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

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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 and age-frequency data for 2004 spawning seasons are now available for the fishery. (A spawning season is defined as July 1 of the previous year to June 30 of the given year.) Length frequency data has now been collected for 12 spawning seasons, and the catch-at-age estimated for 9 seasons. In summary:

- Considerable change has occurred in the size and age distribution of SBT caught in the Indonesian fishery since monitoring began.
- The recruitment of small (<165 cm) fish into the spawning stock that first became apparent in the 2001 spawning season continued through to the 2003 season. In 2004 and 2005 there was a slight decrease in the proportion of SBT <165 cm compared to the previous season.
- The decline in the relative proportion of large SBT (>190 cm) appears to have continued through to the 2005 season.
- The changes in the proportion of small SBT in the catch have occurred irrespective of changes in fishing practices (depth fished as indicated by the BE index).
- A clear change in the age-structure of the catch from older to younger fish is also visible. Between 1995 and 2002, young fish ≤15 years steadily increased in relative abundance, and older fish (20+ years) decreased. In 2003 and 2004, the relative abundance of young fish declined slightly. This suggests that the apparent increase in recruitment of young SBT to the spawning population may not be as strong in 2003 and 2004 compared to the previous 1-2 years.
- The sex ratio of SBT sampled in the 2004 and 2005 spawning season is heavily biased towards females for fish up to ~170 cm fork length.
- The majority (96%) of SBT <160 cm with otoliths sampled were classed female in 2004. Given that it is difficult to identify the sex of SBT landed in Benoa because the fish are gutted at sea (Farley and Davis, 2004), it is possible that some of these small SBT were incorrectly classified. If so, estimates of mean length-at-age by sex will be incorrect for young SBT.

Introduction

Southern bluefin tuna (SBT) spawn in an area between Indonesia and the north-west coast of Australia, in the north-east Indian Ocean. An Indonesian-based longline fishery operates on the northern part of this spawning ground, catching SBT predominantly from September to April (Farley and Davis, 1998). In 1992, CSIRO Marine Research and the Research Institute of Marine Fisheries (RIMF) in Indonesia began monitoring the catch and size composition of SBT landed by the Indonesian longline fishery in Bali. In 1993, this monitoring was extended to include collecting otoliths from a representative sample of the catch for direct ageing purposes. SBT graded as not suitable for export were available for length measurement and otolith sampling (500-700 per spawning season).

In 2002, an IOTC coordinated catch monitoring system was implemented (IOTC, 2003). As part of this monitoring, an enumerator was employed to measure and collect otoliths of SBT in Benoa. This is the same enumerator whose SBT length measurements have been used since monitoring began. Under this new monitoring program, greater numbers of otoliths (>1000) were collected each spawning season, but the collection of otoliths from export SBT is still restricted. Data on the sex of fish with otoliths sampled have been collected since early 1999. All length data collected on SBT from the IOTC monitoring were added to the CSIRO/RIMF database for biological studies. All otoliths are archived at CSIRO.

Obtaining an accurate estimate of the size and age distribution of SBT caught in the Indonesian longline fishery is vital for population modeling and stock assessments. The development of validated methods to directly age SBT using otoliths, and the collection of sufficient otoliths from the Indonesian fishery, has allowed us to accurately estimate the age composition of the Indonesian catch over eight spawning seasons. This data has shown that the parental stock of SBT has undergone dramatic changes since monitoring began. In the 1995 season, the major mode occurred between 18 and 22 years (Gunn et al., 1998). In 2001-2004, the relative proportion of small fish in the catch increased. By the 2003 season, the major mode of SBT caught was between 12-15 years. It has been suggested that this could be an indication that cohorts spawned since quotas were introduced in 1984 have survived to spawning age.

In this paper we update the information given in Farley and Davis (2004) by including the most recent length and age frequency data for the Indonesian fishery. Age frequency data are presented up to the 2004 spawning season, while length frequency data includes the 2005 season.

