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

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Abstract

This report 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 2006/07 and age-frequency data for 2005/06 spawning seasons are now available for the fishery. Length frequency data have now been collected for 14 spawning seasons, and the catch-at-age estimated for 11 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 to 167 cm between 1993/94 and 2002/03, and has remained between 168 and 170 cm for the last four seasons.
- In 2006/07, the relative abundance of SBT <165 cm was similar to the previous season, while the proportion of SBT >190 cm declined slightly.
- Age estimates for the 2005/06 season ranged from 5 to 38 years. This is the first season that a 5 year-old SBT has been sampled on the spawning ground.
- The median of the age distribution shifted from 19-21 years (1994/05 to 1999/00) down to 13-14 years (2001/02 to 2005/06). The mean age of SBT sampled declined from 15.3 yrs in 2004/05 to 13.4 yrs in 2005/06.
- 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 63% in 2006/07.

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 (see Proctor et al., 2006 for details). The majority of targeted SBT sampling, however, still occurs at Benoa.

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 10 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.

Recently, 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. (2006) examined the size data of SBT landed in Benoa and found that small fish (<165 cm fork length) comprised a greater proportion of the catch landed at Processor A compared to the other processors, which is consistent with

historic Japanese catch data which showed that the mode of SBT caught on the spawning ('Oka') ground was higher than for the staging ('Oki') ground to the south (Shingu, 1978). Since it is unknown if SBT caught south of the spawning ground are mature or would migrate to the spawning ground, it is important that these fish are identified in the size monitoring data and excluded from our analysis so that the estimated age composition of the spawning population can be compared to previous seasons. In last years reports to CCSBT-ESC, Farley et al., (2006) stated "that otoliths were not sampled from SBT landed at Processor A (operating south of the spawning ground), largely because of restricted access to sampling at that processor". This, however, was not the case, and otoliths were sampled from Processor A in 2004/05 and thus the age-length key developed included age estimated from SBT caught both on and south of the spawning ground.

In this paper we update the information given in Farley et al. (2006) by including the most recent length and age frequency data for the Indonesian fishery. Age frequency data are presented up to the 2005/06 spawning season, while length frequency data includes the 2006/07 season. The data provided to the CCSBT in the April 2006 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 1181 SBT in the 2005/06 spawning season. These data, and those for the 2006 calendar year, were provided for data exchange with CCSBT in April 2007. Length data for the 2006/07 spawning season were not complete at the time of the data exchange, but have since been received and are presented here (n=1586).

Given that the exact location fished is not known for SBT landed at Benoa, the length frequency data were examined to determine if the fishing company (Processor A) identified in as having operated south of the SBT spawning ground in 2005/06 (Proctor et al., 2006), had again appeared to have operated in this region during 2006/07.

Otolith sampling and direct age estimates

Otoliths were sampled from 1181 SBT caught by the Indonesian fishery in the 2005/06 spawning season (Table 1). Sex was obtained for all but three 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) by a technician at the Central Ageing Facility (CAF) in Victoria using the techniques described by Clear et al. (2000) and Gunn et al. (In press). Extensive training was provided to the CAF technician in 2000 and again in 2002.

Each otolith was read twice by the primary otolith reader (CAF). A subsample of 10% of the otoliths were read twice by a secondary otolith reader (CSIRO). To examine the consistency of readings, the Average Percentage Error (APE) method of Beamish and Fournier (1981)

was used to measure the intra-reader consistency in otolith readings (replicate readings by the primary reader) as well as inter-reader consistency (final age estimate of the primary reader and the mean of replicate readings by the secondary reader). 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 2005/06, 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 (see Farley et al., 2006).

Table 1. Number of otoliths sampled from SBT with known LCF caught by Indonesian longline vessels, and number for which age estimates were obtained, by spawning season.

