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 2008/09 and age-frequency data for 2007/08 spawning seasons are now available for the fishery. 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:

1) Length distribution - the mean of the size distribution declined from 188.1 to 166.8 cm between 1993/94 and 2002/03, and has fluctuated between 168.3 and 171.0 cm for the last 6 seasons.

2) Age distribution - the mean of the age distribution declined from around 19-21 years in the mid- and late-1990s to around 14-15 years since 2001/02. In the latest season examined (2007/08), the mean age increased slightly to 16.8 years.

3) Sex ratio - the data suggests that the Indonesia SBT catch is dominated by females, but that this dominance has gradually declined from 72.0% in 1999/00 to 63.4% in 2006/07. The decline was more marked in 2007/08 with 50.8% of those measured identified as female, but this increased slightly to 53.3% in the latest season.

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 modeling 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 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.

During 2008 there was a significant change in funding arrangements for the Benoa monitoring program. Prior to July 2008, much of the funding for both the port-based monitoring, the associated biological sampling, and for the analyses for age determinations (i.e. otolith readings) was provided by Australia's Department of Agriculture, Fisheries and Forestry (DAFF), and during 2002 – 2003 also by Australian Centre for International Agricultural Research (ACIAR). The DAFF funding ceased at the end of June 2008 and CSIRO then provided 'gap funding' to cover the operating costs for the remainder of 2008 and first half of 2009. These gap funds supplemented what Indonesia's Agency for Marine and Fisheries Research (which includes RCCF and RIMF) provided for Indonesia's increased uptake of responsibility for the fiscal and operational management of the program. Further comments on this increased responsibility are covered below in *Future Developments*.

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 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.

In this paper we update the information given in Farley et al. (2008) by including the most recent length and age frequency data for the Indonesian fishery. The data provided to the CCSBT in the April 2009 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 1692 SBT in the 2007/08 spawning season (Table 1). These data were provided for data exchange with CCSBT in April 2009. Length data for the 2008 calendar year and 2008/09 spawning season were not complete at the time of the data exchange but have since been received (Table 1).

Otolith sampling and direct age estimates

Otoliths were sampled from 1697 SBT caught by the Indonesian fishery in the 2007/08 spawning season (Table 1). Sex was obtained for all 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 'Fish Ageing Services Pty Ltd' (FAS) in Victoria, using the techniques described by Clear et al. (2000). FAS is a new fee-for-service ageing laboratory established in early 2009. The SBT otolith reader at the FAS is the same reader associated with the 'Central Ageing Facility' which has read the Indonesian SBT otoliths for the past 9 years.

Each otolith was read twice by the primary otolith reader (FAS) and then given a final age estimate. A subsample of 50 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 2007/08, 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. 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	1385	1374	1502	488	488
2003/04	1279	1276	1283	494	494
2004/05	1580	1555	1523	493	493
2005/06	1182	1178	1180	486	482
2006/07	1586	1577	1586	491	486
2007/08	1693	1691	1692	485	485
2008/09	1704	1702	1697	-	-
Total	20299	12765	14986	6325	4478

[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 2009, which covers the entire 2008/09 spawning season (Aug 2008 - Apr 2009). The length frequency distributions are plotted by spawning season in Figure 1. Length data obtained from one company that was identified as having fishing vessels regularly operating south of the spawning ground (Processor A) are shown separately (see Farley et al., 2007a). SBT from this processor are not included in our examination of the size/age distribution of the spawning population, but they are 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 (Figure 1). In the early-2000s, the relative proportion of small SBT (<165 cm) 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 has remained between 168 and 171 cm for the past 6 seasons (Figure 3).

The mean size of SBT has remained between 168 and 171 cm since 2003/04. Note that SBT from the first season studies (1993/94) may not be representative as they were all caught in the latter part of the season (December to May). However, if only data for December to May were selected for all seasons, a similar decline in the mean length by season is clear (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 has not been accurately estimated for SBT, but is thought to be around 152-162 cm or greater (Davis, 1995; Schaefer, 2001)]. The relative proportion of large SBT (>190 cm) in the catch has remained relatively constant since 2002/03 at 1.4 - 3.1% of the catch.

