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 2005/06 and age-frequency data for 2004/05 spawning seasons are now available for the fishery. Length frequency data has now been collected for 13 spawning seasons, and the catch-at-age estimated for 10 seasons. In summary:

- The size distribution and length-weight relationships of SBT caught in the 2004/05 and 2005/06 seasons are consistent with the belief that some Indonesian fishing companies are now operating south of the SBT spawning ground. Since it is unknown if all SBT caught in this southern zone are mature or would migrate to the spawning ground, they were not considered part of the spawning population for the 2004/05 and 2005/06 seasons.
- The relative abundance of small SBT (<165 cm) caught on the spawning ground increased slightly in 2005/06 compared to the previous season, but was similar to the 2003/04 season. The proportion of large SBT (>190 cm) has remained at around 2.5-3.0% of the catch for the last three seasons.
- Age estimates ranged from 6 to 35 years for fish sampled in the 2004/05 season. This is the first season that a 6 year-old SBT has been sampled on the spawning ground. The estimated median age of SBT caught on the spawning ground has remained around 13-14 years since 2001/02.
- The relative abundance of young SBT (≤ 10 years) was lower on the spawning ground (13.4%) than south of the spawning ground (24.0%).
- The sex ratio of SBT measured both on and off the spawning ground appears to be heavily biased towards females for fish up to ~170 cm fork length.

Introduction

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), and the Indian Ocean Tuna Commission (IOTC). 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 Andamari et al., 2006 for details). The majority of targeted SBT sampling, however, still occurs at Benoa. The monitoring has been very successful and over 14,000 length measurements and 7,500 otoliths (for age estimation) have been collected.

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 nine spawning seasons. These data has 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 down to 12-15 years in the early-2000s.

Recently, Andamari et al. (2005) indicated that at least one Benoa-based fishing company had shifted their operations to target SBT south of the SBT spawning ground. This was supported by preliminary analysis of the Indonesian Fishery School data which showed that the proportion of hooks observed south of 15°S and 20°S had increased steadily between 2001 and 2005 (Basson et al., 2005). Unfortunately, the exact catch location of SBT landed in Benoa has historically[1] been difficult to obtain, therefore making it difficult to separate the size frequency data for SBT caught on and off the spawning ground. However, through information received by the samplers working in the monitoring program at Benoa, there is strong evidence that at least one company at Benoa has processed SBT caught south of the spawning ground during recent seasons.

In this paper we update the information given in Farley and Davis (2005) by including the most recent length and age frequency data for the Indonesian fishery. Age frequency data are presented up to the 2004/05 spawning season, while length frequency data includes the 2005/06 season. We also examine the differences in the size/age of SBT caught on and south of the spawning ground. 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 and otolith sampling

As in previous years, targeted sampling of SBT occurred at the Port of Benoa. Length measurements were obtained for 1579 SBT in the 2004/05 spawning season and 1181 SBT in the 2005/06 spawning season. The length frequency distribution of the catch for the 2004/05 spawning season and 2005 calendar were provided for data exchange with CCSBT, but the 2005/06 spawning season data were not complete at the time of the data exchange. These data has now been received and are presented.

As already noted, it appears that some fishing companies have been operating south of the SBT pawning ground since 2004. It is important that the size distribution of SBT caught in this "southern zone" are separated from the spawning ground SBT so that the age composition of the spawning population can be determined and compared to previous seasons. Through the SBT monitoring program, one processor was identified as having fishing vessels operating in the southern zone (Processor A). To corroborate this, we examined the size distribution and length-weight relationship of SBT landed at this processor compared to the other processors (combined) in the 2003/04, 2004/05 and 2005/06 spawning seasons to determine if differences could be detected.

Direct age estimates

Otoliths were sampled from 1523 SBT caught on the spawning ground from the 2004/05 spawning season. Otoliths were not sampled from SBT landed at Processor A (operating

[1] A trial scientific observer program was established at Benoa in August 2005, through the ACIAR funded project (FIS/2002/074), and is now providing accurate catch location information for at least some of the Benoa longline fleet.

south of the spawning ground), largely because of restricted access to sampling at that processor. Sex was obtained for all SBT with otoliths sampled. Of those sampled, 500 were selected for age estimation. A fixed number of otoliths were chosen from each 5 cm length class (stratified sampling rather than random sampling) 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.