Methods

Length measurement and otolith sampling

Targeted sampling of SBT occurred at the Port of Benoa, where the majority of SBT are landed in Indonesia. As in previous years, SBT graded as not suitable for export are available for length measurement and otolith sampling. SBT are graded on flesh quality which is dependent on handling and/or condition. However, fish of poor condition will be lighter for a given length. Length measurements were obtained for 1279 SBT in the 2004 spawning season and 1578 SBT in the 2005 spawning season. The length frequency distribution of the 2004 SBT catch was provided for data exchange with CCSBT, but the 2005 data was not complete at the time of the data exchange. Otoliths were sampled from 1283 SBT from the 2004 spawning season. Sex was obtained for all SBT with otoliths sampled.

Direct age estimates

Of the 1283 otoliths sampled in 2004, 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) for the previous eight spawning seasons. Mean length-at-age was calculated for male and female SBT, and compared statistically by unpaired t-tests.

Catch-at-age

To determine the age structure of SBT caught by spawning season, age-length keys were developed using our sample of aged fish sampled in that season. 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. The length frequency was estimated using length measurements obtained as part of the tuna monitoring program in Bali.

Results and Discussion

Length Distributions

Length-frequency data are now available up to the end of April 2005, which effectively covers the entire 2005 spawning season (July 2004-June 2005). The length frequency distributions of all SBT measured at the processing sites is plotted by spawning season (Fig. 1). Considerable change has occurred in the size distribution of SBT caught since monitoring began. In the mid- and late-1990s, the majority of SBT caught were between 170-190 cm FL (mean 176-188 cm). Recently, smaller SBT comprise a greater proportion of the catch; in 2002 to 2005 the mean length of SBT caught was around 165-170 cm. An increase in the relative abundance of small SBT (especially <165 cm) occurred initially in 1998, and again to a greater extent in 2001-2003 (Table 1). The size distribution for the most recent two spawning seasons has proportionately fewer fish less then a 165 cm than in 2002 and 2003. A continuous decrease in the relative abundance of large SBT (≥190 cm) has occurred since around 1999.

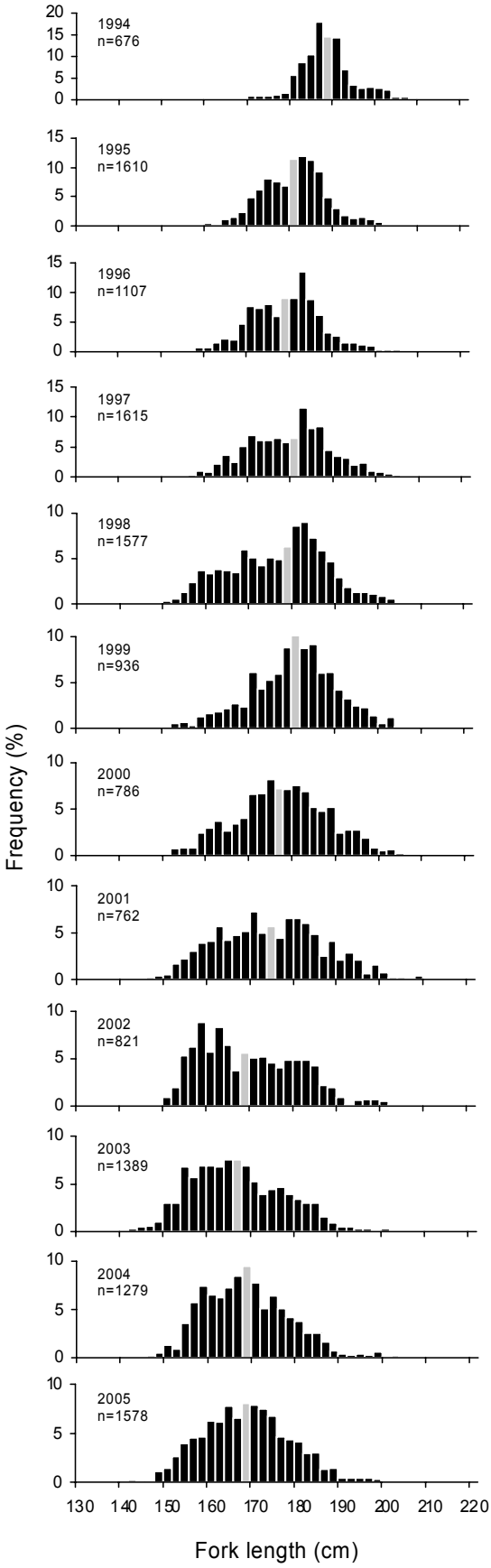

Figure 1. Length frequency (2 cm intervals) of SBT by spawning season. The grey bar shows the median size class.

