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Commercial spotting in the Australian surface fishery, updated to include the 2013/14 fishing season

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Copyright and disclaimer

Important disclaimer

Acknowledgments

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Contents

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 2013 and February 2014 (fishing season 2014). Spotting data has now been collected over 13 fishing seasons (2002 to 2014). 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' inside of the continental shelf break between the 130° and 133°east. In 2009 and 2011-2013 a significant amount of search effort occurred to the east of this core area following the shelf break. In 2014, almost all search effort occurred between longitudes 134° and 138° east; from west of Rocky Island through to south of Kangaroo Island. The surface abundance of SBT (per unit of search effort) in 2014 was spread throughout the search area, rather than being concentrated near the shelf break as observed in previous years.

The commercial spotting data were used to produce nominal and standardised fishery-dependent indices of SBT abundance (surface abundance per unit effort – a SAPUE index). Due to the changes in spotter effort each season, it was most appropriate to include data for all spotters in the analysis as was done last year. We only include data for 2003-2014 in the analysis since both target species and visibility seem to be important in the standardisation, and these factors were not recorded in 2002. The estimated SAPUE index for 2014 is higher than the average for the 2003 to 2014 period but slightly below the 2011 estimate which was the highest for all seasons.

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 (GAB). 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 have continued to collect and analyse SBT sightings data from commercial tuna spotters over the following 12 fishing seasons (2003-2014). Interpretation of the results are difficult as the data suffer from many of the same problems that affect commercial fisheries 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. This report summarises the field procedures and data collected, with emphasis on the 2014 season, and provides results of analyses for all 13 seasons (2002-2014).

Field procedures

As for previous years, the field program in 2014 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 2013 and February 2014 (called the 2014 fishing season). This year, data were collected by three spotters but one had participated in all previous seasons (Table 1).

The spotting data collected in 2014 were collected following the protocols used in the previous 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 patches, 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	-	-	-	-	52.9	-
2012	47.8	-	-	-	-	52.2	-
2013	55.3	-	-	-	17.4	-	27.3
2014	50.4	-	-	-	21.0	-	28.6

Results

Search effort and SBT sightings

Data were collected for 57 commercial spotting flights in the 2014 fishing season (Table 2). The number of flights recorded was lower than for seasons 2011 to 2013, and the second lowest since 2002. The details of search effort and SBT sightings are also given in Table 2. SBT were recorded on 82.5% of the flights in 2014 which is about average for the 2002 to 2014 period (84.7%). 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).

Figure 1 and Figure 2 show the spatial distribution of search effort and surface abundance of SBT. The location of SBT search effort and sightings varied little in 2002-2008 and 2010, with the area of highest SBT effort/sighting occurring within the same ‘core’ fishing area (130.2-132.9°E and 32.7-34.0°S). In 2009, and again in 2011 to 2013, a significant amount of search effort occurred well outside the core area closer to Port Lincoln. In these years, the search effort by spotters moved to the eastern GAB during the season as SBT became more difficult to find in the core. The timing of this shift occurred relatively late in the fishing season in 2009 (mid-March) but earlier in the season in 2011 and 2013 (Farley and Basson, 2013). The percent of total search effort occurring in the core area decreased from ~80-89% in 2002-2008, to less than

60% in 2009 and 2011, and 14% in 2012 (Table 2). In 2013, only 4.1% of effort occurred in the core area, with only 0.5% of the SBT biomass recorded. In 2014, only 0.5% of effort was in the core area and no SBT were sighted. Almost all search effort occurred between 134° and 138° east; from west of Rocky Island to south of Kangaroo Island. The surface abundance per unit effort in 2014 (Figure 2) shows SBT were more generally spread throughout the search area, rather than being concentrated inside of the continental shelf break as observed in previous years (Figure 2).

Note that flight path data for four of the 57 flights were not available in 2014 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).

Table 2. Search effort and SBT sighted by commercial spotters in the 2002-2014 fishing seasons. The 'core' is bounded by 130.2-132.9°E and 32.7-34.0°S.

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
2013	77	362	83.1	1529	67811	4.1	0.5
2014	57	260	82.5	1948	87536	0.5	0.0

[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 2014 (see above).