Spawning	Otoliths sampled		Age estimated	
season	n	Known sex (n)	n	Known sex (n)
1994/95	549	0	486	0
1996/97	602	0	475	0
1997/98	519	0	485	0
1998/99	660	121	474	88
1999/00	533	530	498	495
2000/01	720	717	481	478
2001/02	715	713	489	488
2002/03	1502	1502	488	488
2003/04	1283	1283	494	494
2004/05	1523	1520	493	493
2005/06	1181	1178	487	483
Total	9795	7571	5350	3507

Results and Discussion

Length distribution

Length (and weight) measurements for SBT are now available up to April 2007, which covers the entire 2006/07 spawning season (Sep 2006 - Apr 2007). The length frequency distributions are plotted by spawning season in Fig. 1. Length data obtained from Processor A are also shown for the latter four seasons. It is evident that small fish (<165 cm) comprised a greater proportion of the fish landed at Processor A in the 2004/05 to 2006/07 seasons, and to a lesser extent for 2003/04, which is consistent with this fishing company catching SBT south of the spawning ground from 2005. Although the exact catch location of each fish is unknown, size data from Processor A are not included in our estimation of the age distribution of the spawning population after the 2003/04 season.

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 165-190 cm fork length. By the early-2000s, the proportion of small SBT (<165 cm) in the catch increased peaking at 46% in 2002/03, before declining to between 27-34% over the last four seasons (Fig. 2). The mean length of SBT declined from 188.0 cm in 1993/94 to 166.8 cm in 2002/03, and has remained between 168 and 170 cm over the last four seasons (Fig. 3). The proportion of SBT >190 cm in the catch has been relatively constant for several seasons (2.5 to 3.1%), but declined to 1.4% in 2006/07.

