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

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Abstract

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 for 2007/08 and age-frequency data for 2006/07 spawning seasons are now available for the fishery. Length frequency data have now been collected for 15 spawning seasons, and the catch-at-age estimated for 12 seasons. 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 summary:

- The mean of the size distribution declined from 188.1 to 166.8 cm between 1993/94 and 2002/03, and has remained between 168 and 170 cm for the past 5 seasons.
- In 2007/08, the relative abundance of SBT <165 cm declined slightly compared to the previous season, but has remained at between 27-34% of the catch for the past five seasons. The relative abundance of SBT >190 cm has declined since the mid-1990s, but has remained at between 1.4-3.1% of the catch for the past 5 seasons.
- Age estimates for the 2006/07 season ranged from 7 to 40 years, although an age bias plot indicates a slight upward bias in the age estimates (~1 year) by the primary otolith reader. This bias is being examined and the results presented here for the 2006/07 season should be considered preliminary. Updated age estimates will be provided during the 2009 data exchange if necessary.
- The median of the age distribution shifted from 19-21 years in the mid- and late-1990s to 13-14 years in 2001/02 to 2005/06. In the 2006/07 season, the median age increased slightly to 16 years, but this may be due in part to the suspected bias in age estimates.
- Similarly, the proportion of young SBT (≤ 10 years) in the catch decreased and the mean age increased in 2006/07. The average age of SBT greater than 20 years has remained relatively stable over time, but has shown a slight decline over the past 3 seasons.
- The sex ratio of SBT in the Indonesian catch continues to be skewed towards females. However, this dominance of females has gradually declined over the past 8 seasons from 72% in 1999/00 to 55.6% in 2007/08. Further investigation will be undertaken to determine if the method of sexing SBT has changed over time, which may account for the change in the observed sex ratio.

Introduction

The size and age structure of the SBT spawning population has been monitored since the early 1990s 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 Fisheries 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 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 over 11 spawning seasons. These data have shown that the parental stock of SBT has undergone dramatic 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.

It is understood that from late 2004, a number of vessels began targeting SBT well south of the spawning ground using carrier vessels to bring the catch back to Benoa (Proctor et al., 2007). Since it is unknown if these fish are mature or would migrate to the spawning ground, it was important that they were identified and excluded from our analysis so that the estimated size/age composition of the spawning population can be compared over time. Through the monitoring program, only one company was identified as regularly having fishing vessels operating in the southern zone and SBT from this processor were identified in the data and analysed separately (Farley et al., 2007a).

In this paper we update the information given in Farley et al. (2007a) by including the most recent length and age frequency data for the Indonesian fishery. Length frequency data includes the 2007/08 spawning season, while age frequency data are presented up to the 2006/07 season. The data provided to the CCSBT in the April 2008 data exchange process included the estimated size and age distribution of the whole Indonesian SBT catch, and were not divided into those caught on or south of the spawning ground.

Methods

Length measurement

As in previous years, targeted sampling of SBT occurred at the Port of Benoa. Length measurements were obtained for 1585 SBT in the 2006/07 spawning season. These data, and those for the 2007 calendar year, were provided for data exchange with CCSBT in April 2008. Length data for the 2007/08 spawning season were not complete at the time of the data exchange, but have since been received and are presented here (n=1692).

The length frequency data were examined to determine if the fishing company (Processor A) identified as having operated south of the spawning ground in 2006/07 (Proctor et al., 2006) had operated in this region during 2007/08.

Otolith sampling and direct age estimates

Otoliths were sampled from 1586 SBT caught by the Indonesian fishery in the 2006/07 spawning season (Table 1). Sex was obtained for all but five fish. Of the otoliths sampled, 500 were selected for age estimation. A fixed number of otoliths were chosen from each 5 cm length class to obtain as many age estimates from length classes where sample sizes were small. Otoliths were prepared, sectioned and read (age of fish estimated) at the Central Ageing Facility (CAF) in Victoria using the techniques described by Clear et al. (2000). Extensive training was provided to the CAF technician in 2000, and again in 2002 during the CCSBT's Age Estimation Workshop in 2002 (Anon, 2002).

Each otolith was read twice by the primary otolith reader (CAF) and then given a final age estimate. A subsample of 83 otoliths were read twice by a secondary otolith reader (CSIRO). The coefficient of variation (CV; Chang, 1982) between readings was used to measure consistency. All readings were conducted without reference to the size of the fish, date of capture, or to previous readings.