It has been suggested that changes in the size distribution of SBT caught could be due to changes in the fishing practices (such as fishing depth) of the Indonesian fleet. Davis and Farley (2001) measured relative fishing depth using a bigeye (BE) index (weight of bigeye/(weight of bigeye + weight of yellowfin) and found that fishing depth does affect the size distribution of SBT in the Indonesian catch. However, the proportion of SBT <165 cm in the Indonesian catch increased at around the same time at all levels of the BE index, suggesting that the increase proportion of small SBT occurred independently of any changes in fishing practices (Figure 2). It is also unlikely that the data analysed included SBT caught south of the spawning ground as discussed in CCSBT-ESC/0509/15 (T. Davis, pers. com.).

Table 1. Proportion of SBT caught by spawning season and length class.

Spawning	Proportion of the catch		
Season	<165 cm	165-190 cm	≥190 cm
1994	0.3	62.7	37.0
1995	2.6	86.6	10.8
1996	5.5	85.4	9.1
1997	8.0	77.9	14.1
1998	19.5	70.5	10.0
1999	8.8	75.5	15.7
2000	14.4	73.0	12.6
2001	26.1	62.7	11.2
2002	44.2	51.4	4.4
2003	49.2	48.3	2.4
2004	39.8	57.6	2.6
2005	39.5	58.5	2.0

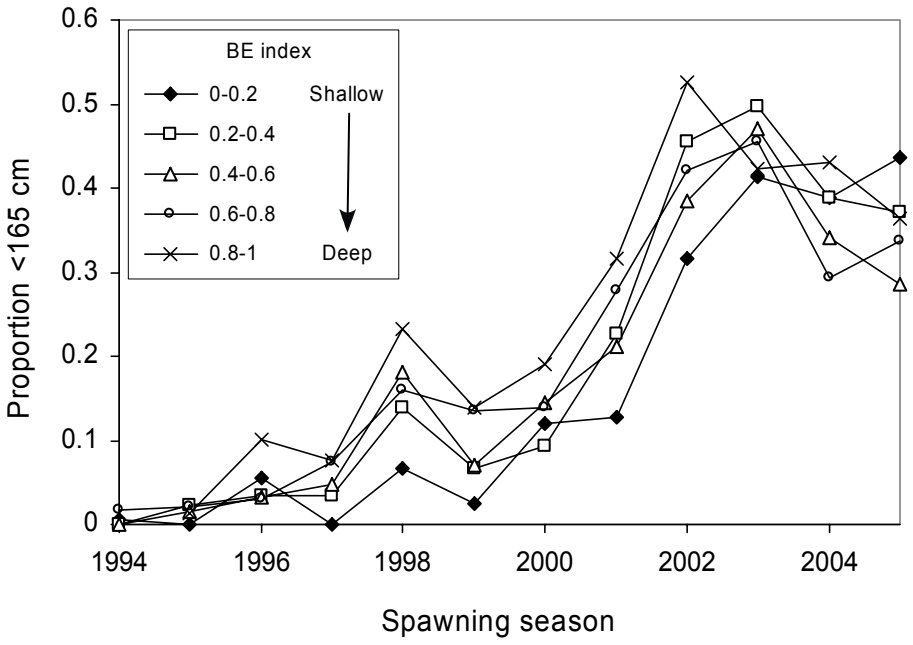

Figure 2. The proportion of SBT <165 cm in length (of all SBT with a length measurement) in each spawning year by bigeye (BE) index. A spawning season is defined as July 1 of the previous year to June 30 of the given year.

Direct age estimates

Age was estimated for a total of 494 SBT in the 2004 spawning season from fish ranging in size from 145-215 cm LCF. The precision of readings was considered good. The second age estimate of the primary reader agreed with the original estimate in 49% of cases and 96% were within two years of the original. The average percent error between primary readings was 2.54, and between primary and secondary readers it was 4.64. These very low levels of error, especially between the two readers suggest consistent interpretation of age in blind tests.