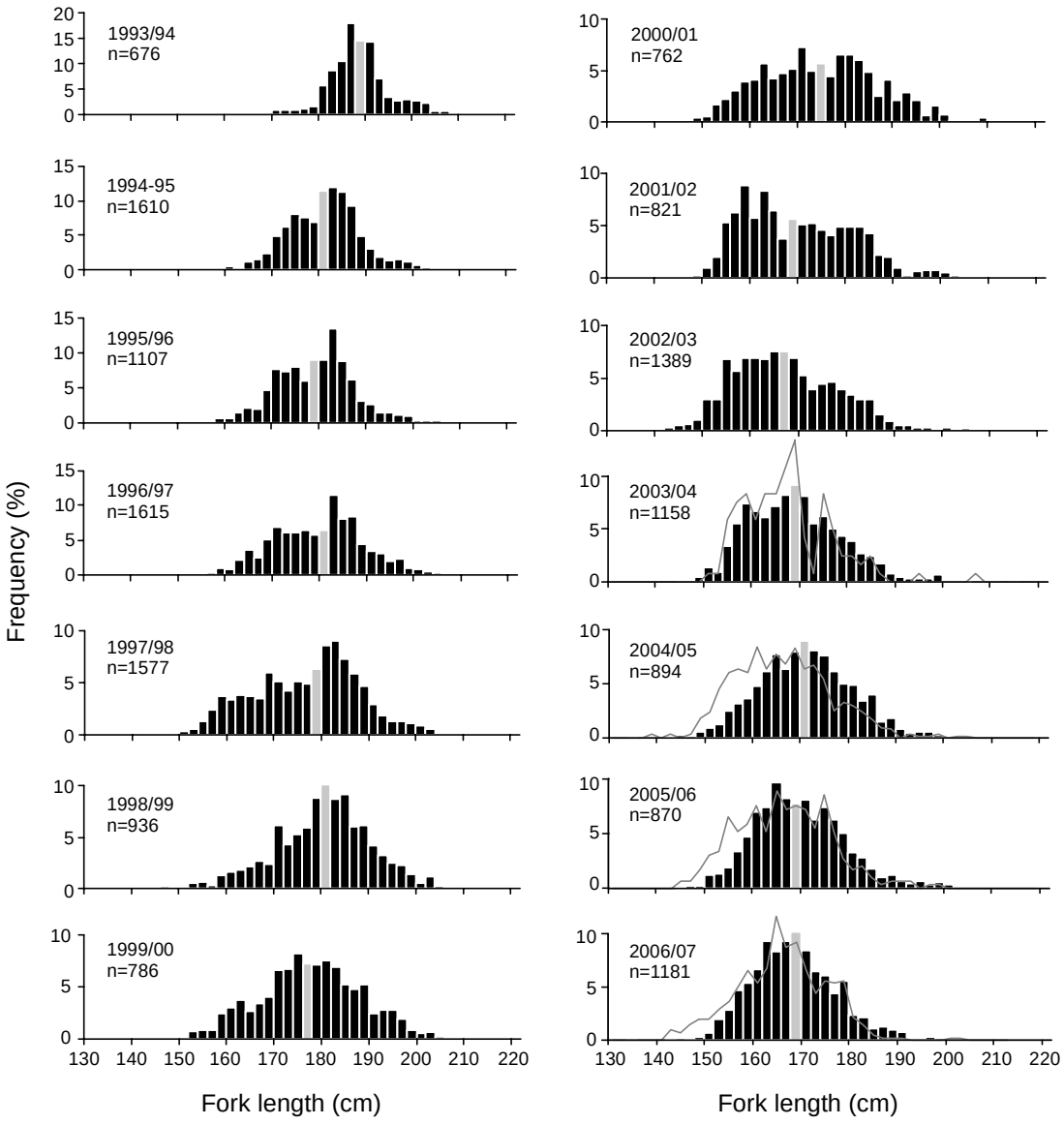

Figure 1. Length frequency (2 cm intervals) of SBT caught on the spawning ground (bars) by spawning season. The grey bar shows the median size class. For comparison, the length distribution of SBT thought to be caught south of the spawning ground (Processor A) is shown for the 2003/04 (n=121), 2004/05 (n=685), 2005/06 (n=311) and 2006/07 (n=411) seasons (grey line). Note that although some fish <130 cm have been measured in the last two seasons, they do not appear on these graphs as the numbers are too low to be visible (n=9).

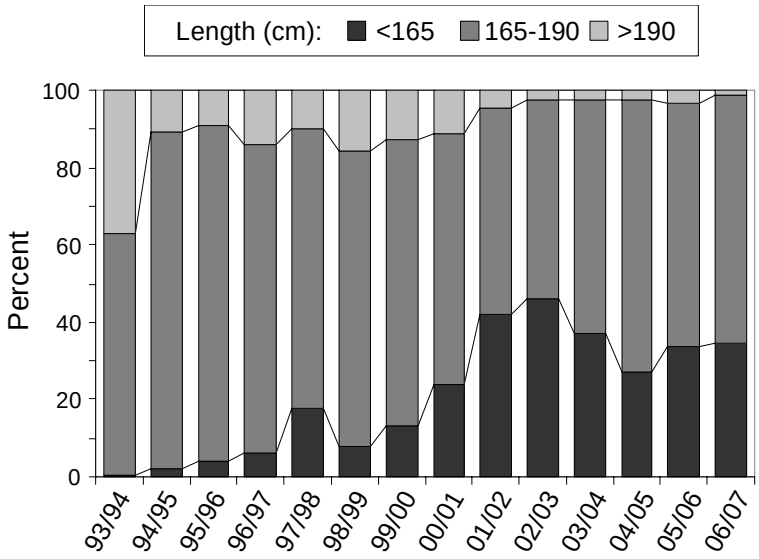

Figure 2. Proportion of SBT caught on the spawning ground by length class and season. Data from Processor A are excluded in the latter three seasons.

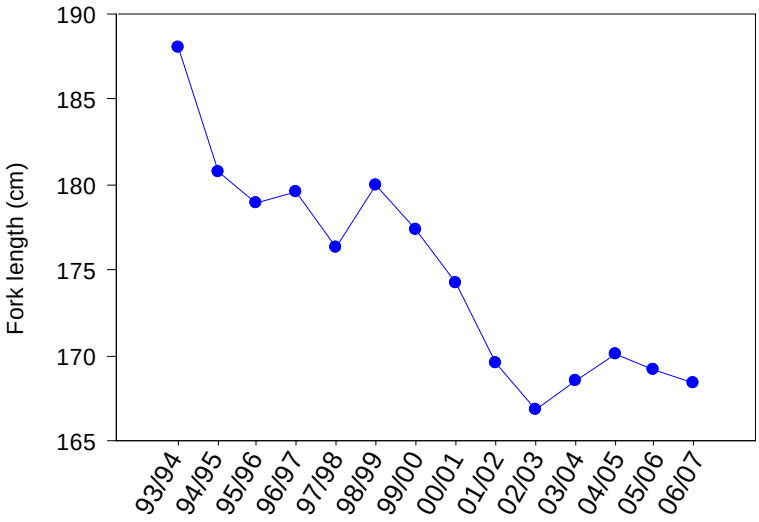

Figure 3. Mean size of SBT in the Indonesian catch on the spawning ground. Data from Processor A are excluded in the latter three seasons.