Age estimates from the current work were combined with those of Gunn et al. (1998), Farley et al. (2001), and Farley and Davis (2002; 2003; 2004; 2005) for the previous eight spawning seasons.

Age composition of the catch

To determine the age structure of SBT caught on the spawning ground, an age-length key has been developed for each season 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.

Results and Discussion

Length distribution

Length (and weight) measurements for SBT are now available up to April 2006, which covers the entire 2005/06 spawning season (September 2005 -April 2006). The length frequency distributions are plotted by spawning season in Fig. 1. For the latter three seasons, the length data of SBT thought to have been caught south of the spawning ground (i.e. Processor A) are also shown.

It is evident from Figure 1 and Table 1 that small fish (<165 cm) comprised a greater proportion of the fish landed at Processor A (and thus mean size is lower) compared to the other processors, especially in the 2004/05 and 2005/06 seasons. This 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). The small difference in the size composition of SBT landed at processor A and the other processors in the 2003/04 season, however, suggests that fishing in the southern zone was not in progress until after mid-2004. Since it is unknown if all SBT caught in this southern area

are mature or would migrate to the spawning ground, they are not included in the spawning population for the 2004/05 and 2005/06 seasons.

As noted in previous reports (Farley and Davis 2002; 2003; 2004; 2005), 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 170-190 cm FL. Since 2002, smaller SBT (<165 cm) have comprised a greater proportion of the catch (Figure 2). The increase in the relative abundance of small SBT occurred initially in 1997/98, and again to a greater extent in 2000/01, before declining (Figure 2). The mean length of SBT caught on the spawning ground declined from 188.0 cm in the 1993/94 season to 166.8 cm in the 2002/03 season, but has increased to around 169-170 cm in the last three seasons. The relative proportion of large SBT (>190 cm) has remained constant at around 2.5-3% of the catch for the last three seasons.

Length-weight relationships

Figure 3 shows the length-weight relationship of SBT caught on and south of the spawning ground by month from our sample of measured fish. The monthly patterns are very similar to those establish by Wirashina and Hisada (1970) and Shingu (1978) in the late-1960s and late-1970s respectively for SBT caught on the "Oka" and "Oki" fishing grounds.

In September, the majority of SBT measured were fatter than average, and were presumably pre-spawning fish caught on (or migrating to) spawning ground. By October, the level of 'fat' fish caught on the spawning ground decreased to around 30%, where it remained until April. This is consistent with the findings of Farley and Davis (1998) who suggested that there was a turn-over of fish on the spawning ground with pre-spawners arriving throughout the season. By April the proportion of "fat" fish present dropped to only 15%, as most fish would be nearing the end of their spawning cycle and in poor condition.

By comparison, fewer fat fish were caught south of the spawning ground from October to April, compared to those caught on the spawning ground. The only exception was in January when fat fish increase to 31% of the catch. These fish may be a second wave of pre-spawners moving onto the spawning ground, as the timing corresponds to a second peak in abundance of SBT known to occur on the spawning ground (Farley and Davis, 1998). From February to April, almost all SBT sampled south of the spawning ground were thinner than average, and were most likely post-spawning fish moving through the area on their way back to the southern oceans after spawning.

The patterns of monthly length-weight relationship corroborate Andamari et al.'s (2005) understanding that some Indonesian fishing companies were recently operating south of the spawning ground.