Length-at-age

Age has now been estimated for a total of 4,370 SBT caught in the longline fishery over nine spawning seasons (Table 2). Of these fish, 2,531 were of known sex; the majority being sampled in the five most recent spawning seasons. The number of age estimates obtained by spawning season have changed slightly to those reported previously, as we now use the capture date (if available) rather than landing date to assign fish to a spawning season.

The average length of SBT increases with age, but the size range overlaps considerable. In previous analyses, mean length-at-age was not significantly different for males and females up to age 14 or 15 years, and thereafter males were on average larger than females at the same age (Farley and Davis, 2004). The 2004 data, however, shows a greater dimorphism in length-at-age between sexes; a significant difference was found in almost all age classes <24 years, including SBT as young as 8-13 years (Table 3). The reason for this is that a greater proportion of SBT <160 cm were classified as females in 2004 (96%) compared to previous seasons (60-83%) (Fig. 3) resulting in a lower mean length-at-age for females compared to males. Given that it is difficult to identify the sex of SBT landed in Benoa because the fish are gutted at sea (Farley and Davis, 2004), it is possible that some of the small SBT were incorrectly classified as females in 2004. If so, the length-at-age estimates we obtained by sex will be incorrect for small SBT. This highlights the need for an alternative method to assess the sex of SBT landed in Indonesia.

Table 2. SBT sampled from the Indonesian-based longline fishery with age estimated by spawning season. A spawning season is defined as July 1 of the previous year to June 30 of the given year.

Spawning	Otoliths sampled		Age estimated	
season	n	Known sex (n)	n	Known sex (n)
1995	549	0	486	0
1997	602	0	475	0
1998	519	0	485	0
1999	660	121	474	88
2000	534	531	498	495
2001	719	716	481	478
2002	715	713	489	488
2003	1503	1503	488	488
2004	1282	1282	494	494
Total	7083	4866	4370	2531

Table 3. Mean length-at-age and standard deviations (SD) SBT caught in the Indonesian longline fishery by sex in the 2004 season. Results (p-value) of an unpaired t-test to compare the lengths at each age are given.

Age	Females			Males			t-test
	Mean LCF	SD	*n*	Mean LCF	SD	*n*	*p*
7	149.0	2	4				
8	151.7	3	11	157.5	2	2	0.028
9	153.4	5	10	165.0	4	3	0.004
10	154.6	4	21	173.3	7	6	<0.001
11	159.3	7	24	171.0	8	6	<0.001
12	161.0	7	37	169.9	9	14	<0.001
13	162.5	6	32	172.2	7	19	<0.001
14	165.0	8	40	174.6	7	21	<0.001
15	164.0	6	27	177.2	8	17	<0.001
16	172.8	9	17	175.9	8	14	0.347
17	170.5	9	17	177.2	7	9	0.061
18	172.8	7	11	178.9	6	14	0.033
19	169.8	7	8	181.8	4	5	0.006
20	181.0	4	7	187.2	6	6	0.045
21	173.8	4	6	191.0	11	5	0.005
22	182.5	8	2	184.6	5	5	0.664
23	174.0	10	2	183.9	4	8	0.036
24	183.0	10	5	185.6	7	5	0.650
25	183.4	8	5	188.0	23	2	0.676
26	189.0	-	1	198.3	9	3	
27	186.7	7	3	191.8	6	8	0.266
28	192.5	8	2	188.5	7	4	0.554
29	190.0	7	3	189.5	4	2	0.936
30	165.0	-	1	189.7	6	3	
31	183.3	20	3	191.3	6	3	0.544
32	190.3	17	4	182.5	10	4	0.454
33				173.0	2	1	
34							
35	211.0	-	1				
36							
37	178.0	-	1				
38							
Total			305			189	

