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Commercial spotting in the Australian surface fishery, updated to include the 2011/12 fishing season

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Copyright and disclaimer

Important disclaimer

Acknowledgments

We again especially thank the commercial spotters and pilots for their continued willingness to collect and record sightings data each fishing season. We also thank the tuna fishing companies in Port Lincoln for their continued support of the project. This study was funded by AFMA, DAFF, Australian Industry, and CSIRO's Wealth from Ocean Flagship.

Contents

1 Abstract

Data on the sightings of SBT schools in the Great Australian Bight (GAB) were collected by experienced tuna spotters during commercial spotting operations between December 2011 and March 2012. Spotting data has now been collected over eleven fishing seasons (2001-02 to 2011-12). In 2002-2008 and 2010, the location of SBT sightings varied little, with the area of highest SBT sighted per nautical mile searched occurring within the same ‘core fishing area’ (130.2-132.9°E and 32.7-34.0°S). In 2009 and again in 2011 and 2012, a significant amount of search effort occurred to the east of the core area. In 2012, the eastward shift occurred in late-January/early-February as suitable fish again became difficult to find to the west. The commercial spotting data was used to produce nominal and standardised fishery-dependent indices of SBT abundance (surface abundance per unit effort – a SAPUE index). The index for 2012 is the second lowest for all years and is well below average.

2 Introduction

In the summer of 2001-02 (called the 2002 season), a pilot study was conducted to investigate the feasibility of using experienced industry-based tuna spotters to collect data on the sightings of SBT during commercial spotting operations in the Great Australian Bight. The data provided a preliminary fishery-dependent index of SBT abundance (surface abundance per unit effort – a SAPUE index) for that fishing season.

Recognising the importance of time-series of indicators, we continued to collect and analyse SBT sightings data from commercial tuna spotters over the following 9 fishing seasons (2003-2011). Interpretation of the results are difficult as the data suffers from many of the same problems that affect catch per unit effort (e.g. changes in coverage over time, lack of coverage in areas where commercial fishing is not taking place, and changes in operations over time), but it may provide a qualitative indicator of juvenile SBT abundance in the GAB. It has always been recognised, however, that a scientific survey with consistent design and protocols from year to year is highly preferable. In 2012, we continued to collect SBT sightings data from commercial spotters. This report summarises the field procedures and data collected, and provides results of analyses for all 10 seasons (2002-2012).

3 Field procedures

As for previous years, the field program in 2012 included the collection of spotting data from experienced commercial tuna spotters in the GAB. (Note, in this report we use the terminology ‘spotter’, not ‘observer’). Data were collected on SBT patches (schools) sighted by spotters engaged between December 2011 and March 2012 (called the 2012 fishing season). This year, data were collected by only 2 spotters, both of which had participated in all previous seasons and contributed the majority of the search effort recorded each year (Table 1).

The spotting data collected in 2012 were collected following the protocols used in the previous ten fishing seasons. Within each plane there was a spotter and pilot. For most flights, the spotter searched the sea surface on both sides of the plane for surface patches of SBT. During some flights, the pilot also searched for patches. When a “sighting” of SBT was made, a waypoint (position and time) was recorded over the patches (or patches). The spotter estimated a range for the size of fish in the patches (in kg) and the biomass of each patch (in tonnes). It is important to note that many SBT patches are recorded as single patches (~35-60% by season). Some schools, however, are recorded in groups of 2-10 or even 50+ schools. Environmental observations were recorded at the start and end of each flight and when the conditions changed significantly during the day. The environmental observations included wind speed and direction, air temperature, cloud, visibility, spotting conditions and swell. The target species of each flight (SBT, skipjack tuna, mackerel, or a combination of these) was also recorded. There were no restrictions on the environmental conditions for commercial spotting operations.

Table 1. Relative contribution (%) by spotters to the total search effort (time) by fishing season.

SEASON	SPOTTER 1	SPOTTER 2	SPOTTER 3	SPOTTER 4	SPOTTER 5	SPOTTER 6	SPOTTER 7
2002	61.3	7.6	11.7	-	5.6	13.9	-
2003	20.2	11.5	33.2	1.2	4.4	29.5	-
2004	42.2	15.2	19.4	-	-	23.2	-
2005	39.7	9.3	19.5	-	5.0	26.5	-
2006	44.2	11.6	-	-	14.8	29.5	-
2007	38.0	11.1	-	-	22.1	28.8	-
2008	37.3	23.7	-	-	-	39.0	-
2009	39.0	9.0	-	-	-	41.4	10.7
2010	28.9	16.4	-	-	4.0	50.7	-
2011	47.1	0	0	0	0	52.9	0
2012	47.8	0	0	0	0	52.2	0

4 Results

4.1 Search effort and SBT sightings

Data were collected for 73 commercial spotting flights in the 2012 fishing season (Table 2). Although only 2 spotters recorded data this season, the number of flights recorded was higher than for 2010 and 2011, but lower than the preceding 8 years where often well over 100 flights were recorded. The details of search effort and SBT sightings are also given in Table 2. SBT were recorded on 87.7% of the 73 commercial flights in 2012 which is just above the average (85.1%) for the 2002 to 2012 period. Note that the total biomass shown in Table 2 does not represent the total biomass of SBT present in the survey area, as many schools were potentially recorded several times (either by different spotters on the same day or over several days). Note also that due to GPS problems, flight path data for 4 of the 73 flights were not available in 2012 and thus the proportion of search time and biomass sighted in the 'core' fishing area are currently unknown for these flights, although the total search effort and biomass for the flights are known and are included in the standardisation analysis (below).

Figure 1 and Figure 2 shows the spatial distribution of search effort and surface abundance of SBT. In 2002-2008 and 2010, the location of SBT sightings varied little, with the area of highest SBT sighted per nautical mile searched occurring within the same 'core fishing area' (130.2-132.9°E and 32.7-34.0°S) and around the inshore lumps/reefs. In 2009 and again in 2011 and 2012, a significant amount of search effort occurred well outside the core area closer to Port Lincoln. In 2009, this shift in effort occurred around mid-March as SBT became more difficult to find in the core. In 2011, the shift occurred in mid-February although some search effort returned to the core fishing area in late March. In 2012, the eastward shift occurred in late-January/early-February as fish again became difficult to find in the core area.

Table 2. Search effort and SBT sighted by commercial spotters in the 2002-2012 fishing seasons.