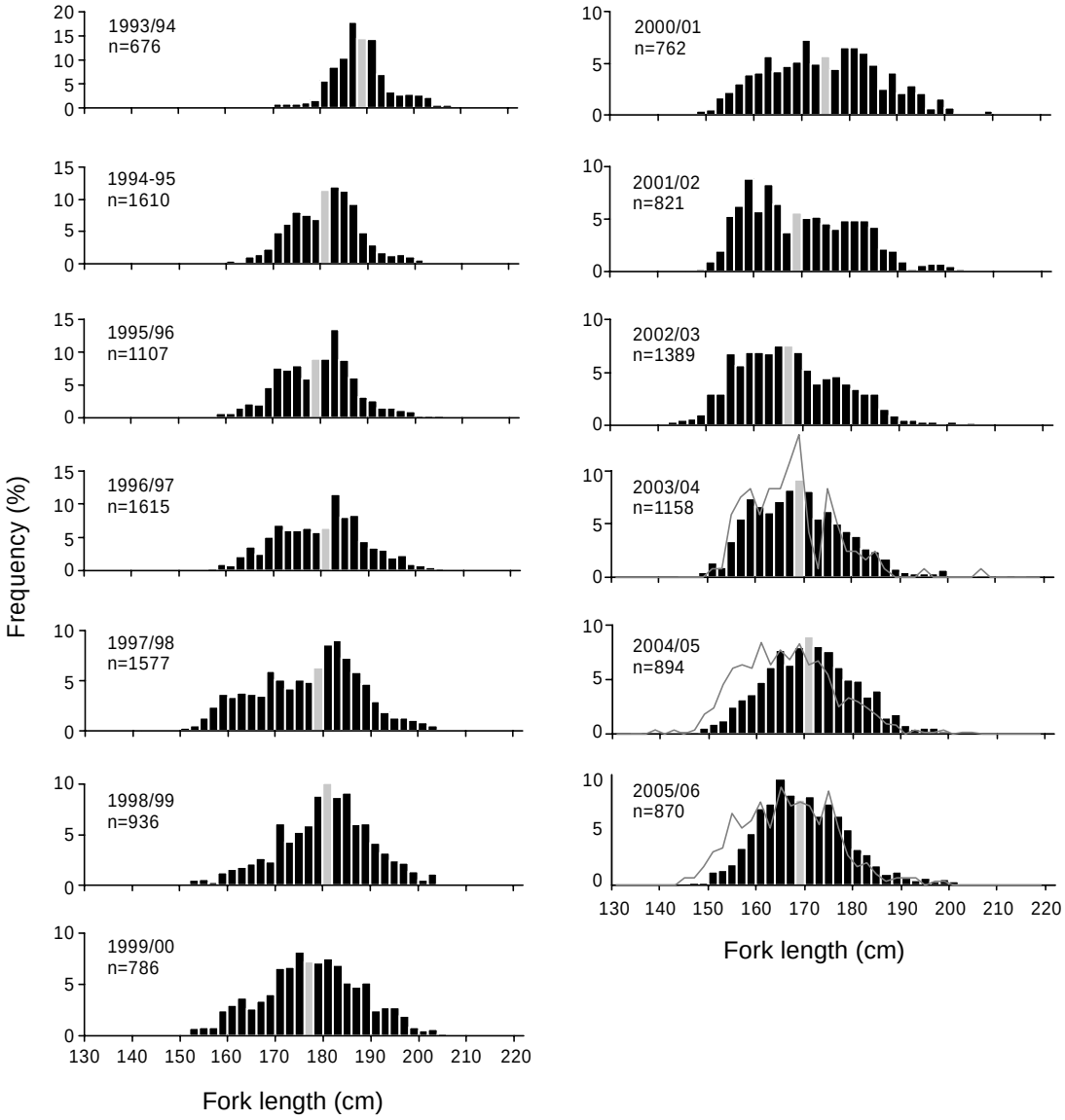

Figure 1. Length frequency (2 cm intervals) of SBT caught on the spawning ground (bars) by spawning season. The grey bar shows the median size class. For comparison, the length distribution of SBT thought to be caught south of the spawning ground is shown for the 2003/04 (n=121), 2004/05 (n=685) and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

Table 1. Mean length and percent of SBT < 165 cm in landings measured at Processor A (caught south of the spawning ground) and the other processors combined (caught on the spawning ground) by spawning season.