To determine the age structure of the Indonesian catch of SBT in 2006/07, an age-length key was developed using our 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. Age distributions were estimated for the spawning population on the spawning ground, and for SBT caught south of the ground (using size data from Processor A). The age distributions obtained were compared to the estimated age distributions for previous seasons.

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

Spawning season	Length data		Otolith/age data		
	Measured	Known sex	Otoliths collected	Age estimated[1]	Age with sex known
1993/94	676	-	-	-	-
1994/95	1610	-	549	486	-
1995/96	1107	-	225	-	-
1996/97	1615	-	602	475	-
1997/98	1577	-	519	485	-
1998/99	936	59	660	474	88
1999/00	786	778	533	498	495
2000/01	762	757	720	481	478
2001/02	821	818	715	489	488
2002/03	1383	1373	1502	488	488
2003/04	1279	1276	1283	494	494
2004/05	1580	1555	1523	493	493
2005/06	1180	1176	1180	486	483
2006/07	1586	1577	1586	491	486
2007/08	1692	1690	1692	-	-
Total	18611	11054	*11615*	*5840*	*3507*

[1] A random sub-sample of 500 are selected for ageing

Results and Discussion

Length distribution

Length (and weight) measurements for SBT are now available up to April 2008, which covers the entire 2007/08 spawning season (Sep 2007 - Apr 2008). The length frequency distributions are plotted by spawning season in Figure 1. Length data obtained from Processor A are shown separately for the 2003/04 to 2006/07 seasons, and from this it is assumed that SBT from this processor were caught south of the spawning ground in the 2004/05 to 2006/07 seasons only (see Farley et al., 2007a). SBT from this processor are not included in our examination of the size/age distribution of the spawning population. The 2007/08 data does not contain length measurements from Processor A (as the landings were frozen) so it assumed that all SBT monitored were caught on the spawning ground and are thus included in our analysis. SBT landed at Processor A are, however, included in IOTC's monitoring to estimate the total catch of SBT landed at Benoa (Proctor et al., 2008).

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. In the early-2000s, the relative proportion of small SBT (<165 cm) in the catch increased peaking at 46% in 2002/03, before declining slightly to between 27% and 34% for the past five seasons (Figure 2). The mean length of SBT declined from 188.1 cm in 1993/94 to 166.8 cm in 2002/03, and has remained between 168 and 170 cm since 2003/04

(Figure 3). The relative proportion of large SBT (>190 cm) in the catch decreased throughout the late-1990s to early 2000s, but has remained relatively constant since 2002/03 at 1.4 - 3.1% of the catch. Note that SBT from the 1993/94 season were all caught in the latter part of the season (December to May) and may not be representative of the catch for the season. However, if only data for December to May were selected for all seasons, a similar decline in the mean length by season was found (Figure 3). It has been suggested that the increase in the catch of SBT <165 cm since 2000 could be an indication that fish spawned since quotas were introduced in 1984 have survived to spawning size/age. Note that length at 50% maturity accurately estimated for SBT, but is thought to be around 152-162 cm or greater (Davis, 1995; Schaefer, 2001).