FISHING SEASON	NO. FLIGHTS	SEARCH EFFORT (HRS)	% FLIGHTS WITH SBT RECORDED	TOTAL NUMBER OF SCHOOLS	TOTAL BIOMASS[1] RECORDED	% OF EFFORT IN THE CORE[2]	% OF BIOMASS IN THE CORE[2]
2002	86	325	83.7	1182	44626	80.6	87.7
2003	102	425	82.4	1301	38559	78.9	76.5
2004	118	521	77.1	1133	33982	88.9	90.4
2005	116	551	94.0	2395	87447	88.5	83.2
2006	102	452	82.4	1554	50524	83.1	73.4
2007	120	600	91.7	2600	94018	86.5	80.0
2008	93	451	80.6	2529	100341	94.2	92.6
2009	114	527	77.2	1353	41514	54.2	67.7
2010	49	210	83.7	918	32907	72.3	68.3
2011	64	328	95.3	1472	75887	57.3	70.8
2012	73	378	87.7	799	31959	14.0	11.1

[1] The total biomass recorded does not represent the total biomass of SBT present in the survey area, as many schools were potentially recorded several times (either by different spotters on the same day or over several days).

[2] Does not include data for flights where flight path data was not obtained; e.g. 4 flights in 2012 (see above).

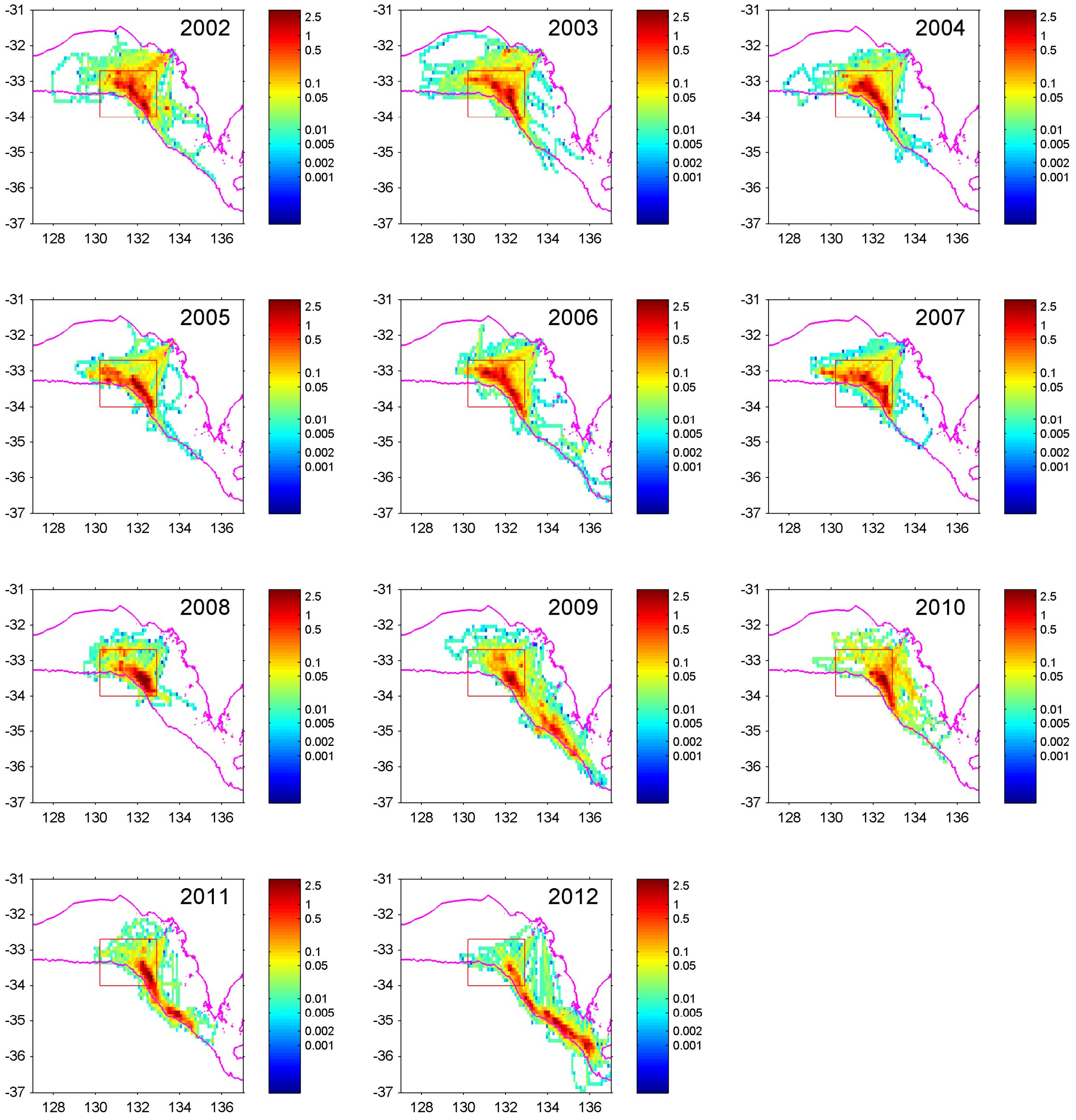

Figure 1. Search effort (nm flown/0.1° square) in the GAB by fishing season. Note the log scale. The core fishing area is shown by a red square.