Sex ratio on the spawning ground

The Indonesian catch of SBT on the spawning ground appears to be dominated by females in all length classes up to ~175-180 cm (Fig. 4). It is interesting to note that this dominance of females has gradually declined over the past 8 seasons from 72% in 1999/00 to 63% in 2006/07 (Fig. 5). 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, since the direct age data indicates sexual dimorphism in length-at-age (see Fig. 6 below), it seems likely that sex has been correctly identified in most cases. Clearly, higher catch rates of females by Indonesia over time will ultimately lead to a decrease in the abundance of females in the spawning population, and a subsequent decline in the reproductive potential of SBT.

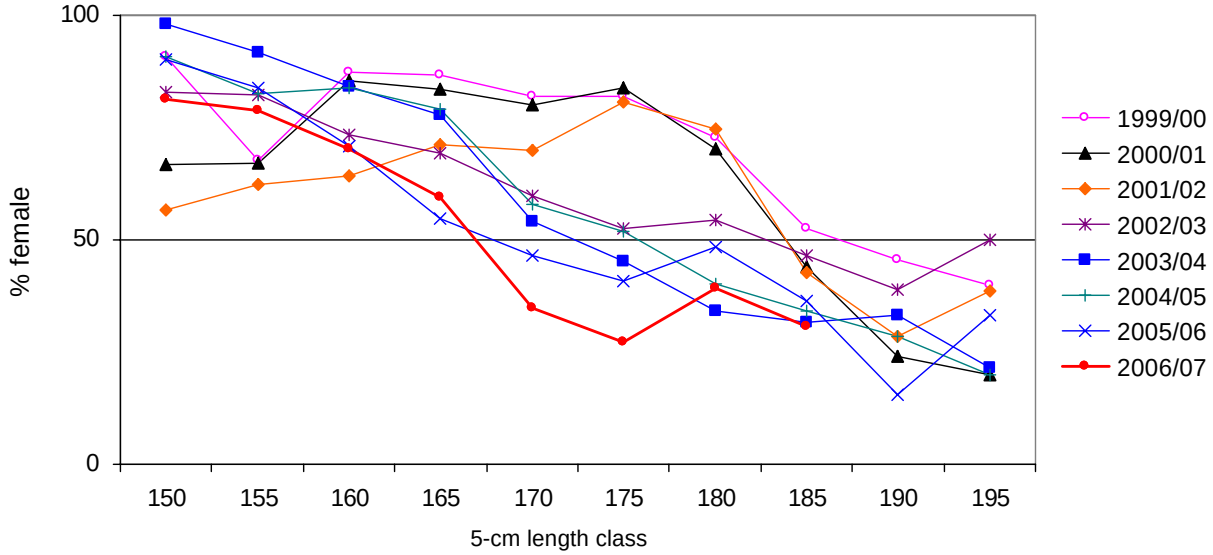

Figure 4. Percent female by 5-cm age class for SBT caught on the spawning ground by spawning season. Data point excluded if n<5. (Data from Processor A excluded).

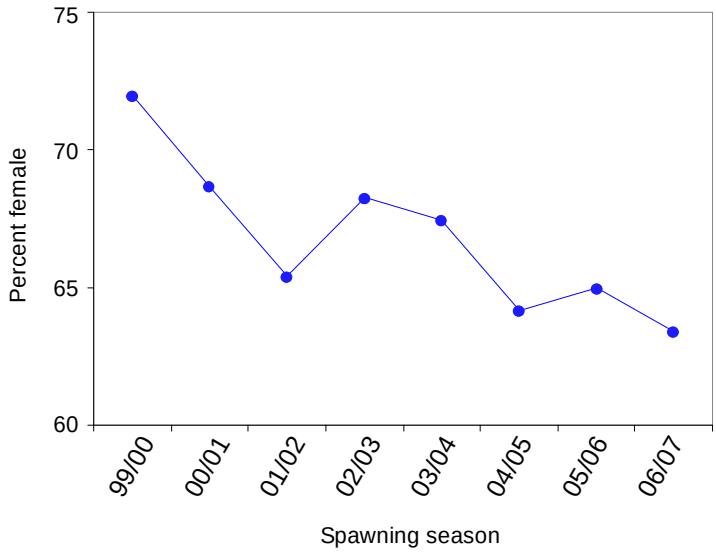

Figure 5. Change in the sex ratio of SBT in the Indonesian catch since the 1999/00 spawning season.