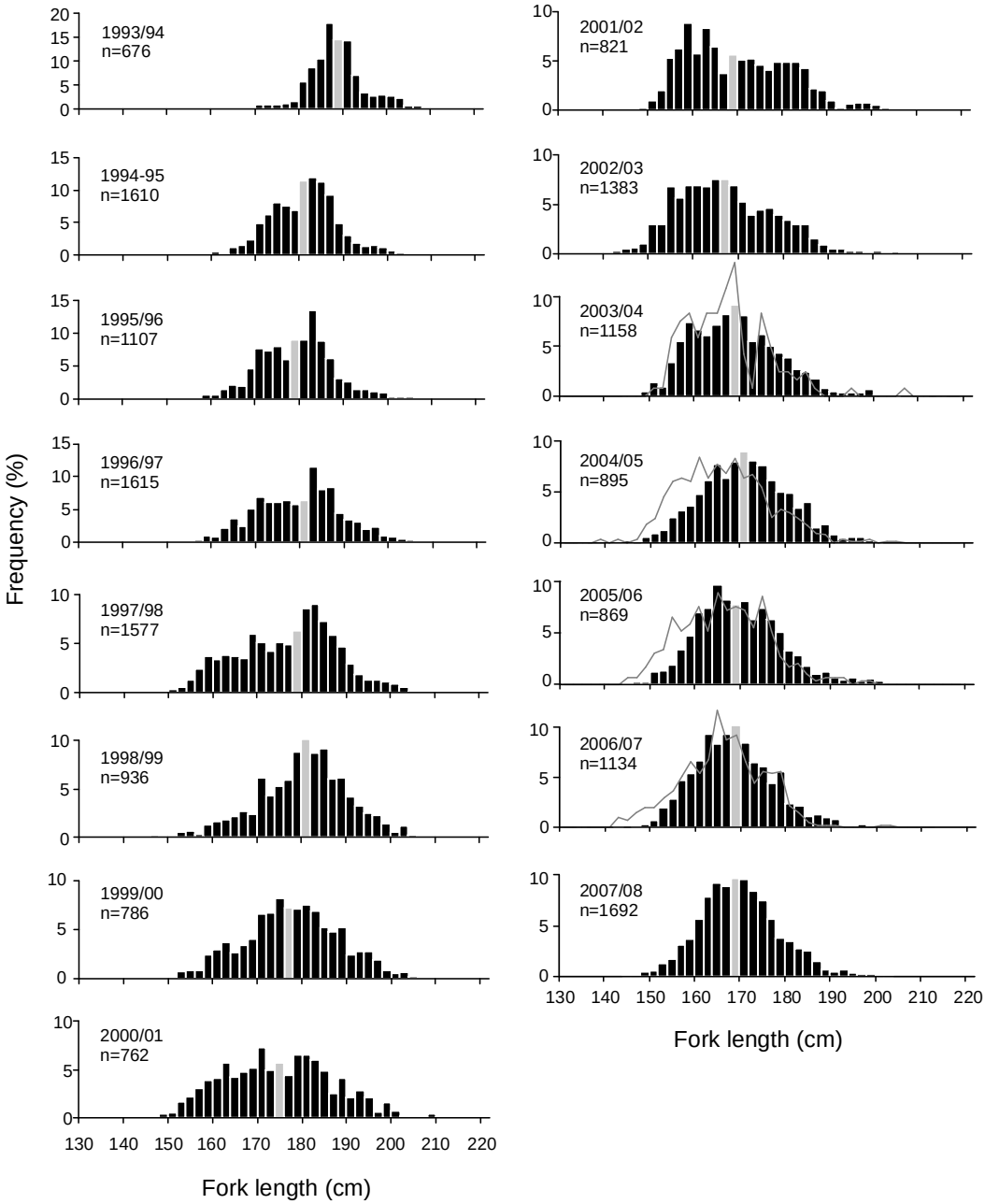

Figure 1. Length frequency (2 cm intervals) of SBT caught on the spawning ground (bars) by spawning season. The grey bar shows the median size class. For comparison, the length distribution of SBT thought to be caught south of the spawning ground (Processor A) is shown for the 2003/04 (n=121), 2004/05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

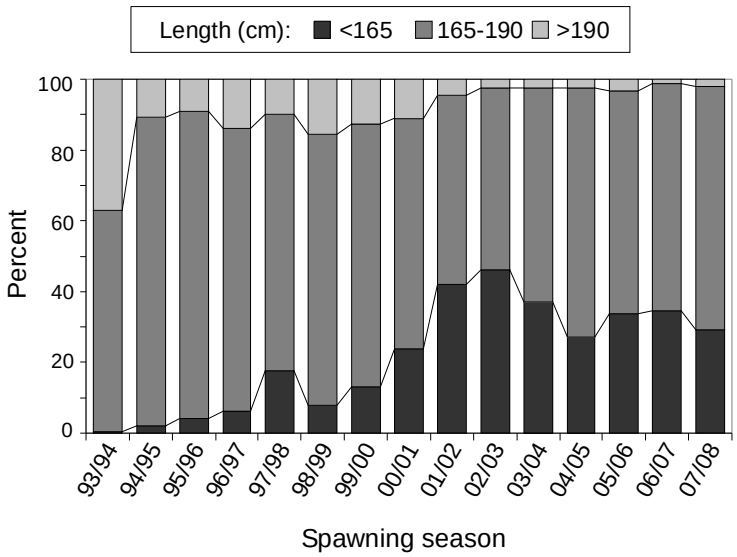

Figure 2. Proportion of SBT caught on the spawning ground by small (<165 cm), medium (165-190 cm) and large (>190 cm) SBT by season. Data from Processor A are excluded.