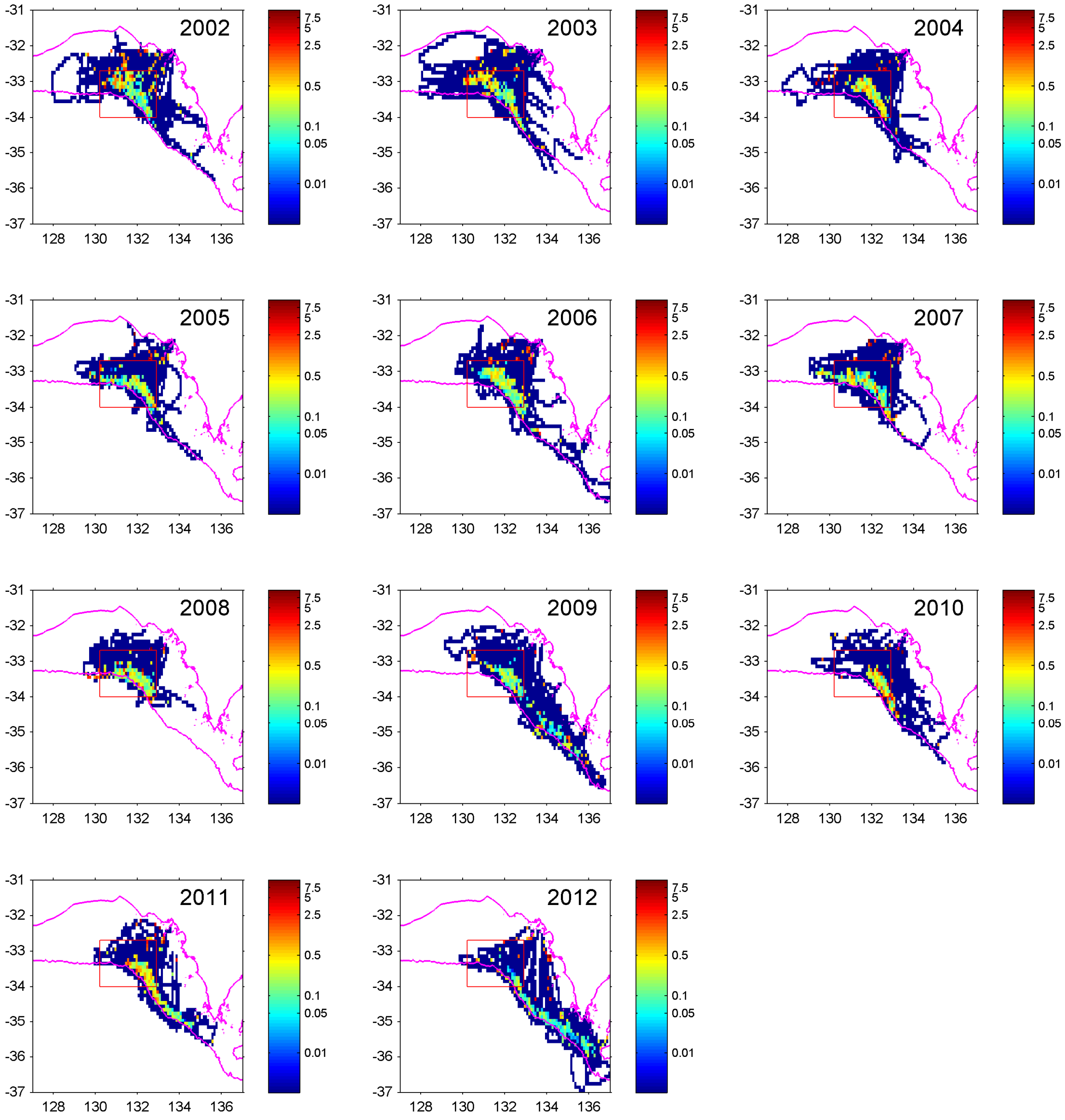

Figure 2. SAPUE (tonnes/nm/0.1° square) in the GAB by fishing season. SAPUE data are displayed as the % of total effort for the season. Areas of darkest blue in the SAPUE plot indicate zero SAPUE. Note the log scale. The core fishing area is shown by a red square.

Figure 3 and Figure 4 show the size of SBT schools and fish recorded by Spotter 1 between 2002 and 2012. Using data from one spotter removes the problem of differences between spotters in their estimates of school and fish size. Spotter 1 was selected because he had collected data on the greatest number of SBT schools each season. The mean size of schools recorded has varied over time, but was at its lowest in 2009 (30.0 tonnes) and highest in 2011 (61.1 tonnes). In 2012, the mean size of schools was only slightly lower than in 2011 at 48.7 tonnes (Figure 3). The proportion of schools recorded over 100 tonnes was also the second highest after 2011, but only just higher than in 2008. The mean size of fish recorded in 2012 was only 16.0 kg, the lowest of any season (Figure 4). The proportion of fish < 15 kg was the highest recorded (42.1%) while the proportion of fish > 25 kg was the lowest (7.8%).

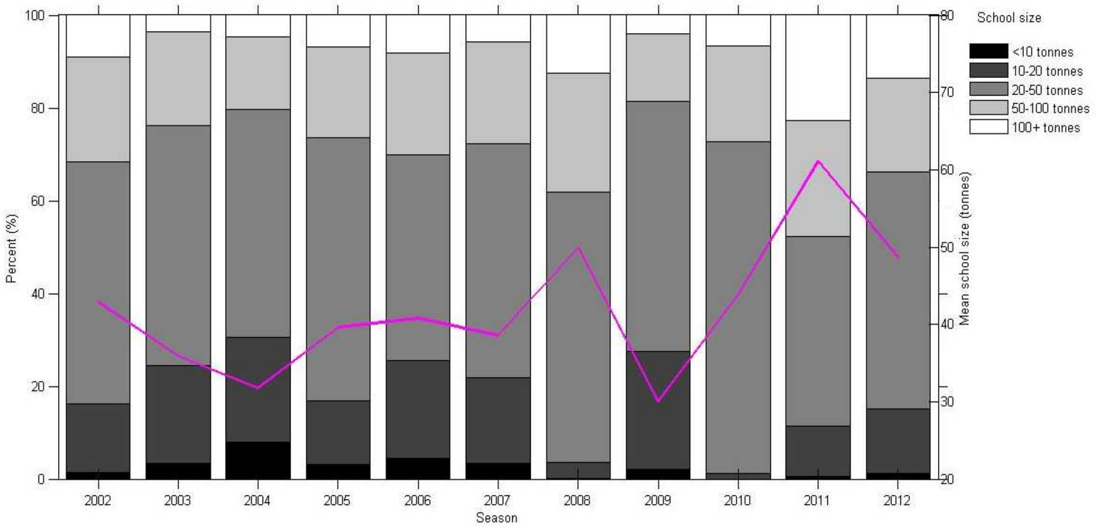

Figure 3. Proportion of SBT schools by size class (bars) and mean school size (line) recorded by one commercial spotter in the 2002-2012 fishing seasons. Total number of school size estimates is 7,888.

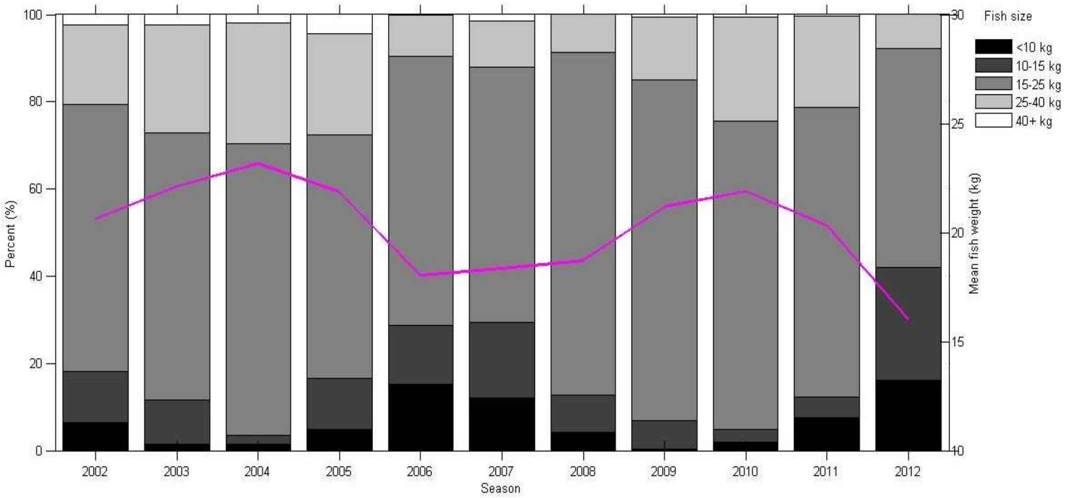

Figure 4. Proportion of SBT by fish weight class (bars) and mean weight in kg (line) recorded by one commercial spotter in the 2002-2012 fishing seasons. Data are weighted by school size. Fish size data collected for 7,721 schools.