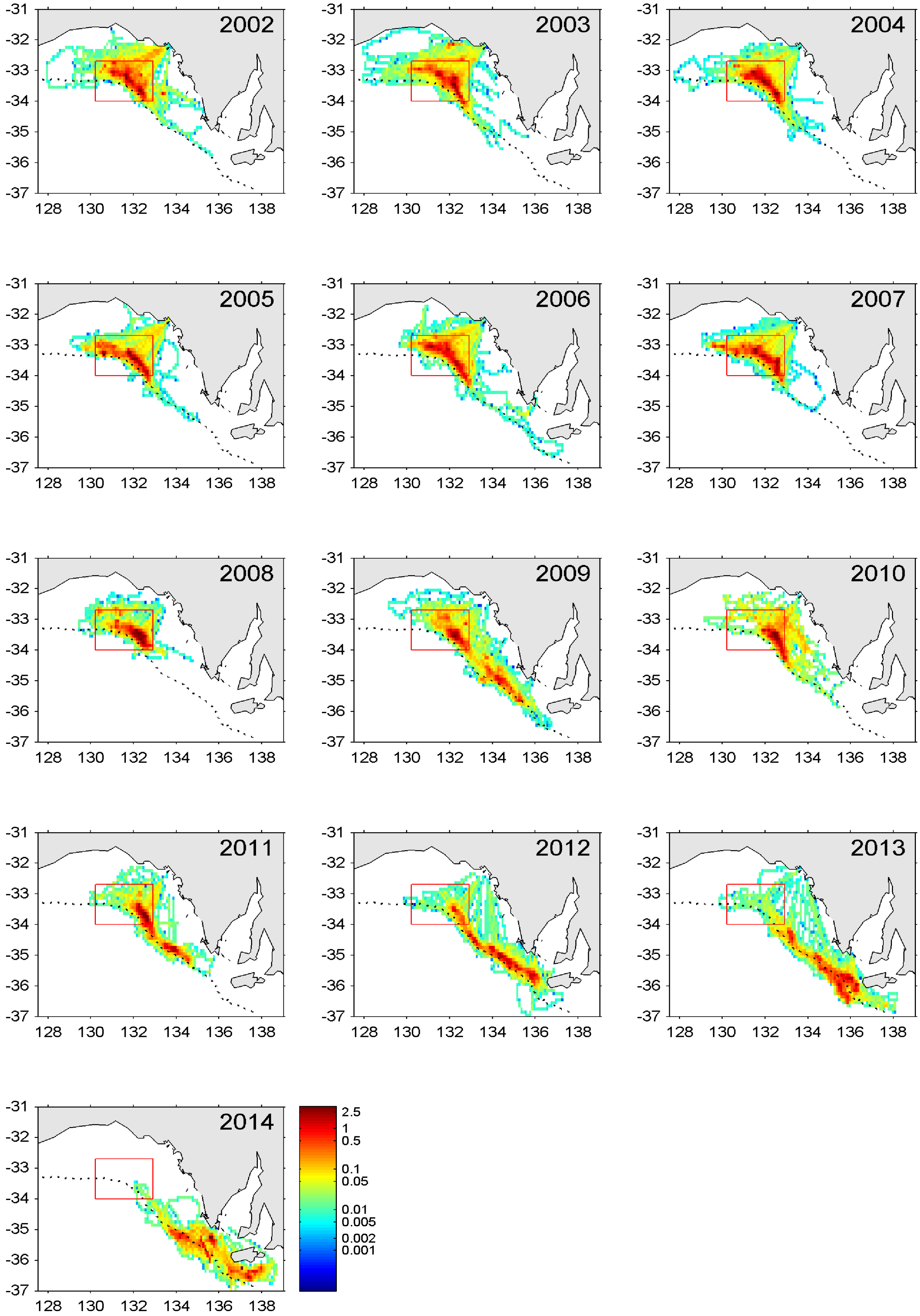

Figure 1. Search effort (nm flown/0.1° square) in the GAB by fishing season. Note the log scale. The 2002-2010 'core fishing area' is shown by a red square.