Spawning season	Processor A			Other processors		
	Mean LCF (cm)	% < 165 cm	n	Mean LCF (cm)	% < 165 cm	n
2003/04	167.1	43.0	121	168.7	36.3	1158
2004/05	166.1	46.3	658	170.1	27.1	894
2005/06	166.5	42.4	311	169.6	33.8	870

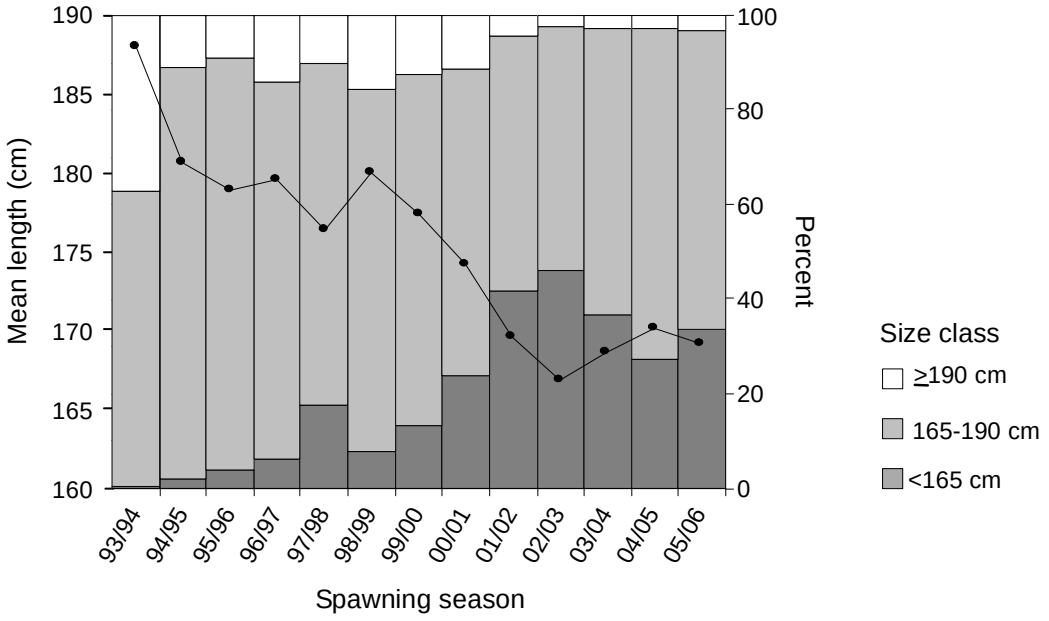

Figure 2. Mean length (left axis; line) and percent by length class (right axis; bars) of SBT caught on the spawning ground by spawning season. (Excluding data from Processor A in the latter two seasons).