4.2 Nominal SAPUE

As for previous years, the duration of “search” sectors during flights were calculated using the GPS logged position and time. The logbook data on SBT sightings were summarised to give the total number of sightings, schools, and total biomass per plane per day. The data were extracted to ensure consistency between seasons. Flights were excluded if they were outside the main fishing seasons (December to March) and were less than 30 minutes duration because these were considered too short to have a meaningful SAPUE estimate. As these data were removed for all seasons, it should not affect the relative index of abundance.

Nominal (unstandardised) indices of juvenile SBT abundance (surface abundance per unit effort – SAPUE) were calculated, based on the mean of biomass sighted (tonnes) per unit of search effort (minutes). The SAPUE indices were calculated by geographic area (whole GAB and core fishing area) and for flights where SBT was/was not targeted.

The four nominal SAPUE indices of juvenile abundance are shown in Figure 5. All four indices fluctuate similarly between 2002 and 2012. The 2012 indices were lower than for 2010 and 2011, and were lower than the 2002-2012 average. This year, all flights targeted SBT, thus the index for SBT targeted flights and all flights were identical.

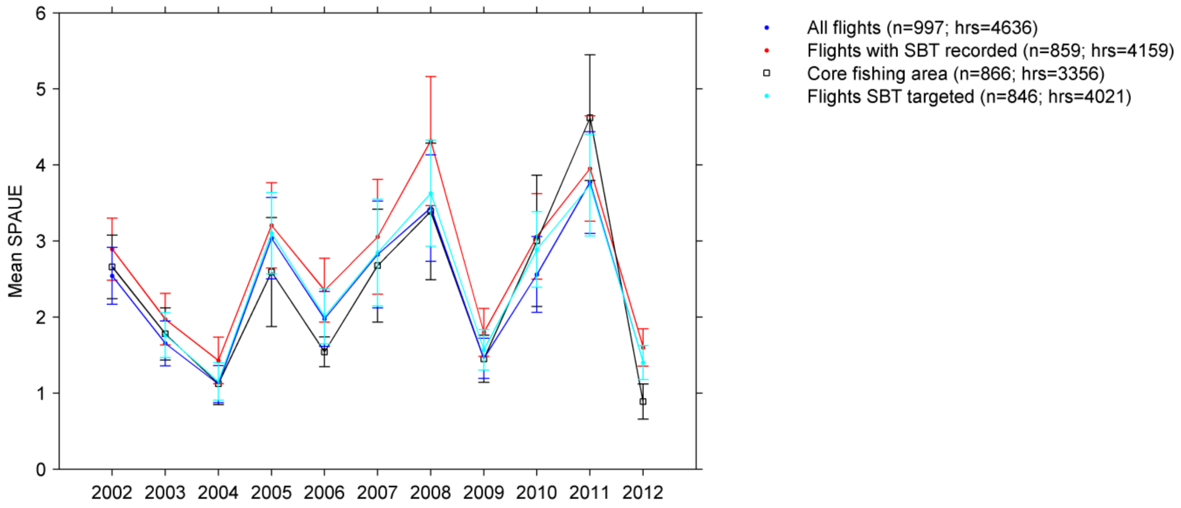

Figure 5. Nominal SAPUE indices (+/-se) (tonnes of SBT sighted per minute searching) for the 2002-2012 fishing seasons for all flights, flights in the core area, and flights that SBT were recorded. Note that only flights in December to March were included, and when search effort was >30 minutes.

4.3 Standardised SAPUE

Commercial spotting data are available for eleven seasons. These data can potentially be standardised to obtain an index of juvenile abundance (ages 2-4 primarily) in the GAB between December and March. Although up to seven spotters have operated at different times since 2002, only 2 spotters’ data can be used in standardisation analyses as they operated in all years (Table 3). In the past, we have explored the sensitivity of results to the inclusion/exclusion of data from different spotters and results showed that the index is not sensitive to this (see CCSBT-ESC/0809/25). The number of spotters required by industry has decreased, as there has been a tendency over time for fewer fishing companies to catch tuna for the other companies in the fishery. As in the past, we note that the commercial spotting data can suffer from many of the same hard-to-quantify biases that affect catch per unit effort, for example, changes in coverage over time, lack of coverage in areas where commercial fishing is not taking place –for whatever reasons – and changes in operations over time. From a statistical perspective, the scientific aerial survey, which uses a line transect design and consistent protocols, is far preferable as an approach to an index compared to the commercial spotting. However, these additional (commercial spotting) data can potentially provide further insights given the relatively large amount of effort (hours flown).

Given the changes in spotting effort (Table 3), only data from spotters 1, and 6 are in the updated modelling presented below. Data from four months (Dec, Jan, Feb and March) were included in the analyses, as in the past.

4.4 Environmental variables

As noted in the past (e.g. CCSBT-ESC/0409/19) sighting conditions and surfacing behaviour are influenced by weather and environmental variables. The environmental variables recorded by season are summarised in Table 4 and Figure 6. Note that the scientific aerial survey transects are only flown during certain conditions, so that summaries of environmental conditions recorded during the scientific aerial survey and during commercial spotting operations would tend to differ. The data suggests that during the 2012 commercial spotting flights, environmental conditions were similar to last year and close to the average. However, the average wind speed was high relative to the early- and mid-2000s, while air temperature and the overall spotting conditions were low relative to several of the years prior to 2009, suggesting that conditions in recent years were not as good relative to some of the earlier years surveyed.

We have noted previously (e.g. CCSBT/ESC/0609/17) that although the mean air temperature can be quite similar between seasons, the monthly temperatures can be very different. Figure 7 shows the monthly mean temperatures from the data collected over the past 10 seasons. In 2012, the average temperature increased from December to January, but then decreased in February before increasing again in March. The decline in temperature in February coincided with a period of relatively cold, cloudy and wet weather experienced across southern Australia. The December average temperature was the warmest compared to previous years, while the January and March temperatures were also above average. Although the February average was colder than January, it was on average with previous years.

Table 3. Number of days flown by spotter, year and month (Dec-Mar) within a year. Note that the 'season' is the same as the 'year' for all months except December; for example December 2001 will fall in the 2002 Season.