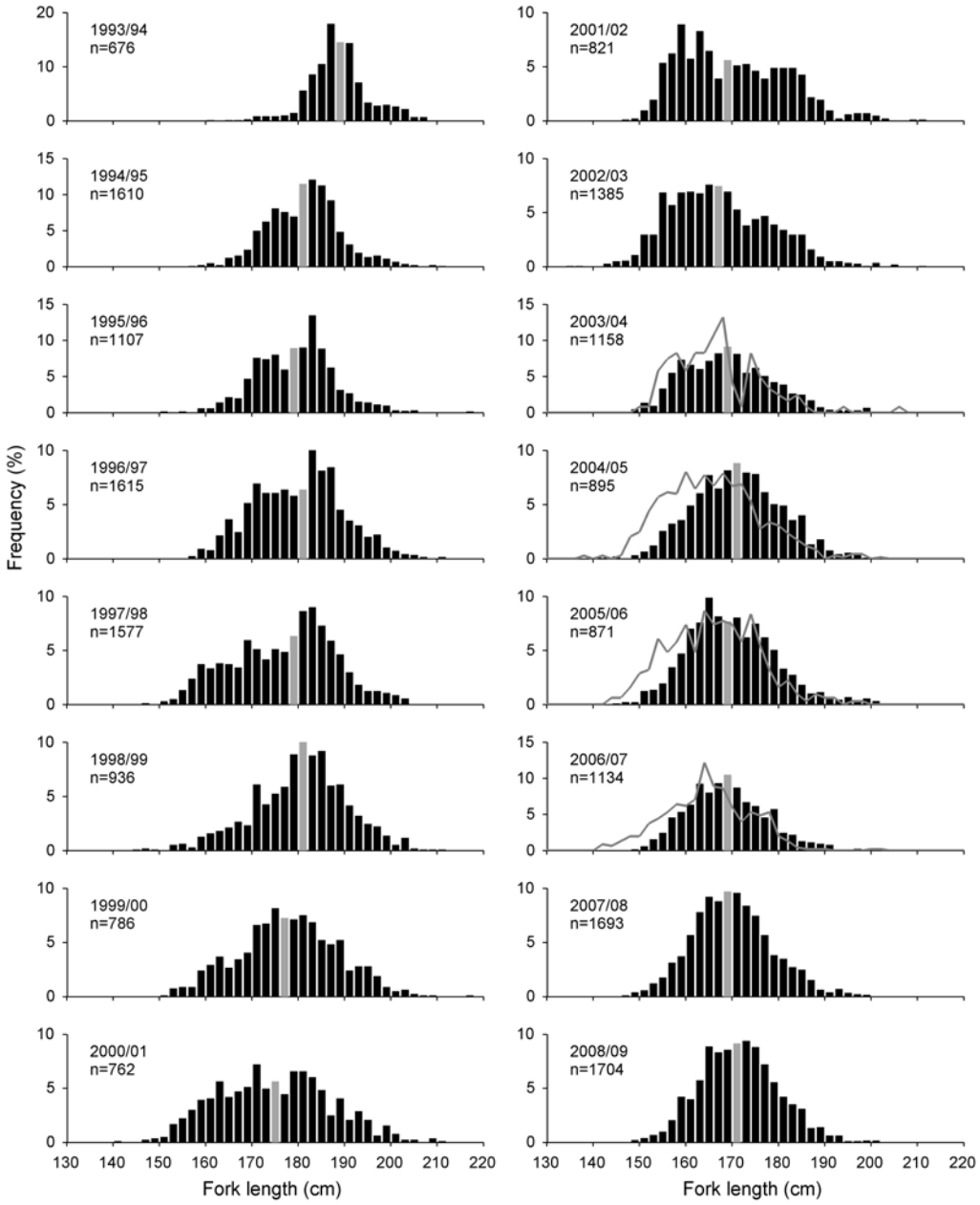

Figure 1. Length frequency (2 cm intervals) of SBT caught on the spawning ground (bars) by spawning season. The grey bar shows the median size class. For comparison, the length distribution of SBT thought to be caught south of the spawning ground (Processor A) is shown for the 2003/04 (n=121), 2004/05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