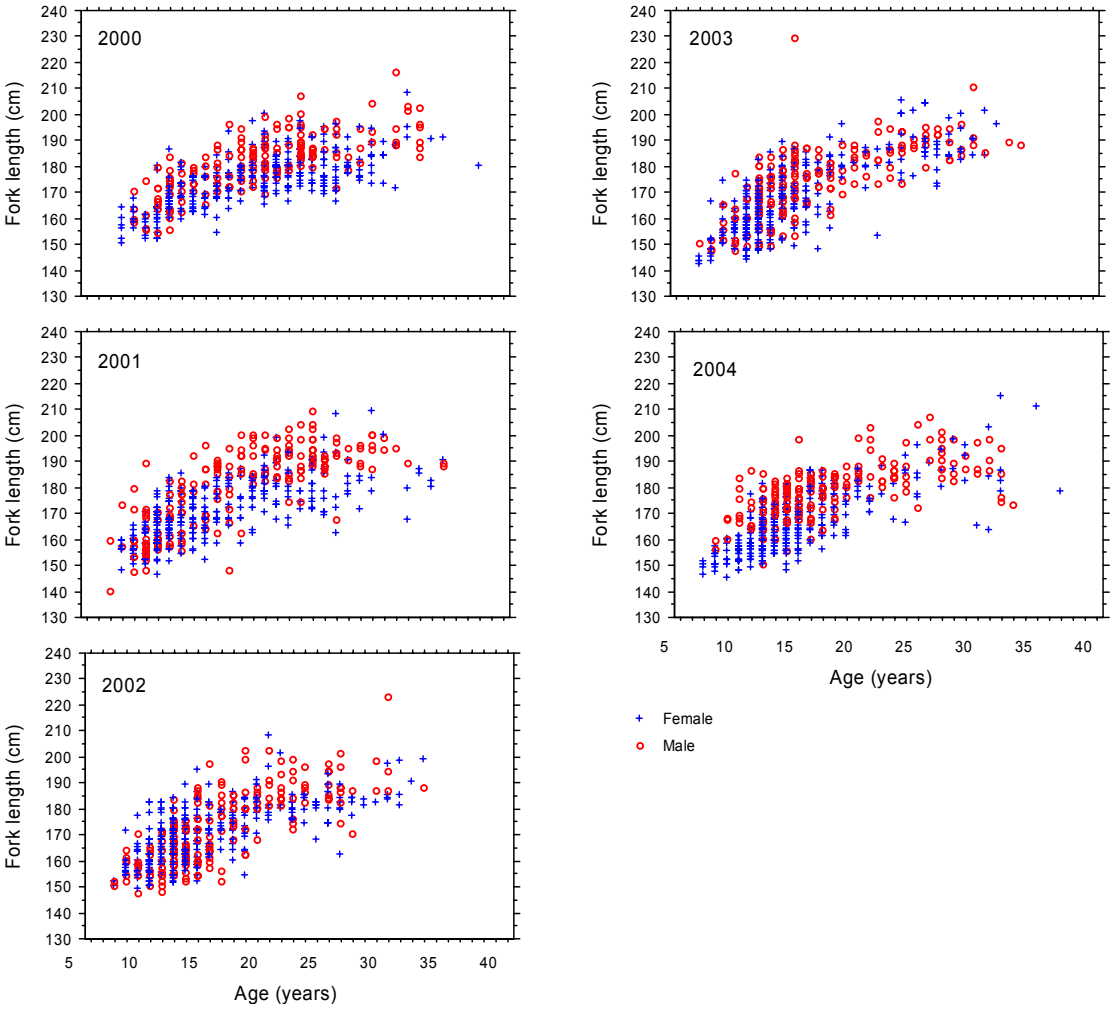

Figure 3. Length-at-age by sex of SBT caught in the Indonesian longline fishery in the 2000-2004 spawning seasons.

Catch-at-age

The Indonesian longline fishery catch SBT aged between 7 and 40 years. A clear change in the age-structure of the catch from older to younger fish is visible (Fig. 4). Between 1995 and 2002, young fish ≤15 years steadily increased in relative abundance, and older fish (20+ years) decreased (Fig. 5). The estimated mean age of SBT decreased from around 20 years in the 1990s, to 15 years in 2002 to 2004. This increase in the relative abundance of young fish is thought to support theories that cohorts spawned since quotas were introduced in 1984 have survived to spawning age. However, the relative abundance of the youngest age classes (<15 years) declined slightly in both 2003 and 2004, suggesting that the apparent increase in recruitment of young SBT to the spawning population may not be as strong in 2003 and 2004. Polacheck et al. (2004) showed that the mean age of SBT aged 20+ in the Indonesian catch had increased over the period 1995 to 2003 from 24 to 25 years. The mean age of 20+ SBT in the 2004 season is even higher at 25.5 years. A shift in mean age could occur as the older population aged without significant replacements by younger fish.