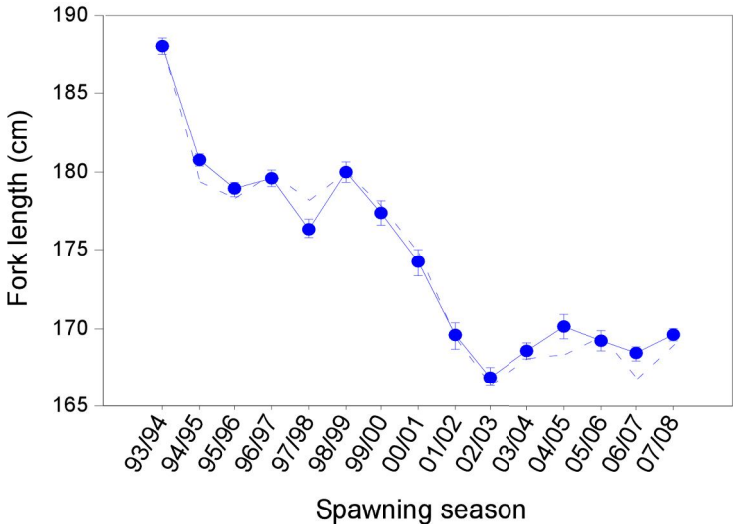

Figure 3. Mean length (+/- 95%CI) of SBT in the Indonesian catch on the spawning ground. Data from Processor A are excluded. Dashed line is the mean length of SBT caught in December to May only.

Sex ratio on the spawning ground

Sex has been recorded for the majority of SBT since 1999 (Table 1). The data suggests that sex ratio of SBT in the Indonesian catch is biased towards females in all seasons, but that this dominance has gradually declined from 72.0% in 1999/00 to 63.4% in 2006/07 (Figure 4). In 2007/08, the decline was more marked with 55.6% of those measured were identified as female. When examined by size class, the Indonesian catch is dominated by females in the smaller length classes and by males in the larger length classes (Figure 5). However, the length class where males start to dominate has gradually declined from the 185 and 190 cm classes in 1999/00 to 2002-03, to the 170 cm class in the last two seasons. Farley et al., (2007b) showed that the sex ratio of SBT caught by Japanese longliners in the southeast

Indian Ocean in the early-1990s was ~1:1 up to the 170cm length class, after which males dominated. The Indonesian sex ratio data for the 2007/08 season is similar to the Japanese data in that males dominate in length classes ≥170 cm, however, there is still a bias towards females in the smaller length classes that was not observed in the Japanese data (Figure 5).

The reason for the apparent dominance of females in the Indonesian catch, and the change in the sex ratio over time, is not known. It has been suggested that the determination of sex may not be accurate for SBT landed in Benoa as it is based on remnant gonad tissue left in the visceral cavity after the fish is cleaned. However, it was assumed that since the direct age data indicates sexual dimorphism in length-at-age, it seemed likely that sex had been correctly identified in most cases. Further investigation will be undertaken to determine if the method of sexing SBT has changed over time, which may account for the change in the observed sex ratio. Another hypothesis is that the spawning behaviour of SBT may differ by sex (e.g. feeding, depth stratification, and residency) which may affect catchability or availability on the spawning ground.