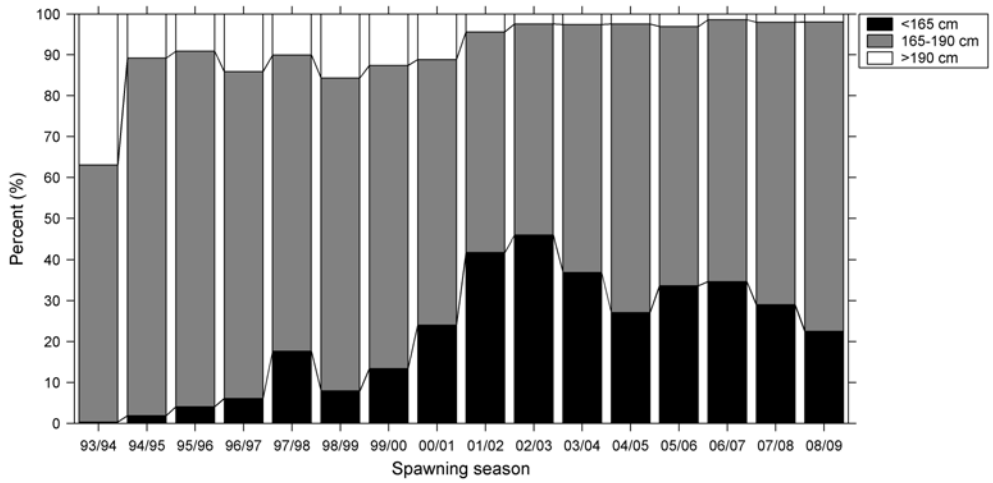

Figure 2. Proportion of SBT caught on the spawning ground by small (<165 cm), medium (165-190 cm) and large (>190 cm) SBT by season. Data from Processor A are excluded.

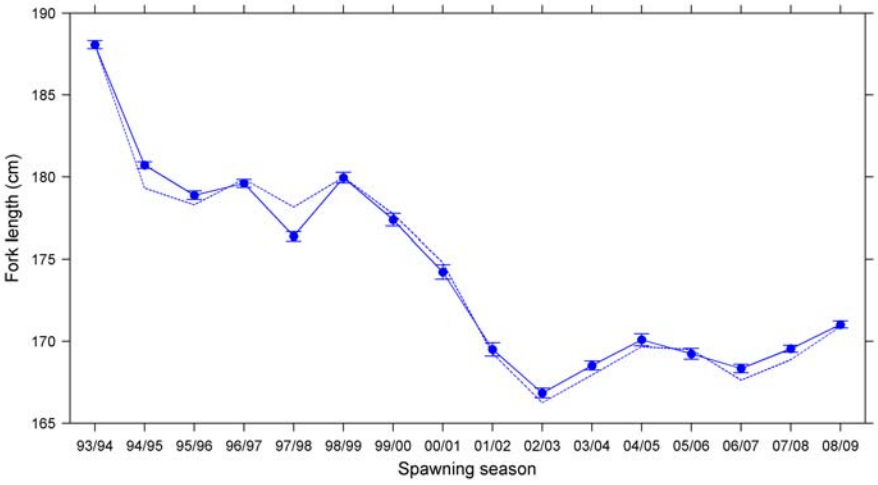

Figure 3. Mean length (+/- 95%CI) of SBT in the Indonesian catch on the spawning ground. Data from Processor A are excluded. Dashed line is the mean length of SBT caught in December to May only.

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, but that this dominance has gradually declined from 72.0% in 1999/00 to 63.4% in 2006/07 (Figure 4). The decline was more marked in 2007/08 with 50.8% of those measured identified as female, but increased to 53.3% in the latest season.

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 2008/09 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 but may be due to inaccurate identification of sex, or different spawning behaviour by sex (see Farley et al 2008). 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.

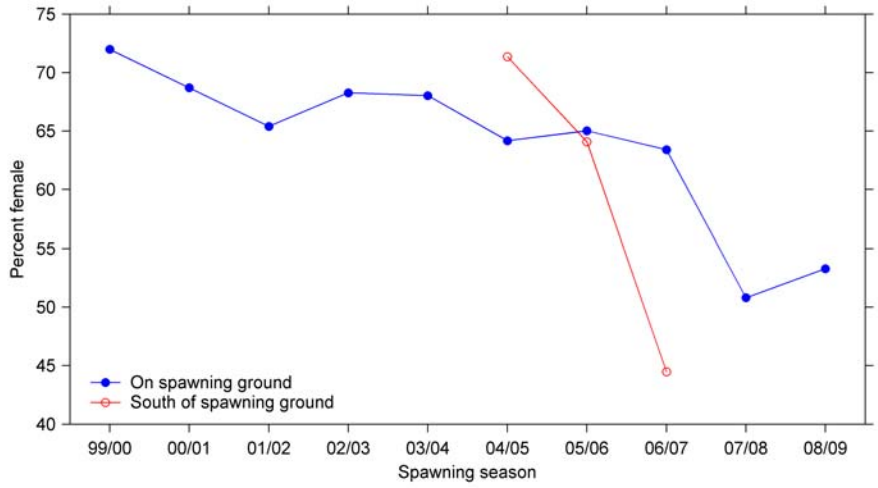

Figure 4. Change in the sex ratio of SBT in the Indonesian catch since the 1999/00 spawning season.