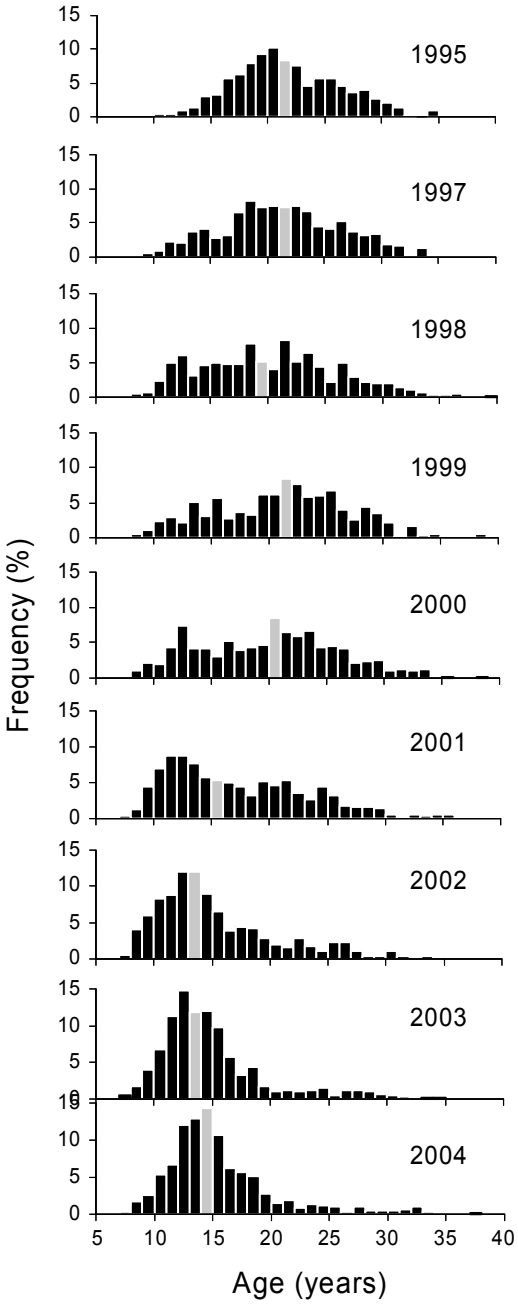

Figure 4. Age frequency of SBT by spawning season. The grey bar shows the median age class.

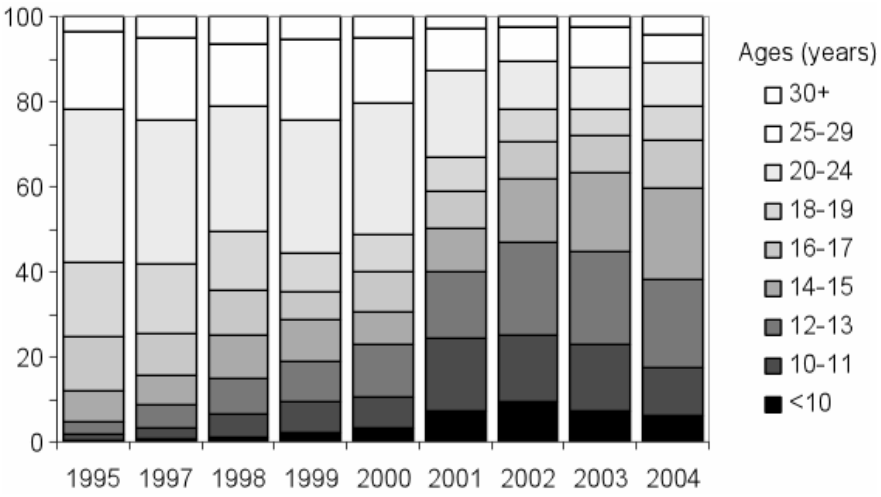

Figure 5. The proportion of SBT caught by age class and spawning season.