YEAR	MONTH	SPOTTER1	SPOTTER2	SPOTTER3	SPOTTER4	SPOTTER5	SPOTTER6	SPOTTER7
2001	Dec	14		8			4	
2002	Jan	7	5	5			7	
2002	Feb	7	3	3		4	4	
2002	Mar	11						
2002	Dec			10			10	
2003	Jan	10	6	9		5	10	
2003	Feb	2	3	6	2	1	4	
2003	Mar	5		6			4	
2003	Dec			11			10	
2004	Jan	9	7	5			11	
2004	Feb	15	10	9			6	
2004	Mar	16		2			4	
2004	Dec			4			3	
2005	Jan	11	7	9		1	7	
2005	Feb	9	2	10		6	16	
2005	Mar	19		2			8	
2005	Dec	9				3	4	
2006	Jan	8	4			3	8	
2006	Feb	9	8			9	9	
2006	Mar	12				4	10	
2006	Dec	6				2	7	
2007	Jan	15	7			10	14	
2007	Feb	9	6			7	7	
2007	Mar	12				11	6	
2007	Dec	5					11	
2008	Jan	11	11				9	
2008	Feb	11	6				12	
2008	Mar	8	5				4	
2008	Dec						9	
2009	Jan	11	4				13	
2009	Feb	9	7				11	
2009	Mar	15					9	7
2009	Dec						7	
2010	Jan	8	5			1	14	
2010	Feb	4	3			3	4	
2010	Mar							
2010	Dec	8					2	
2011	Jan	11					14	
2011	Feb	8					7	
2011	Mar	3					11	
2011	Dec	10					4	
2012	Jan	8					10	
2012	Feb	15					17	
2012	Mar	3					6	

Table 4. Average environmental conditions during search effort on commercial flights by season (all companies, Dec-Mar). Note visibility was not recorded in 2002.

FISHING SEASON	WIND SPEED (KNOTS)	SWELL HEIGHT (0-3)	AIR TEMP (°C)	CLOUD COVER (/8)	SPOTTING CONDITION (/5)	VISIBILITY (NM)
2002	7.06	1.46	18.06	4.48	2.64	
2003	6.90	1.18	23.35	3.62	2.81	5.58
2004	7.92	1.65	19.75	3.95	2.64	7.77
2005	6.99	1.59	21.14	4.23	2.55	8.95
2006	7.59	1.95	22.11	4.01	2.75	7.64
2007	6.98	1.87	21.10	3.60	2.78	7.92
2008	7.94	1.48	22.88	2.90	2.91	10.80
2009	8.47	1.53	20.33	3.42	2.72	5.81
2010	8.90	1.85	22.09	2.82	2.41	5.98
2011	8.50	1.56	21.94	4.51	2.64	7.93
2012	8.12	1.50	22.85	3.97	2.69	7.84

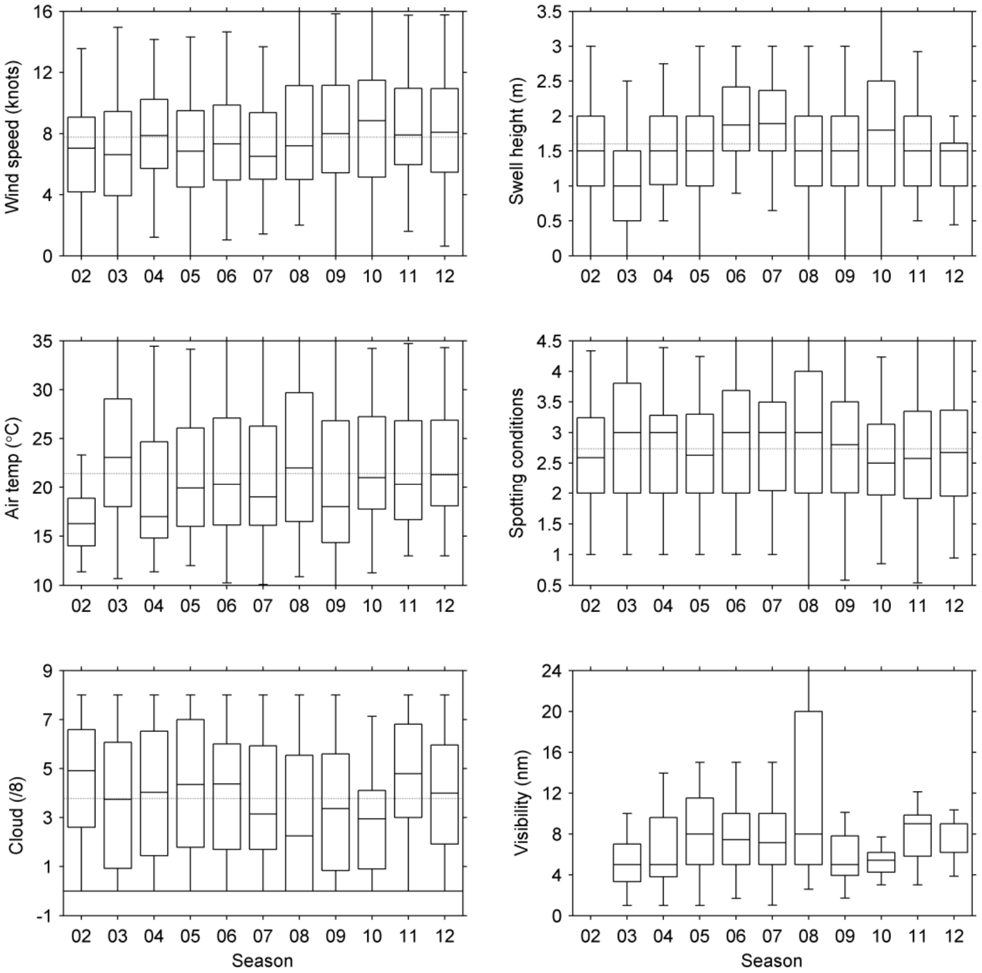

Figure 6. Boxplots summarizing the environmental conditions present during search effort on commercial flights by season (all companies, Dec-Mar). The horizontal band through a box indicates the median, the length of a box represents the inter-quartile range, and the vertical lines extend to the minimum and maximum values. The dashed line running across each plot shows the overall average across all survey years. Note visibility was not recorded in 2002.

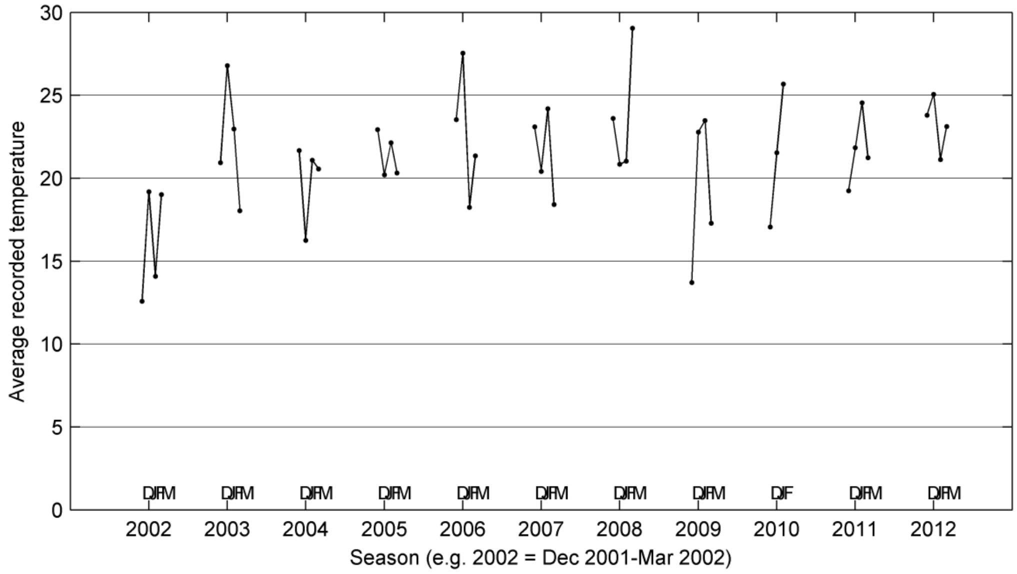

Figure 7. Average monthly temperatures (all companies, Dec to Mar) from the spotting data for the past 10 seasons. DJFM = Dec, Jan, Feb, Mar. Date were only recorded for Dec to Feb in 2010.