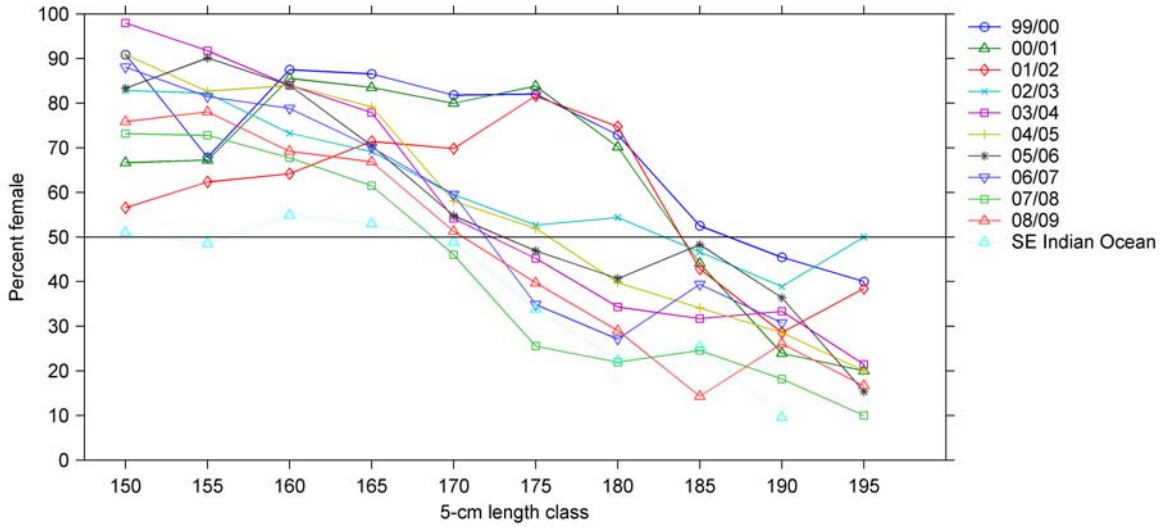

Figure 5. Percent female by 5-cm age class for SBT caught on the spawning ground by spawning season, and percent female for SBT caught by Japanese longliners in the southeast Indian Ocean in the early-1990s (see Farley et al., 2007b). Data point excluded if n<5.

Direct age estimates

2006/07 spawning season:
At last years CCSBT meeting, Farley et al (2008) reported a possible bias in the age estimates of SBT in the Indonesian catch for the 2006/07 season. A comparison of age with otolith weight suggested that the primary reader was overestimating age by around 1 year (on average). This bias was further examined in February 2009 and it was concluded that the bias was due to the primary reader counting an extra increment at the edge of all otoliths. The updated data were provided to the CCSBT in the data exchange process, and are included in Figures 6-8 below.

2007/08 spawning season:
A final age was estimated for 485 SBT in the 2007/08 spawning season from fish ranging in size from 145-203 cm LCF. Age estimates ranged from 6 to 40 years. The precision of readings by the primary reader (intra-reader consistency) was considered good; the CV between readings was 4.09. 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 CV between the primary and secondary readers was 5.02. An age bias plot (Campana et al., 1995) showed no bias in the age estimates between readers.

Age composition of the catch

Age has been estimated for a total of 6,325 SBT caught in the longline fishery over 13 spawning seasons (Table 1). Figure 6 shows the estimated age structure of the Indonesian catch by spawning season based on ALKs developed using our aged fish. As reported in previous reports to CCSBT, the age composition of the catch has changed dramatically since monitoring began (Figure 6). The mean age of SBT has decreased from ~19-21 years in the mid- to late-1990s to only ~14-15 years in the 2001/02 to 2005/06 seasons. In 2007/08, the mean age of SBT caught increased slightly to 16.8 years (Figure 7). The relative abundance of 20+ year old fish in the catch increased in 2007/08 compared to the previous few years (Figure 8).