Direct age estimates

Age was estimated for 483 SBT in the 2005/06 spawning season from fish ranging in size from 122-200 cm LCF. The precision of readings was considered good. The second age estimate of the primary reader agreed with the original estimate in 47% of cases and 96% were within two years of the original. The average percent error between primary readings was 2.51, and between primary and secondary readers it was 4.15. These low levels of error, especially between the two readers suggest consistent interpretation of age in blind tests.

For the 2005/06 season, the age estimates ranged from 5 to 38 years. This is the first season that 5 year-old SBT have been sampled on the spawning ground; the otoliths were from 122 cm and 125 cm SBT. These two fish were not sampled at Processor A, and thus were caught on the spawning ground rather than to the south. Age has now been estimated for a total of 5,350 SBT caught in the longline fishery over 11 spawning seasons (Table 1). Of these fish, 3,507 have sex identified; the majority being sampled in the six most recent spawning seasons. Figure 6 shows the mean length at age for the 2005/06 season compared to the mean length-at-age for all data. The sexual dimorphism in length-at-age is clear in the data.

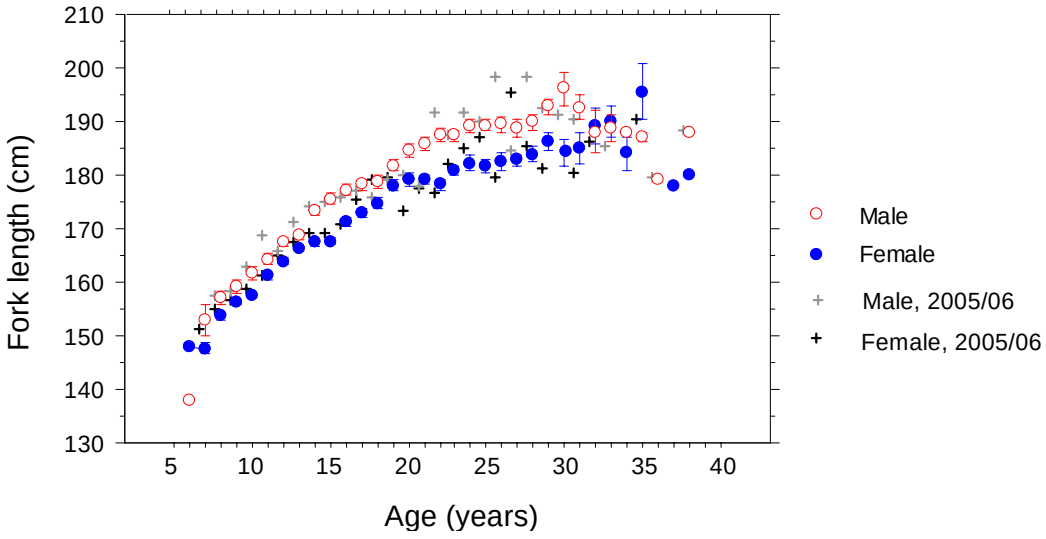

Figure 6. Mean length-at-age by sex (+/-se) for SBT in the Indonesian catch on the spawning ground for all seasons combined and for 2005/06. Note that sex was not recorded for all SBT with an age estimate (Table 1).

Age composition of the catch

Figure 7 shows the age structure of SBT caught by spawning season. The median age of SBT caught on the spawning ground has remained around 13-14 years since the 2001/02 season. The proportion of young fish (≤ 10 years) increased slightly in the latest season examined (Fig. 8). The mean age of SBT caught in 2005/06 (15.3 yrs) was lower than in 2004/05 (13.4 yrs), and estimates for the past 5 seasons are all well below the average in the late-1990s (Fig. 9). The average age of SBT greater than 20 years old has remained relatively stable over time.

The age distribution of SBT caught south of the spawning ground in 2005/06 appear to have a greater proportion of young fish (≤ 10 years) than caught on the spawning ground. This suggests that some young/small SBT may undertake a "trial" migration towards the spawning ground, but stop in the staging area.