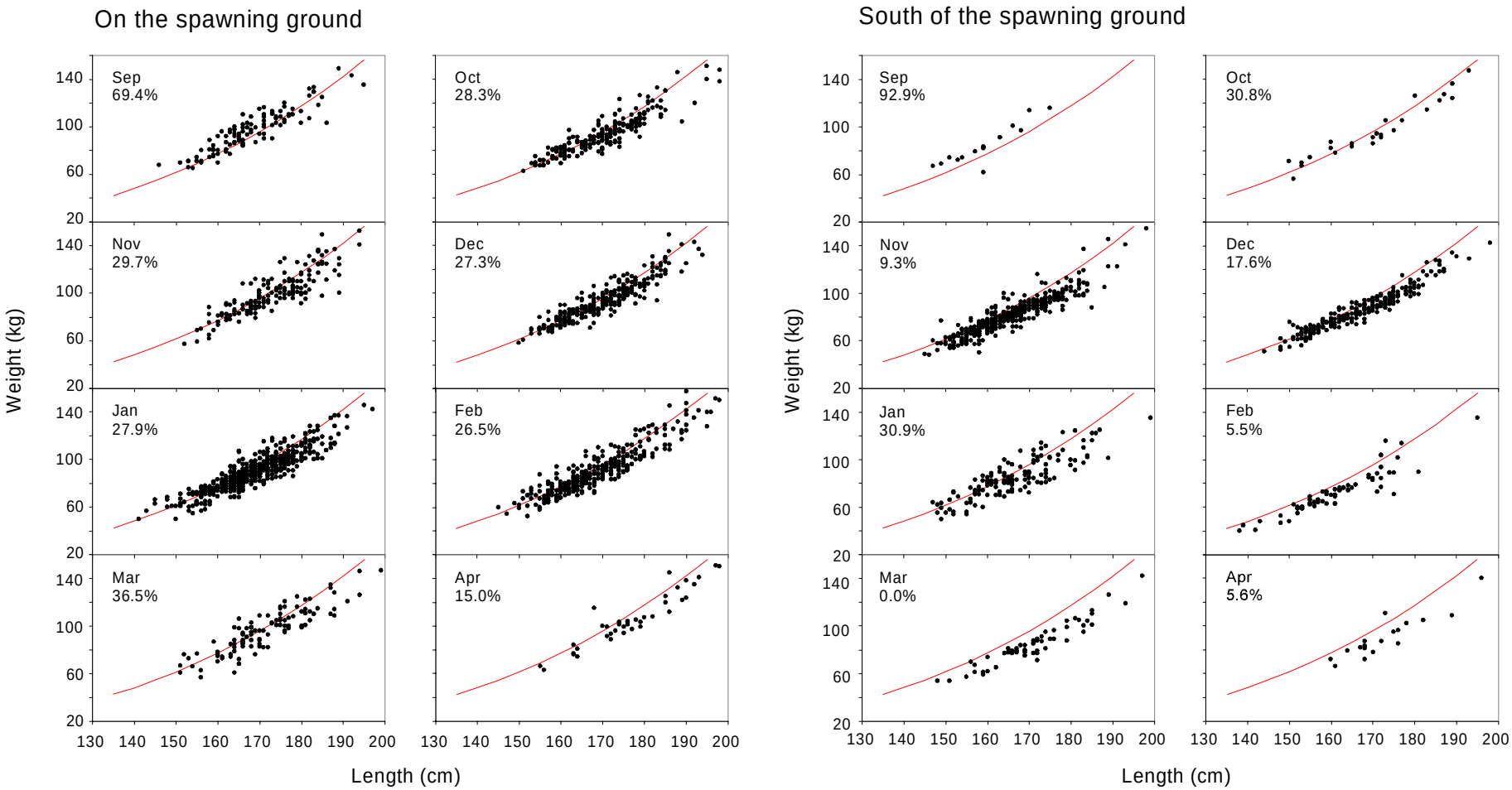

Figure 3. Length and weight relationship of SBT caught by month on and south of the spawning ground in the 2004/05 and 2005/06 spawning seasons (combined). The line indicates the average regression line for SBT >130 cm ($W = 1.2205 \times 10^{-5} \times L^{3.5399}$) estimated by Wirashina and Hisada (Caton, 1991). The percent of SBT above the regression line (pre- or early-spawning fish) is indicated.

Sex ratio

As indicated in previous reports to CCSBT-ESC, the sex ratio of SBT in the Indonesian catch SBT catch is highly skewed towards females. The proportion female ranged between 64% and 72% of the measured catch in the 1999/00 to 2005/06 spawning seasons. Similarly, the sex ratio of SBT caught south of the spawning ground in the 2004/05 and 2005/06 seasons was also highly skewed towards females; 65% and 69% of the fish were female. When examined by 5-cm length class, females dominate in all classes up to 170-180 cm, after which males tended to dominate (Figure 4).

Given that males grow faster and attain a larger size than females, it follows that males would become more prominent as size increases. However, the dominance of females in the smaller length classes is difficult to explain. It has been suggested that the method used to determine the sex of SBT landed in Benoa is not accurate. However, since the data indicates sexual dimorphism in length-at-age (see Figure 5), it seems likely that the sex of some fish at least have been correctly identified. Clearly, higher catch rates of females by Indonesia 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.