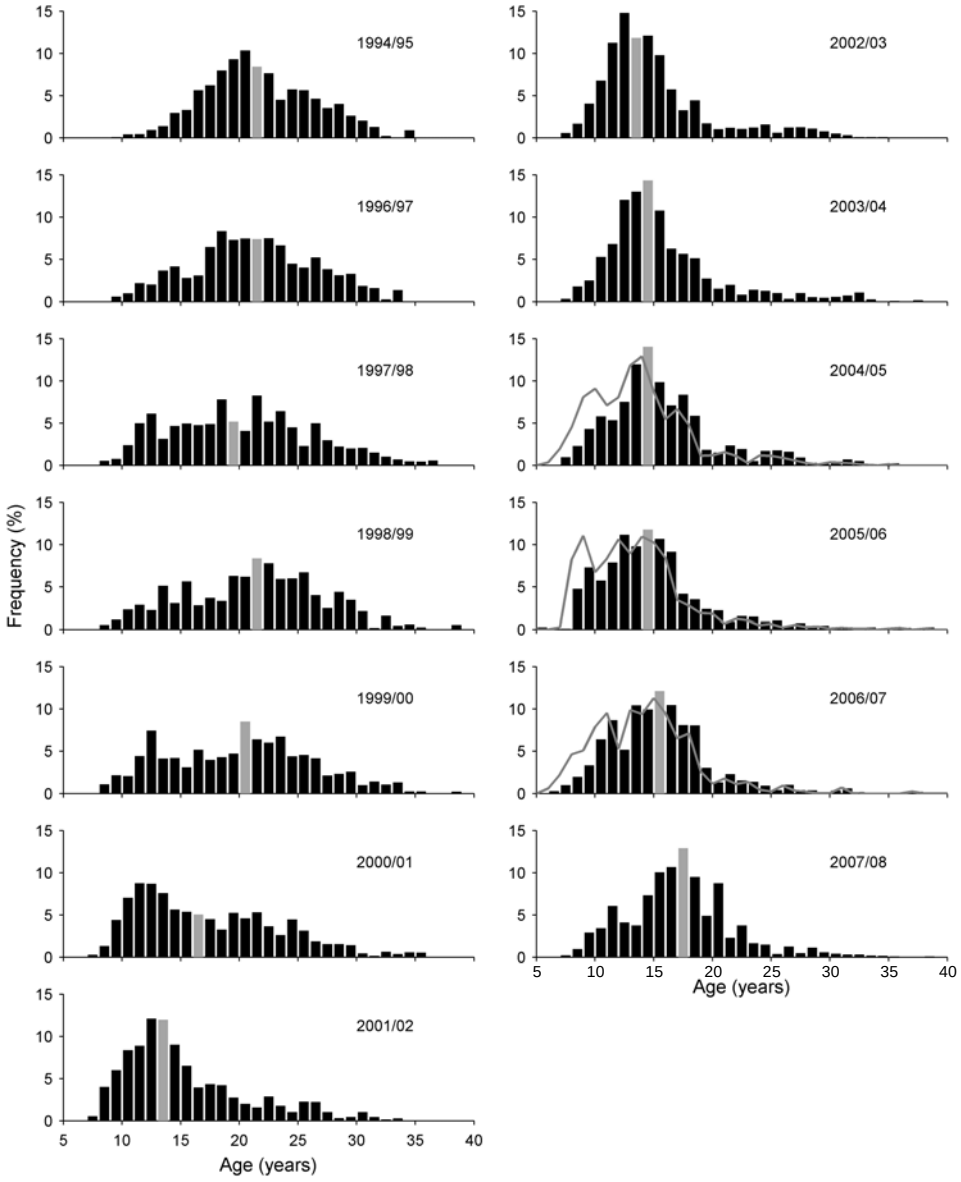

Figure 6. Age frequency distribution of SBT in the Indonesian catch on the spawning ground by spawning season estimated using age-length keys from our sub-samples of aged fish and length frequency data obtained through the Indonesian monitoring program. The grey bar shows the median age class. For comparison, the age distribution of SBT caught south of the spawning ground (Processor A) is shown for the 2004/05, 2005/06 and 2006/07 seasons (grey line).