4.5 The sightings data

The data are compiled as the biomass sighted and effort in hours flown on each day by each spotter. We have previously commented on alternative ways of compiling the data at finer spatial and temporal scales for analyses (CCSBT-ESC/0509/23). However, given the complexity of such a task and the availability of data from the aerial survey, we have followed the approach used in the past. The associated environmental variables are taken as the means for that day and spotter. The data were compiled as a set for the entire area and all the analyses were done on the 'whole area' dataset. Table 5 shows a summary of the number of days flown with no biomass sighted. This information can be treated as a simple 'presence'/'absence' index. The percentage days with no sightings were below average in 2005 and 2007, and the lowest in 2011 (3.9%; the average is 10.4%). It was slightly higher in 2012, but still below average.

In the 2009 and 2010 seasons there was an increase in the number of flights targeted at Mackerel (Table 6). These flights generally occur outside the core area for SBT and therefore there is less likelihood of spotting SBT than on flights 'targeted' at SBT or even at skipjack. If this is taken into account by excluding flights with target="Mack", then the percentage days with zero biomass are:

2009 16.7 (compared to 18.9 for all flights)

2010 11.4 (compared to 16.3 for all flights)

If flights that target skipjack and mackerel (SKJ/Mack) are also excluded, then the percentage days with zero biomass drops further to 9.3% in 2010. The only other year in which this combination of targeting was recorded is 2006, but the effort was less than 1% (Table 6) and the estimate of percentage zero biomass days is unchanged. In interpreting the targeting information, it is assumed that recording of target has been consistent over time, at least by each spotter. Note though that the effort by spotters has changed considerably over time (Table 3). In 2011 the majority of effort (93.3%) and in 2012 all the effort was designated as being targeted at SBT.

Table 5. Number of days flown with no biomass sighted and days with some biomass sighted (all companies, Dec to Mar). Since different levels of effort are associated with each day, the % effort in hours associated with days when no biomass was sighted is also shown. Results are not aggregated over spotters, i.e. on a given day, if one spotter saw 0 biomass it contributes 1 to the 'zero biomass days', and if 2 spotters saw some biomass on the same day, they contribute 2 to the 'Positive biomass days'.

SEASON	ZERO BIOMASS DAYS	POSITIVE BIOMASS DAYS	TOTAL DAYS	% DAYS WITH ZERO BIOMASS	% EFFORT (HOURS) ASSOCIATED WITH ZERO BIOMASS
2002	10	72	82	12.2	10.0
2003	15	76	91	16.5	11.9
2004	25	90	115	21.7	15.7
2005	6	108	114	5.3	4.1
2006	16	84	100	16.0	11.5
2007	9	110	119	7.6	4.8
2008	19	74	93	20.4	17.2
2009	18	77	95	18.9	16.1
2010	8	41	49	16.3	10.8
2011	3	61	64	4.7	3.9
2012	9	64	73	12.3	8.0

Table 6. Summaries of percentage search effort by 'target' type and season. This information was not recorded in the first season, 2002. (SBT=southern bluefin tuna; SKJ=skipjack; Mack=Mackerel)

TARGET	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
SBT	55.6	82.6	79.8	70.3	87.2	89.7	48.8	76.1	93.3	100
SBT/SKJ	42.1	2.6	11.4	4.9	1.9	1.1	10.3			
SBT/Mack				9.1	6.8	0.8	22.8	13	4.5	
SBT/SKJ/Mack				3.4	0.7	4.9	11.7			
SKJ	2.4	14.9	8.8	8	2.3	3.4	1.6			
SKJ/Mack				0.6				2.3		
Mack			3.7	1.1			4.8	8.6	2.2	

4.6 Modelling approach

We used the same modelling approach as in the past and updated those analyses with data from the 2012 season. The main intention of modelling of these data is to standardise the raw index (e.g. average biomass per unit effort sighted) for differences between spotters and different environmental, weather and spotting conditions from year to year. As mentioned previously, only data for spotters 1 and 6 are consistently available in recent years, so only these spotters were included in the analyses presented here. Last year, we were still able to include data for spotter 2, but there are no data for this spotter in the most recent two seasons. As in the past, data for December, January, February and March are included in the analysis. Some of the variables (e.g. moon illumination) most likely only affect surfacing behaviour of tuna, whereas others (e.g. wind, swell) may affect both spotting ability and surfacing behaviour. The "regression model" used must be able to cope with the zero observations, and with the strong dependency of the variance on the mean. A convenient way to do this is to fit GLMs using the Tweedie family of distributions (Jørgensen, 1997; Candy 2004) with a log-link, so that different factors combine multiplicatively. The mean-variance relationship in Tweedie distributions follows a power-law with adjustable exponent Φ, and for $\Phi<2$ there is no problem with zero observations. When fitting the models, the exponent Φ was entered ($1< \Phi <2$). Note that the value of $\Phi=1$ coincides with the Poisson distribution, and a value of $\Phi=2$ with the Gamma distribution. A value of $\Phi=1.5$ was found to be acceptable in the past, and was again used as the default in this working paper. Sensitivity trials with values greater and less than 1.5 supported the appropriateness of a value of 1.5.

All analyses were done in R using library (Tweedie) to enable use of "family=tweedie()" in the standard GLM routine. The Akaike Information Criterion (AIC) statistic was primarily used to compare model fits.

The basic model was as before:

Model 1:

biomass ~ as.factor(season) + as.factor(spotter) + as.factor(month) + wind + spotcon + cloud + temperature + offset(log(effort))

Only sensitivity with regard to the Tweedie exponent was investigated.

4.7 Results

Diagnostics for Model 1 (Figure 8) shown that residuals are reasonably well-behaved, though the qq-plots are (as always) rather poor, and not linear as expected. This is unlikely to badly affect the point-estimates of coefficients, but does indicate a 'fat' tail in the data. In a relative analysis such as this, where the focus is on year-to-year comparisons, poor qq-plots do not generally imply bias in the point-estimates, but do point to the need to validate standard errors.

