the spawning grounds. Hence, these recent changes will influence how these data can be used in the future in the CK abundance estimation.

5 References

Andamari, P., Davis, T.L.O., Iskandar, B., Retnowati, D., Herrera, M., Proctor, C.H. and Fujiwara, S. 2005. The catch of SBT by the Indonesian longline fishery operating out of Benoa, Bali in 2004. CCSBT-ESC/0509/15

Anonymous. 2002. A manual for age determination of southern bluefin Thunnus maccoyii. Otolith sampling, preparation and interpretation. The direct age estimation workshop of the CCSBT, 11-14 June 2002, Queenscliff, Australia, 39 pp.

Anonymous, 2014. Report of the Extended Scientific Committee for the Nineteenth Meeting of the Scientific Committee, Commission for the Conservation of Southern Bluefin Tuna, 1-6 September, Auckland, New Zealand.

Campana, S.E., Annand, M.C., McMillan, I. 1995. Graphical and statistical methods for determining the consistency of age determinations. Trans. Amer. Fish. Soc. 124: 131–138.

Chang, W.Y.B. 1982. A statistical method for evaluating the reproducibility of age determinations. Can. J. Fish. Aquat. Sci. 39:1208-1210.

Farley, J., Andamari, R., and Proctor, C. 2007. Update on the length and age distribution of SBT in the Indonesian longline catch. CCSBT-ESC/0709/10.

Farley, J.H., and Davis, T.L.O. 1998. Reproductive dynamics of southern bluefin tuna *Thunnus maccoyii*. Fish. Bull. 96:223-236.

Farley J.H., Eveson J.P., Davis T.L.O., Andamari R., Proctor C.H., et al. 2014. Demographic structure, sex ratio and growth rates of southern bluefin tuna (*Thunnus maccoyii*) on the spawning ground. PLoS ONE 9(5): e96392. doi:10.1371/journal.pone.0096392. CCSBT-ESC/1509/Info2.

Farley, J., Nugraha, B. and Proctor, C. 2014. Update on the length and age distribution of SBT in the Indonesian longline catch. CCSBT-ESC/1409/20.

Proctor, C.H., Andamari, R., Retnowati, D., Herrera, M., Poisson, F., et al. 2006. The catch of SBT by the Indonesian longline fishery operating out of Benoa, Bali in 2005. CCSBT-ESC/0609/10.

Shingu, C. 1978. Ecology and stock of southern bluefin tuna. Fish.Study Jap. Assoc. Fish. Resources Protection, 31:81 p. (In Japanese; English translation in Rep.CSIRO Div.Fish.Oceanogr., 131:79 p., 1981.)

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