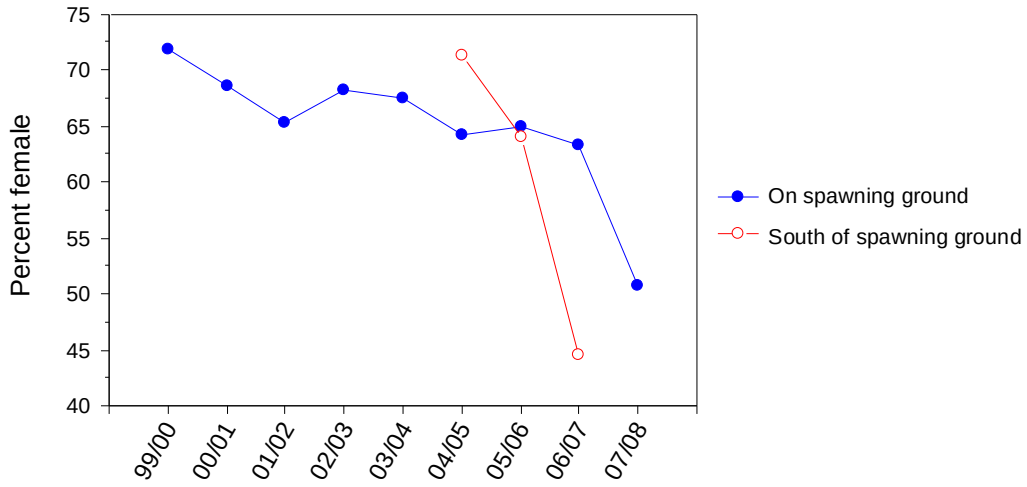

Figure 4. Change in the sex ratio of SBT in the Indonesian catch since the 1999/00 spawning season.

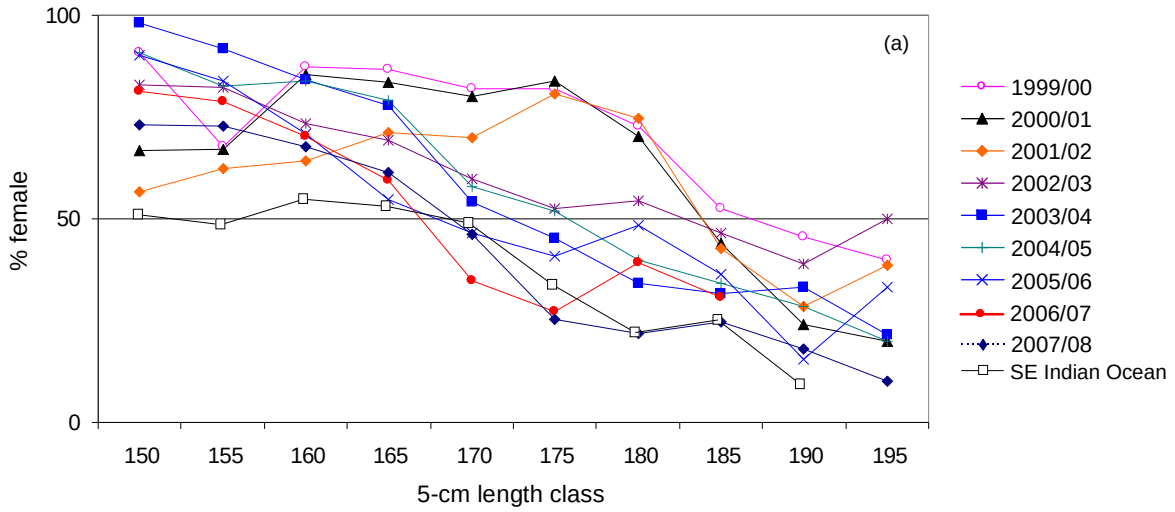

Figure 5. Percent female by 5-cm age class for SBT caught on the spawning ground by spawning season, and percent female for SBT caught by Japanese longliners in the southeast Indian Ocean in the early-1990s (see Farley et al., 2007b). Data point excluded if n<5.

Direct age estimates

Age was estimated for 491 SBT in the 2006/07 spawning season from fish ranging in size from 130-200 cm LCF. Age estimates ranged from 7 to 40 years. The precision of readings by the primary reader (intra-reader consistency) was considered good. The second age estimate agreed with the original estimate in 40.8% of cases, and 83.2% were within one years of the original. The APE between primary readings was 3.67. The CV between the primary and secondary readers was 7.13. An age bias plot (Campana et al., 1995) suggests a slight bias in the age estimates by the primary reader compared to the secondary reader (Figure 6). An initial comparison of age with otolith weight suggests that the primary reader may be overestimating age by around 1 year (on average). This bias is currently being examined and the results presented here for the 2006/07 season should be considered preliminary. Updated age estimates will be provided during the 2009 data exchange if necessary.