Estimated coefficients are given in Appendix A, and the estimated annual index is shown in Figure 9 below. The spotter and month effects are all significant as are the included environmental variables – wind, spotting condition, cloud and temperature. The year effects are highly significant for 2003 and 2004 (at <1% level); these coincide with the lowest standardised index. The year effect for 2011 is also highly significant and it coincides with the highest index value seen so far. The index for 2012 is the second lowest – lies between values for 2003 and 2004 – and is well below average.

The ranges shown in Figure 9 were obtained by taking the predicted values + or – 2 standard deviations on the log scale and then converting to the normal scale. Note though, that the standard deviations themselves take into account the fact that the index has been scaled to the mean. Results of the estimated index value and standard error are shown in tabular form in Table 7. Since the index is scaled to the series mean, values for earlier years will change as new seasons' data are added to the analysis, even if the model does not change.

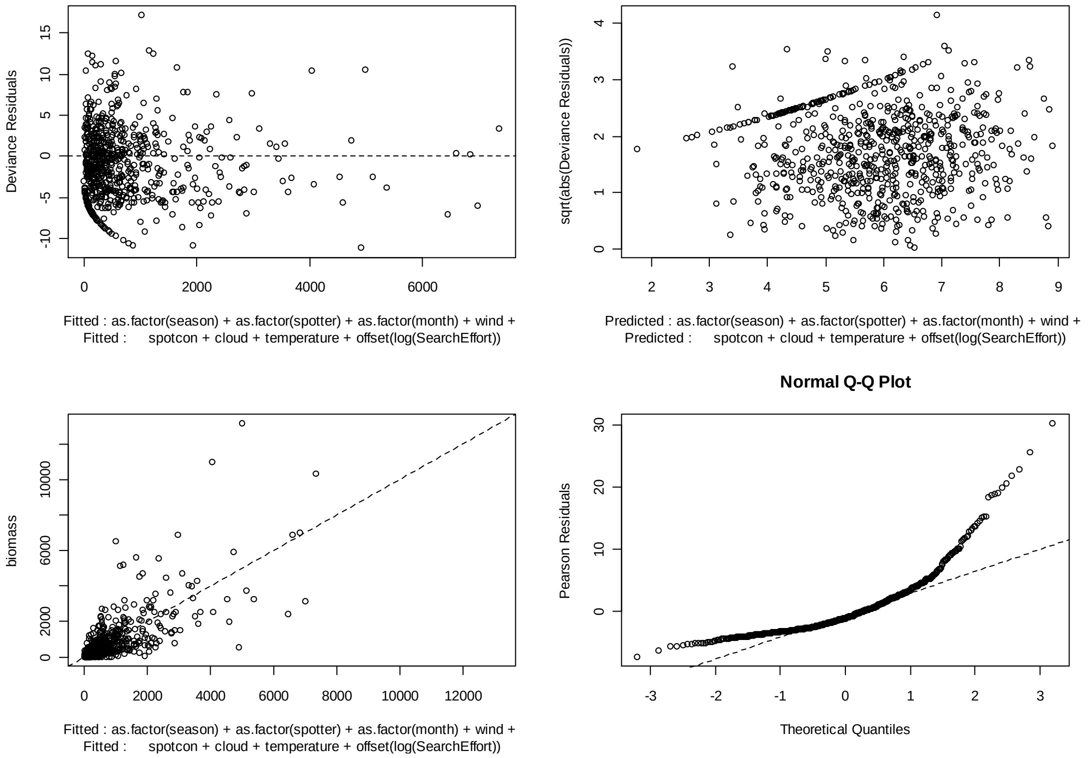

Figure 8. Diagnostics for Model 1 (see text above) with spotters 1 and 6, months Dec – Mar.

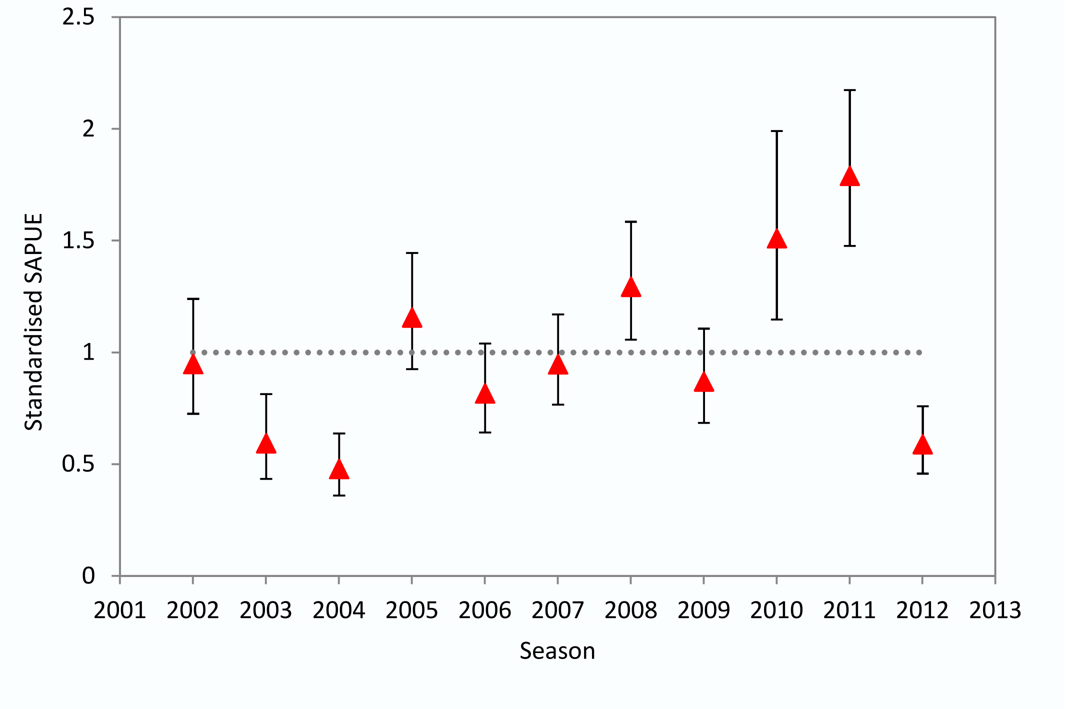

Figure 9. Estimates of standardised relative surface abundance, scaled to the mean over the relevant period, for Model 1 (see text for details). Data from spotters 1 and 6, and months December – March were used. The median and exp(predicted value + or – 2 standard errors) are shown. The horizontal line at 1 indicates the mean. 'Season' is indicated by the second year in a split year so that, e.g. 2002 implies the 2001/2002 season.

Table 7. Standardised SAPUE index of juvenile SBT in the GAB for Model 1. Data from all months (December – March) and spotters 1 and 6 (see text for further detail) were used. Season refers to the second year in a split year, i.e. 2002 = the 2001/2002 season. The estimated values are also illustrated in Figure 9 above.