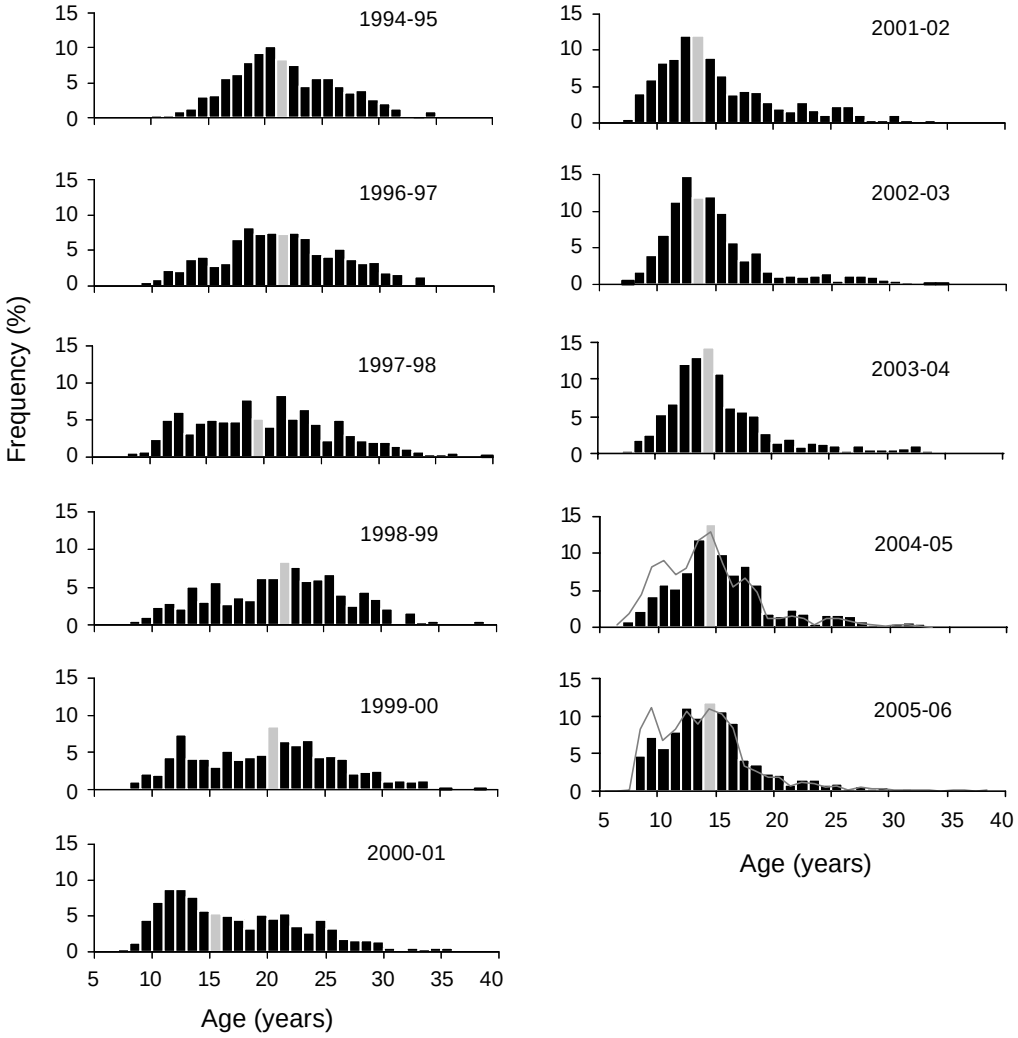

Figure 7. Age frequency distribution of SBT in the Indonesian catch on the spawning ground by spawning season. The grey bar shows the median age class. For comparison, the age distribution of SBT caught south of the spawning ground (Processor A) is shown for the latter two seasons (grey line).