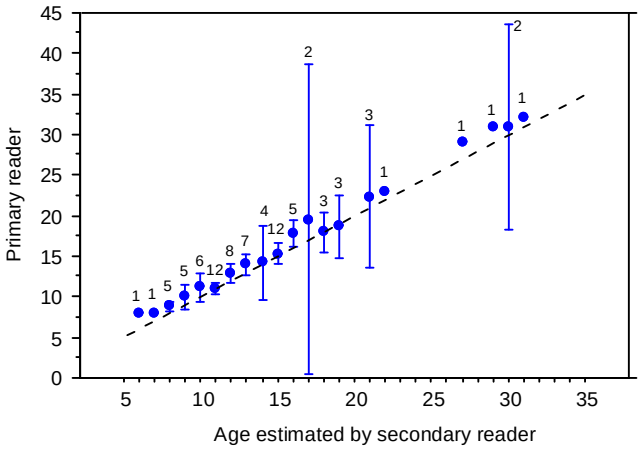

Figure 6. An age bias plot showing relatively consistent error throughout the age range. Error bars represents 95% confidence intervals about the mean age of the primary reader for all ages by the secondary reader (number of age estimate shown; n=83). The line represents 1:1 agreement.

Age composition of the catch

Age has been estimated for a total of 5,840 SBT caught in the longline fishery over 12 spawning seasons (Table 1). Figure 7 shows the estimated age structure of the Indonesian catch by spawning season based on ALKs developed using our aged fish (see previous reports to CCSBT for results from earlier years e.g. Farley et al., 2007a). The median age of SBT caught was 13-14 years in the 2001/02 to 2005/06 seasons. In 2006/07, the median age increased slightly to 16 years, but this may be due to the suspected bias in age estimates. Similarly, the proportion of young SBT (≤ 10 years) in the catch decreased and the mean age increased in 2006/07 (Figure 8; Figure 9). The average age of SBT greater than 20 years has remained relatively stable over time, but has shown a slight decline over the past 3 seasons.