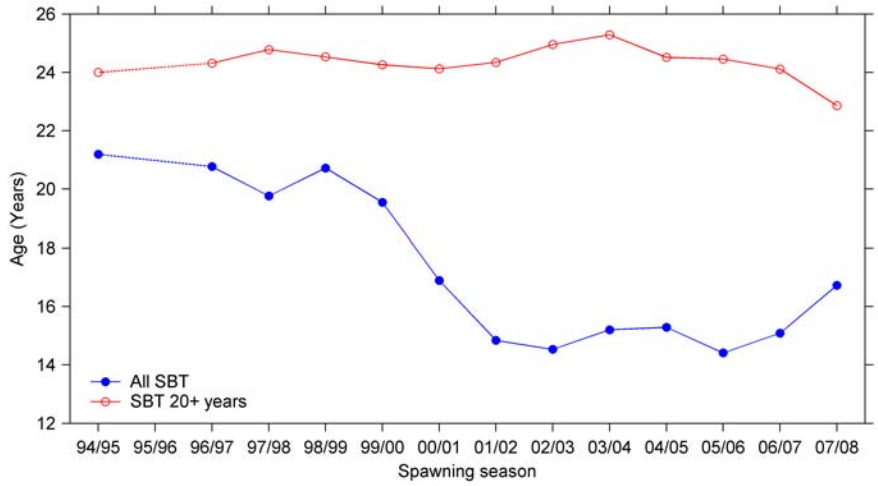

Figure 7. Estimated mean age of SBT in the Indonesian catch on the spawning ground.

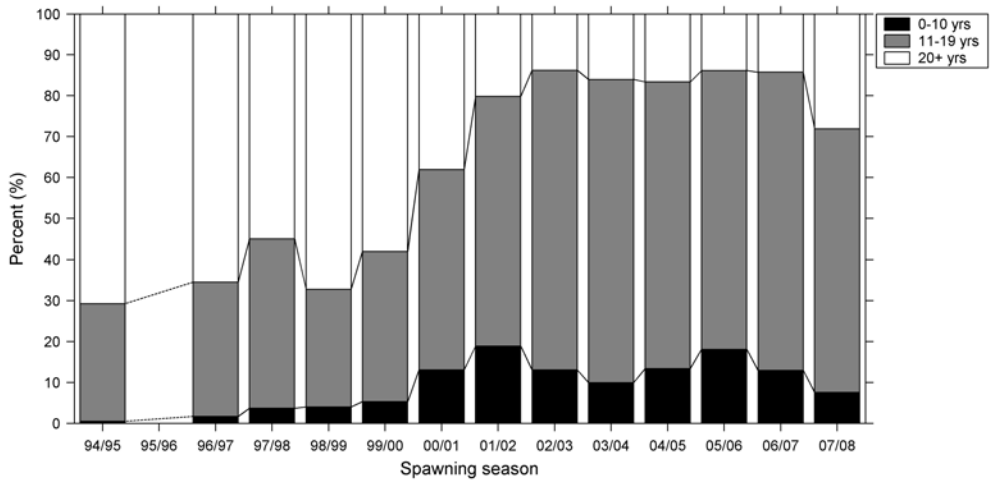

Figure 8. Estimated proportion of SBT by age class in the Indonesian catch on the spawning ground. Note there are no age data for the 1995/96 season.

Future Developments

As mentioned in the Introduction, year 2008/2009 saw a significant change in the funding arrangements for the Benoa monitoring program and a further increase in the level of responsibility by Indonesia for its management, both in fiscal and operational terms. This increased responsibility coincides with the establishment of a new Tuna Monitoring and Research Facility[1] at Benoa, which is now the base for the port-based monitoring program and the ongoing trial observer program for the longline fishery. The new facility is located within the Benoa Fishing Port precinct, only a few hundred metres from the previous monitoring office. As part of activities of the current ACIAR funded tuna fisheries project, RCCF/RIMF and CSIRO have been developing a strategy for capacity development beyond

[1] The official title of the new Tuna Monitoring and Research Facility has yet to be announced by AMFR.

the end of the current project (i.e. beyond end of 2009). Included in that strategy is the planned development of research activities at the Benoa facility – research in addition to the ongoing port-based monitoring and biological sampling. Later this year (currently scheduled for Oct'09), through the ACIAR project, CSIRO will provide training as a first step towards Indonesia participating in the reading of otoliths for age determinations and in the associated analyses for characterisation of the age structure of the SBT spawning population. All involved in these capacity development collaborations hope that within several years Indonesia will be in a strong position to lead many of the research activities that have, up until now, been largely done by outside agencies. Further discussion of the activities planned and potential resource requirements are provided in the related information paper (CCSBT-ESC/0909/16).

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. We also acknowledge the support of all other agencies within Ministry of Marine Affairs and Fisheries (Indonesia) for the research activities. This work was funded by Australia's Department of Agriculture, Fisheries and Forestry, and CSIRO's Wealth from Oceans Flagship.

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