Sex ratio

As indicated in Farley et al. (2002; 2003; 2004) the sex ratio of SBT in the Indonesian SBT catch is highly skewed towards females. The 2005 length frequency data showed a ratio of 2.3:1 (females : males). When examined by 5-cm length class, females dominate in all classes up to 170 cm, after which males dominate. Only 1 SBT <153 cm (n=43) was male. Gunn et al. (2004) determined that the sex ratio of SBT in the southern oceans is about 1:1 for length classes ≤170 cm, and males outnumber females in larger length classes because males reach larger sizes than females. Given this, the dominance of females in length classes ≤170 cm in the 2005 Indonesian catch is difficult to explain and could have major implications for population egg production estimates, modeling stock dynamics and fisheries management.

There are concerns that the method used to determine the sex of SBT landed in Benoa is not accurate. Establishing the sex of SBT is difficult because they lack external sexual characters and almost all are already gutted when landed in Benoa. Currently, the sex of SBT is determined by an enumerator from a small sample of remnant gonad tissue left in the visceral cavity when the fish in landed. This method is crude and there is potential for error. Thus, it is vital that an effective alternative method to assess the sex of SBT is developed to establish whether the preponderance of females in samples is in fact correct or an artefact of the way in which sex is determined.

References

Beamish, R.J. and D.A. Fournier. 1981. A method for comparing the precision of a set of age determinations. Can. J. Fish. Aquat. Sci. 38(8): 982-983.

Clear, N.P., Gunn, J.S., Rees, A.J. 2000. Direct validation of annual increments in the otoliths of juvenile southern bluefin tuna, *Thunnus maccoyii*, through a large-scale mark-and-recapture experiment using strontium chloride. Fish. Bull. 98, 25-40.

Davis, T.L.O. and J.H. Farley. 2001. Size partitioning by depth of southern bluefin tuna (*Thunnus maccoyii*) on the spawning ground. Fish. Bull. 99: 381-386.

Gunn, J., Farley, J. and Clear, N. 1998. The age distribution and relative strength of cohorts of SBT on the spawning grounds. CCSBT Scientific Meeting; 23-31 July 1998, Far Seas Fisheries Res. Lab, Shimizu, Japan. CCSBT/SC/9808/39.

Gunn, J.S., Clear, N.P., Carter, T.I., Rees, A.J., Stanley, C.A., Farley, J.H., Kalish, J.M., In Press. The direct estimation of age and growth in southern bluefin tuna, *Thunnus maccoyii* (Castelnau), using otoliths, scales and vertebrae. Fish. Bull.

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., Davis, T.L.O. 2002. Length and age distribution of SBT in the Indonesian longline catch on the spawning ground. CCSBT Scientific Meeting; 9-11 September 2002, Canberra, Australia. CCSBT/SC/0209/25

Farley, J.H., Davis, T.L.O. 2003. Length and age distribution of SBT in the Indonesian longline catch on the spawning ground. CCSBT Scientific Meeting; 1-4 September 2003, Christchurch, New Zealand. CCSBT/SC/0310/18.

Farley, J.H., Davis, T.L.O. 2004. Update on the length and age distribution of SBT in the Indonesian longline catch on the spawning ground. CCSBT Meeting of the Stock Assessment Group (SAG5) and the 9th Meeting of the Scientific Committee (SC9): 6-11 and 13-16 September 2004, Seogwipo KAL Hotel in Jeju, Korea. CCSBT/SC/0409/12.

Farley, J.H., Davis, T.L.O., Eveson, J.P. 2001. Length and age distribution of SBT in the Indonesian longline catch on the spawning ground. CCSBT Scientific Meeting; 28-31 August 2001, Tokyo, Japan. CCSBT/SC/0108/12.

IOTC (2003). Notes on IOTC data collection activities in Indonesia. CCSBT Indonesian Catch Monitoring Review, 10-11 April 2003, Queenstown, New Zealand. CCSBT-ICM/0304/17.