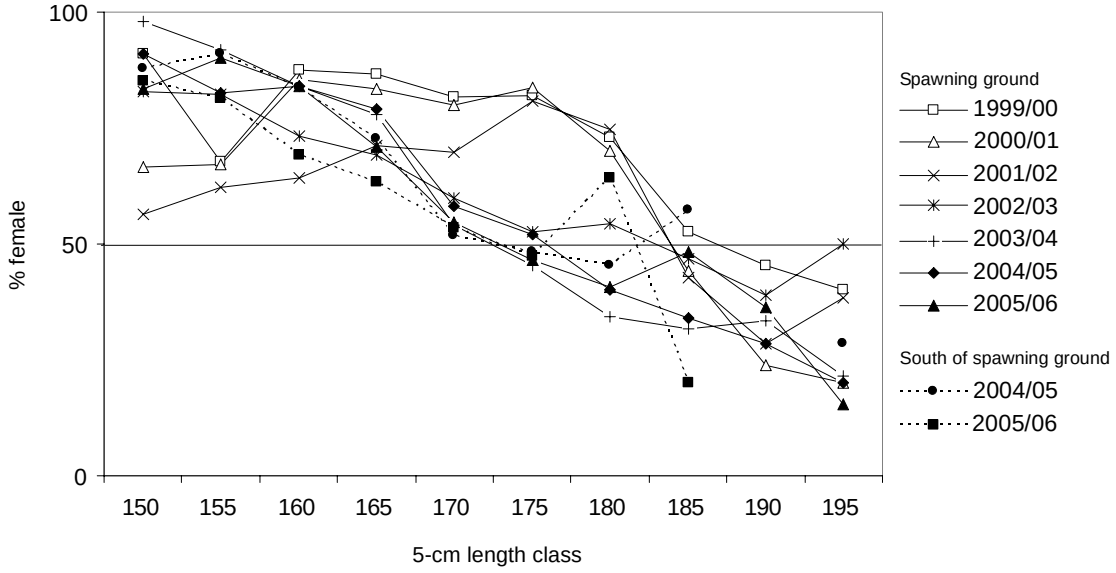

Figure 4. Percent female by 5-cm age class for SBT caught on the spawning ground by spawning season. Data point excluded if n<5.

Direct age estimates

Age was estimated for 493 SBT in the 2004/05 spawning season from fish ranging in size from 138-203 cm LCF. The precision of readings was considered good. The second age estimate of the primary reader agreed with the original estimate in 45% of cases and 96% were within two years of the original. The average percent error between primary readings was 2.67, and between primary and secondary readers it was 3.52. These very low levels of

error, especially between the two readers suggest consistent interpretation of age in blind tests.

Age has now been estimated for a total of 4,863 SBT caught in the longline fishery over ten spawning seasons (Table 2). Of these fish, 3,024 have sex identified; the majority being sampled in the five most recent spawning seasons. The 2004/05 data shows less sexual dimorphism in length-at-age than observed in the 2003/04 season, but males were still longer on average for a given length (Figure 5).

Table 2. Number of otoliths sampled from SBT 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
Total	8606	6386	4863	3024

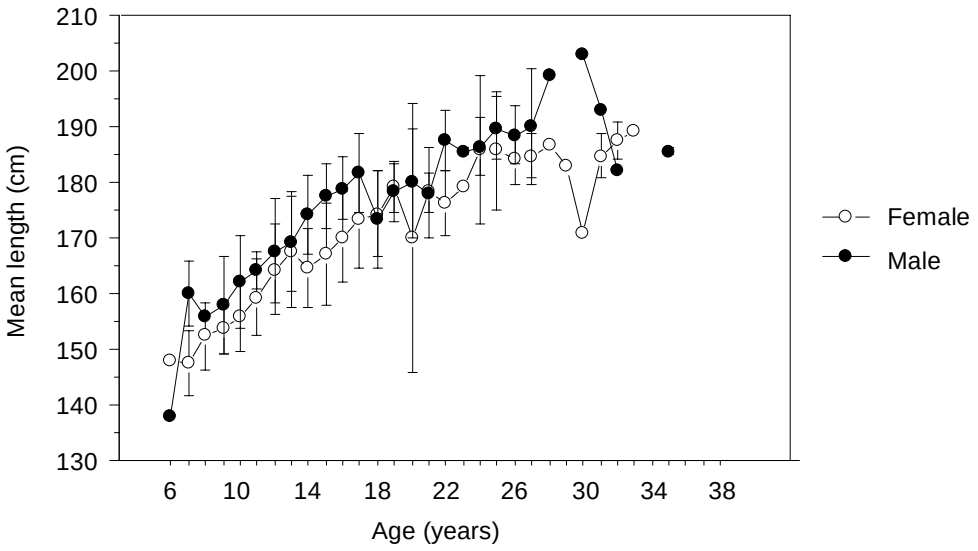

Figure 5. Mean length-at-age by sex (and standard deviations) for SBT caught on the spawning ground in the 2004/05 season.