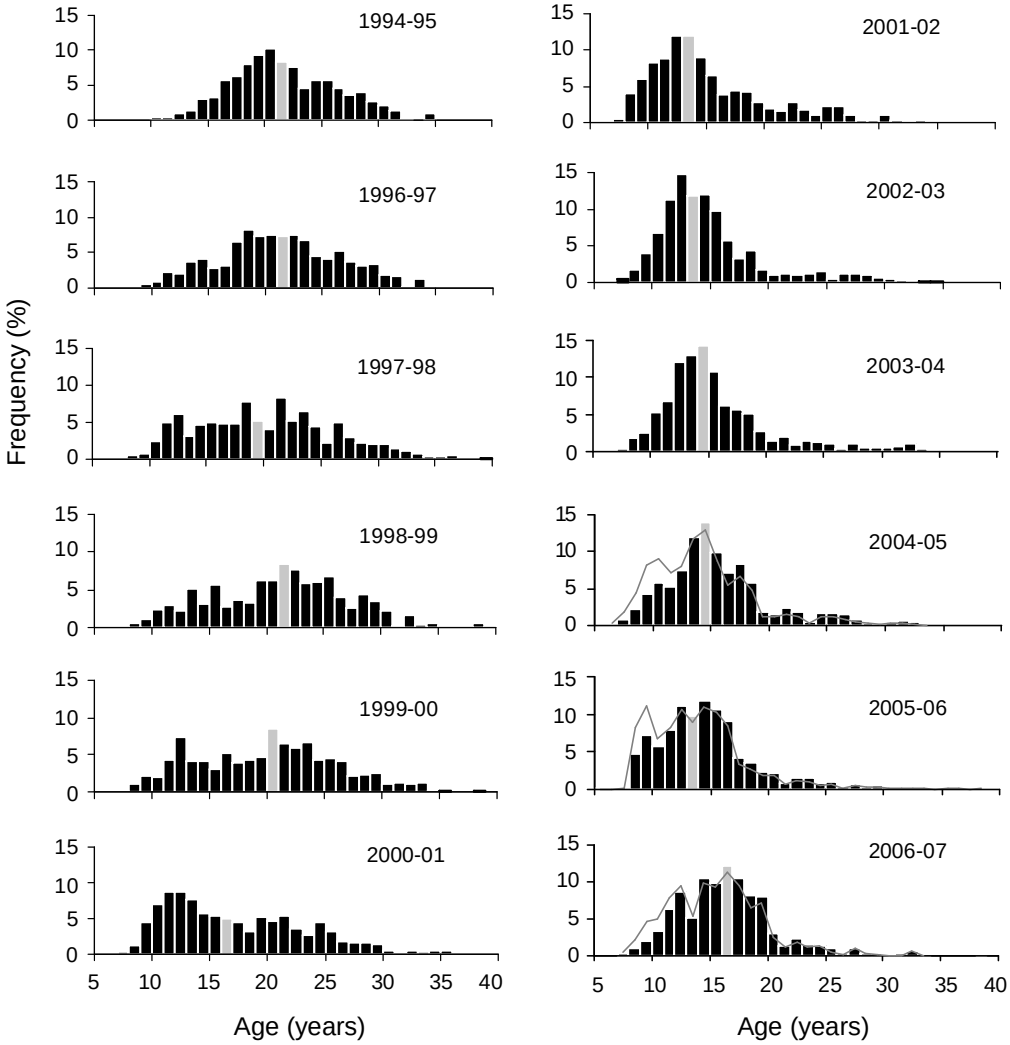

Figure 7. Age frequency distribution of SBT in the Indonesian catch on the spawning ground by spawning season estimated using age-length keys from our sub-samples of aged fish and length frequency data obtained through the Indonesian monitoring program. The grey bar shows the median age class. For comparison, the age distribution of SBT caught south of the spawning ground (Processor A) is shown for the latter three seasons (grey line).

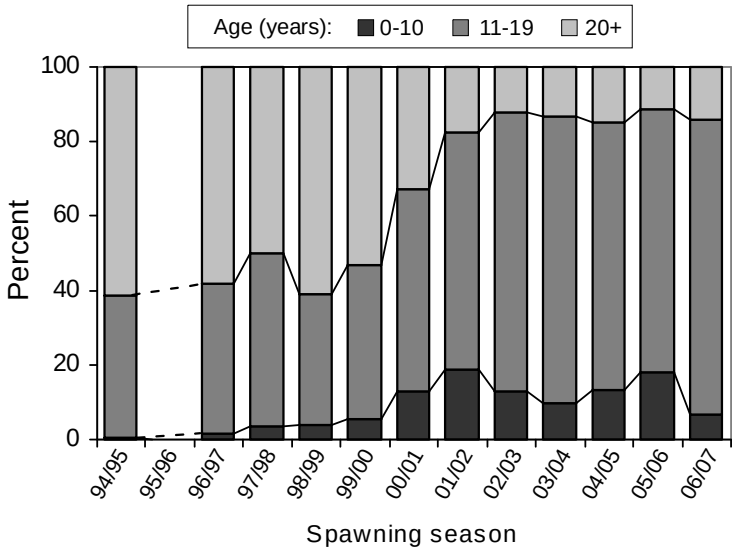

Figure 8. Estimated proportion of SBT by age class in the Indonesian catch on the spawning ground. Note there are no age data for the 1995/96 season.

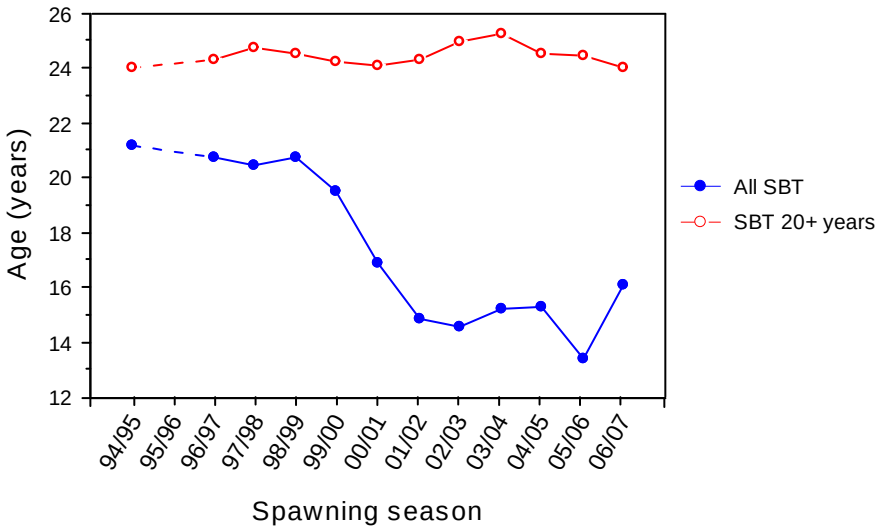

Figure 9. Estimated mean age of SBT in the Indonesian catch on the spawning ground.

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