SEASON	MODEL 1 ESTIMATE	SE
2002	0.95	0.127
2003	0.59	0.093
2004	0.48	0.069
2005	1.16	0.129
2006	0.82	0.099
2007	0.95	0.100
2008	1.29	0.131
2009	0.87	0.105
2010	1.51	0.208
2011	1.79	0.173
2012	0.59	0.074

5 Summary

We present results of a standardised ‘surface abundance per unit effort’ (SAPUE) index, based on fitting a general linear model to the data. Due to the changes in spotter effort since 2006, it is currently most appropriate to only include data for spotters who have consistent and broad temporal coverage; these are now only spotters 1 and 6. In the past, most sensitivity trials made very little, if any, difference to the estimated index of abundance (see e.g. CCSBT-ESC/1009/15); only sensitivity to the Tweedie exponent was considered, and a value of 1.5 is still considered to be suitable.

One of the factors which can potentially affect the index seems to be ‘targeting’. Operational changes can complicate standardisation and even the recorded ‘target’ information may not fully capture changes in spotting activity between seasons. Although we did not explore this here (and note that 93.3% of effort was designated as targeting “SBT” in 2011 and all effort was targeting SBT this year), we again suggest that information on targeting continue to be recorded, so that the sensitivity of results to this covariate can be considered. Ideally the definitions of each targeting category should remain consistent between seasons, but this may be difficult to achieve.

The most important environmental variables for this dataset are still: wind, spotting condition and temperature. Cloud is also relevant but appears to be ‘weaker’ than the other environmental covariates (significance at a lower level).

Last year, the standardised SAPUE index was the highest seen so far. The index in 2012 is the second lowest (lying between values for 2003 and 2004, Figure 9). The index reflects the abundance of 2, 3 and 4 year olds combined. We have previously commented on the low index in 2003 and 2004 representing the 1999, 2000 and 2001 year-classes (as 4,3,2-year olds in 2003) and the 2000, 2001 and 2002 year classes (as 4,3,2-year olds in 2004). The very low index in 2012 following the very high index in 2011 is, however, somewhat of a puzzle if we assume that it was again a combination of ages 2, 3, and 4. Figure 4 suggests that there was a larger proportion of fish below 15kg (and a smaller proportion of >25kg fish) than in the past. This is in line with the large number of 1-year olds spotted by the Aerial survey last season (CCSBT-ESC/1107/15). Nonetheless, there were fewer surface schools than in the recent past and of the surface schools that were to be found, a large proportion consisted of small (<15kg) individuals compared to previous years.

The drop the index between 2011 and 2012 is difficult to explain given that it represents the combined abundance of ages 2-4 years. Without additional information it is impossible to establish the reason, or reasons, for this drop. The presence of a substantial number of small fish in the scientific aerial survey last year (2011 season; Eveson et al. 2001) suggests that the drop is unlikely to be the result of a very small cohort. However, it seems unlikely that such a large drop could entirely be accounted for by the oldest year-class not returning to the GAB. The possible causes for the drop include: higher than usual mortality (natural and/or fishing) on some or all the age classes (i.e. 1 to 4), a change in surfacing behaviour (fish were in the GAB but not forming surface schools), or a change in movement (a large proportion of fish did not return to the GAB or did not remain in the GAB for the usual December-April period).

We plan to explore whether there have been changes in environmental conditions (SST and Chl-a, for example), noting that SBT appeared to be much further east than usual (see Appendix B, Figure 1). However, the SeaWiFS satellite that recorded oceanic chlorophyll-a failed at the end of 2010, and a product linking SeaWiFs and MODIS (a more recent satellite) chl-a is not yet available. Even if changes in environmental conditions are found, it would not be possible to definitively “correct” the indices for such an effect. Although results from the recent archival tagging project (Basson et al. 2012) suggest that it is unlikely that there is a large proportion of juveniles off South Africa each year, the dataset used in that study represents the early 2000s and does not (yet) include data from this past season.

The index should be treated with caution as usual and, for the reasons given above, particular care should be taken with the 2012 index.

6 References

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Candy, S.G. 2004. Modelling catch and effort data using generalised linear models, the Tweedie distribution, random vessel effects and random stratum-by-year effects. CCAMLR Science, Vol 11:59-80.

Eveson P., Basson, M., Farley, J., and Bravington, M. 2009. Southern bluefin tuna aerial survey in the Great Australian Bight – 2009: Preliminary results of aerial survey and commercial spotting data. Final Report to DAFF, June 2009.

Jørgensen, B. 1997. Theory of Dispersion Models. Chapman and Hall, London: Chapter 4.

Appendix A

Estimates of coefficients, standard errors and related ‘significance’ quantities for model 1.

Model 1: basic model with no targeting.

```
sapu> summary(wmod2012)

Call:
glm(formula = biomass ~ as.factor(season) + as.factor(spotter) + 
    as.factor(month) + wind + spotcon + cloud + temperature + 
    offset(log(SearchEffort)), family = mvb.tweedie(1.5, 0), 
    data = workdat12)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-11.195   -4.379   -1.390    1.587   17.187  

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)    
(Intercept)            0.38706    0.34487   1.122 0.262116    
as.factor(season)2003 -0.46747    0.21674  -2.157 0.031369 *  
as.factor(season)2004 -0.68340    0.19964  -3.423 0.000655 ***
as.factor(season)2005  0.19831    0.18139   1.093 0.274643    
as.factor(season)2006 -0.14935    0.18576  -0.804 0.421658    
as.factor(season)2007 -0.00129    0.17524  -0.007 0.994130    
as.factor(season)2008  0.31091    0.17655   1.761 0.078673 .  
as.factor(season)2009 -0.08587    0.18701  -0.459 0.646266    
as.factor(season)2010  0.46551    0.20989   2.218 0.026889 *  
as.factor(season)2011  0.63582    0.17591   3.615 0.000323 ***
as.factor(season)2012 -0.47524    0.18856  -2.520 0.011948 *  
as.factor(spotter)6   -0.73128    0.08258  -8.856  < 2e-16 ***
as.factor(month)2     -0.34722    0.09957  -3.487 0.000519 ***
as.factor(month)3     -0.88751    0.11146  -7.963 6.95e-15 ***
as.factor(month)12     0.25271    0.10393   2.432 0.015288 *  
wind                  -0.10111    0.01614  -6.263 6.65e-10 ***
spotcon                0.36672    0.06763   5.422 8.15e-08 ***
cloud                 -0.03514    0.01666  -2.109 0.035276 *  
temperature            0.02217    0.00604   3.670 0.000261 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 

(Dispersion parameter for Tweedie family taken to be 21.71507)
```

```
    Null deviance: 32022  on 707  degrees of freedom
Residual deviance: 13951  on 689  degrees of freedom
AIC: 9315.4

Number of Fisher Scoring iterations:
```

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