Age composition of the catch

Age estimates ranged from 6 to 35 years for fish sampled in the 2004/05 season. This is the first season that a 6 year-old SBT has been sampled on the spawning ground. The age length key developed for 2004/05 was applied separately to length frequency data for SBT caught on and south of the spawning ground. Figure 6 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) has increased slightly in the latest season examined (2004/05) (Figure 7) and the mean age has increased over the last two seasons (Figure 8). Although the average size of SBT aged 20+ years has been increasing recently, it decreased slightly in the 2004/05 season.

Estimating the age composition of SBT south of the spawning ground using the key developed for the spawning ground can introduce significant bias. Unfortunately, otoliths were not sampled from the southern fish to develop a separate key. Despite this, the age distribution of SBT caught south of the spawning ground appear to have a greater proportion of young fish (≤ 11 years) than caught on the spawning ground in 2004/05. This ground suggests that some young/small SBT may undertake a "trial" migration towards the spawning ground, but stop in the staging area. This is consistent with work by Farley et al. (2001) which found that maturity appeared to be related to size in SBT, with larger fish for an age class (up to age 15) being caught on the spawning ground compared to those caught in the West Wind Drift.

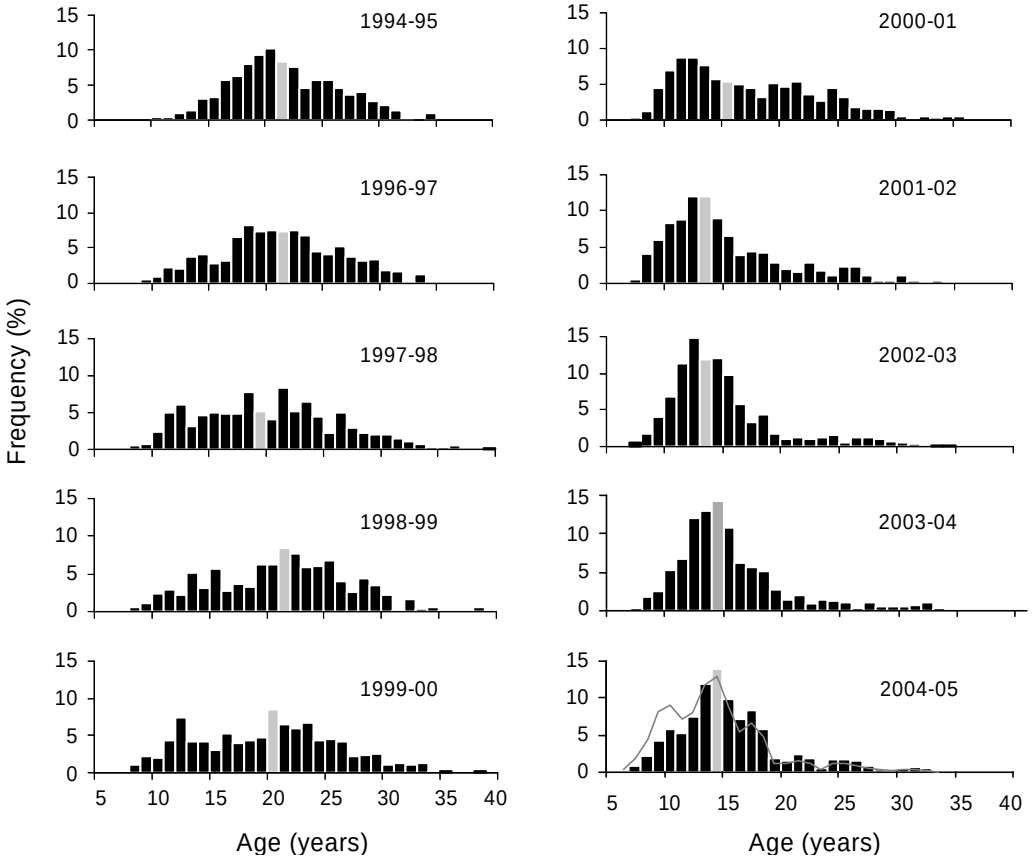

Figure 6. Age frequency distribution of SBT caught on the spawning ground by spawning season. The grey bar shows the median age class. For comparison, the age distribution of SBT caught south of the spawning ground is shown for the 2004/05 seasons (grey line).

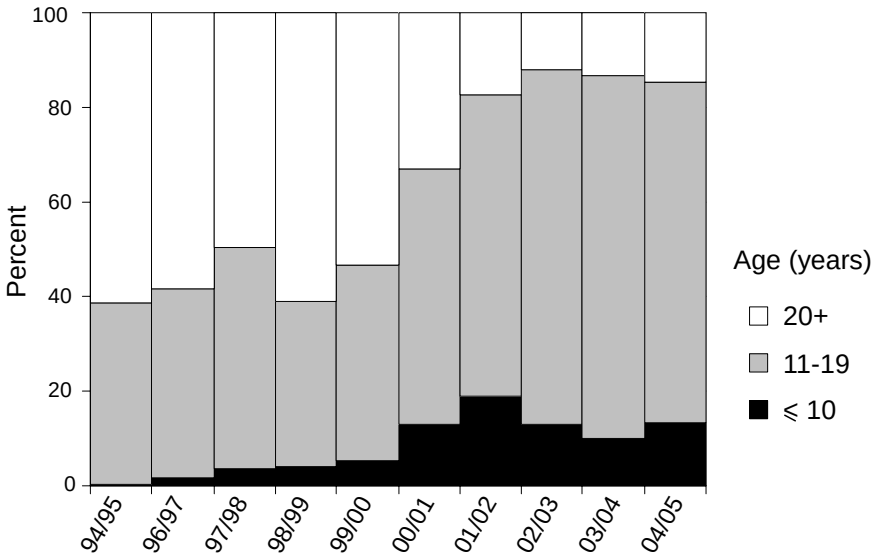

Figure 7. Estimated proportion of SBT caught by age class on the spawning ground. Note there are no age data for the 1995/96 season.

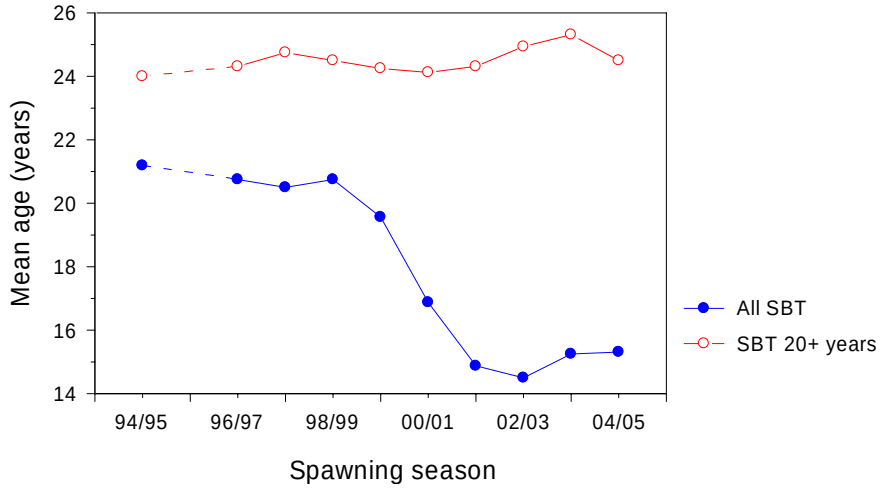

Figure 8. Estimated mean age of SBT on the spawning ground by spawning season for all SBT and SBT aged 20 years and above.

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 (ie 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 for all entry of data into the SBT biologicals database, and to Ms Retno Andamari for her tireless supervision and management of the Benoa sampling program. 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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