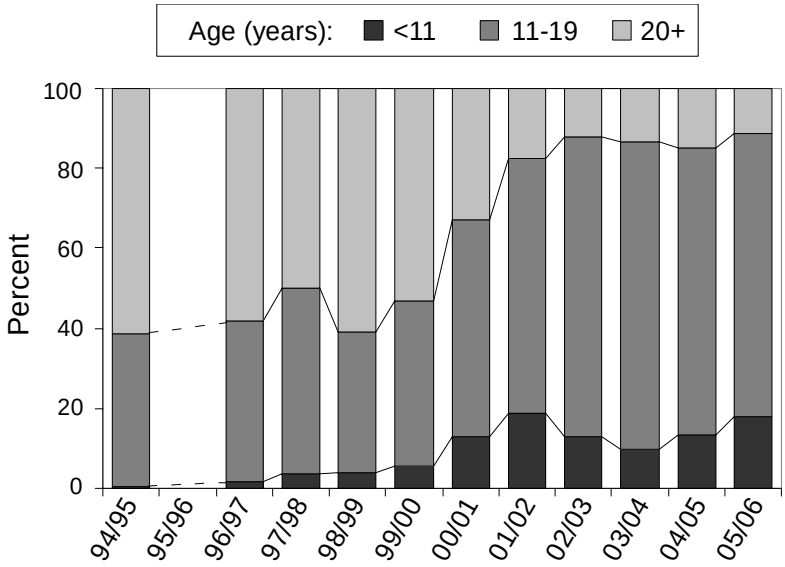

Figure 8. Estimated proportion of SBT by age class in the Indonesian catch on the spawning ground. Note there are no age data for the 1995/96 season.

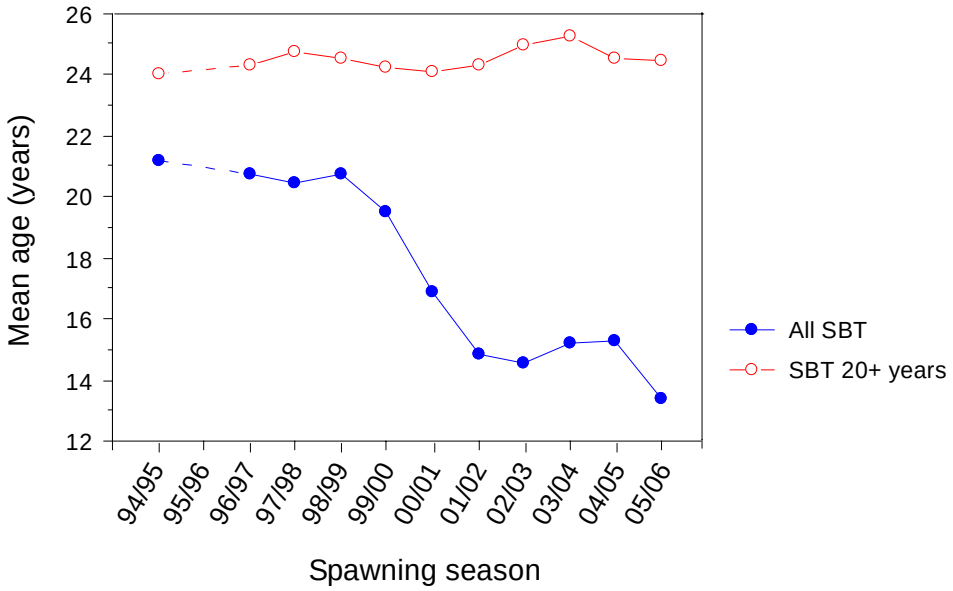

Figure 9. Estimated mean age of SBT in the Indonesian catch on the spawning ground.

Issues to be considered for future sampling

The differences found in the size distribution of SBT caught on and south of the spawning ground highlights the need to identify the catch location of SBT monitored, so that SBT not considered part of the spawning population can easily be excluded from analysis. Data on catch locations will also allow for further investigations of the size/age distribution of SBT by latitude to determine if, for example, older and larger SBT migrate further north than younger and smaller fish (i.e. migration increases with size/age). In addition, targeted sampling of otoliths and gonads from SBT caught in the "southern zone" will allow us to determine if the small fish caught in this region are mature, and examine differences in length-at-age that might help determine whether sexual maturity is size or age related.

Acknowledgements

The success of the SBT monitoring program was only possible due to the dedicated efforts of all the enumerators at Benoa, and in particular that of Mr Kiroan Siregar, the otolith sampler and primary measurer of the fish. We also thank Mr Enjah Rahmat (RIMF) for all entry of data into the SBT biologicals database and to Mr Budi Iskandar Prisantoso (RCCF) in his role as database manager. 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.

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