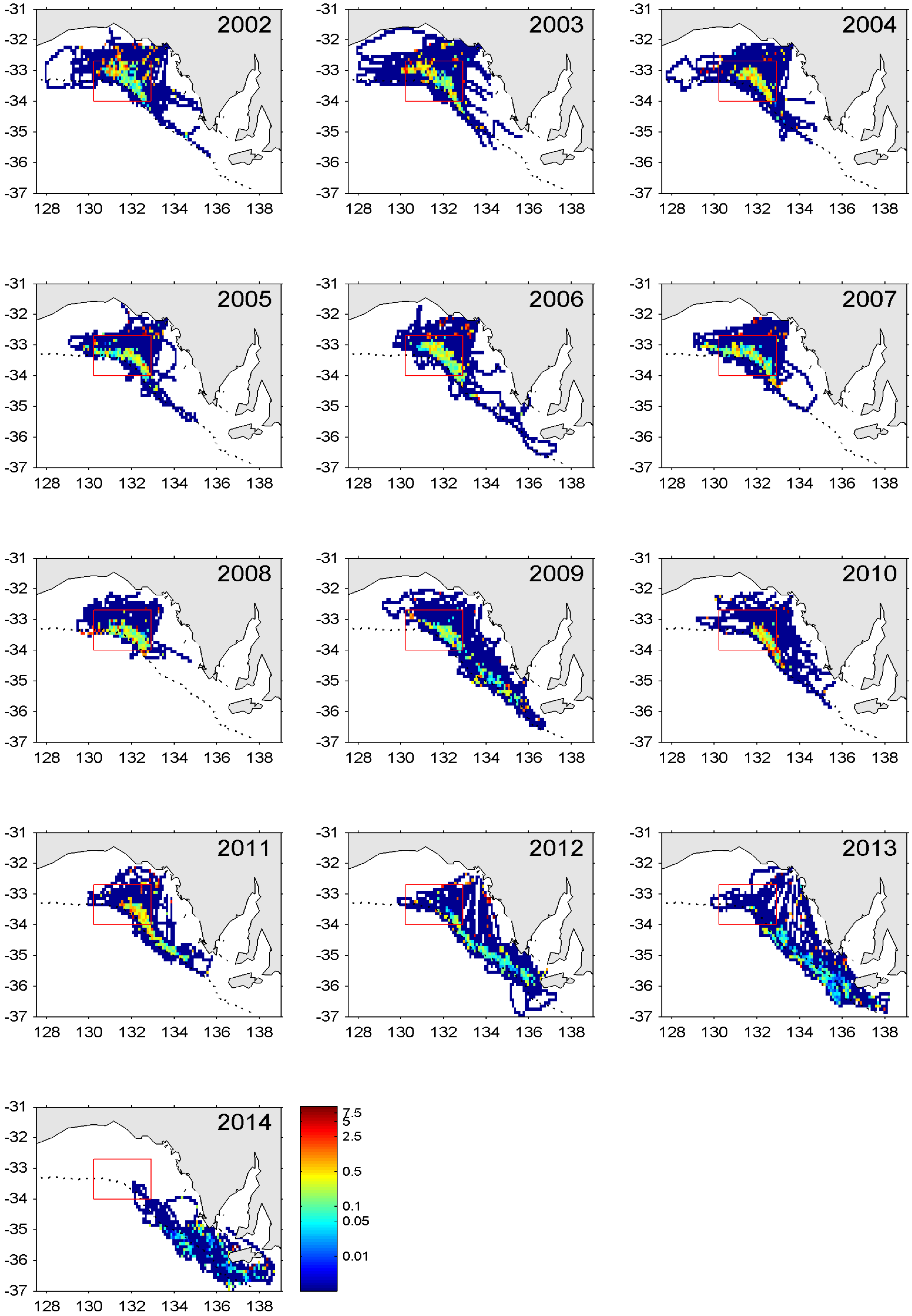

Figure 2. SAPUE (tonnes/nm/0.1° square) in the GAB by fishing season. Areas of darkest blue in the SAPUE plot indicate zero SAPUE. Note the log scale. The 2002-2010 'core fishing area' is shown by a red square.

Figure 3 and Figure 4 show the size of SBT schools and fish recorded by Spotter 1 between 2002 and 2014. 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 and is now the only spotter to collect data in 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 2014, the majority (56.9%) of fish were in schools of 10-20 tonne in size and the mean size of schools was 31.4 tonnes (Figure 3). The mean size of fish recorded was 20.6 kg (Figure 4) which is about average for the 2002-2014 period.

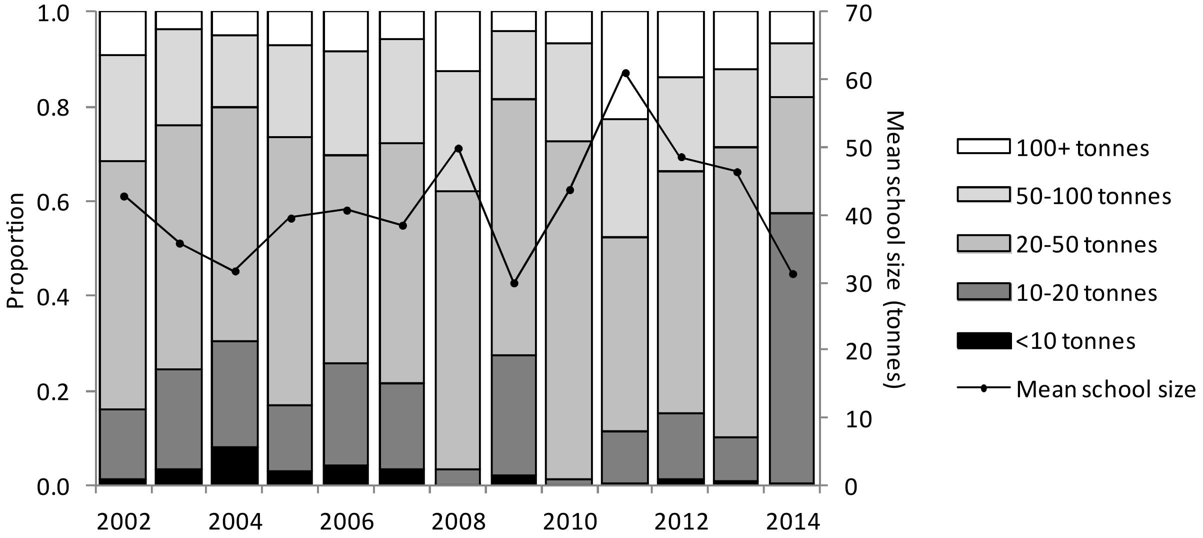

Figure 3. Proportion of SBT schools by size class (bars) and mean school size (line) recorded by one commercial spotter in the 2002-2014 fishing seasons. Total number of school size estimates = 9,923.

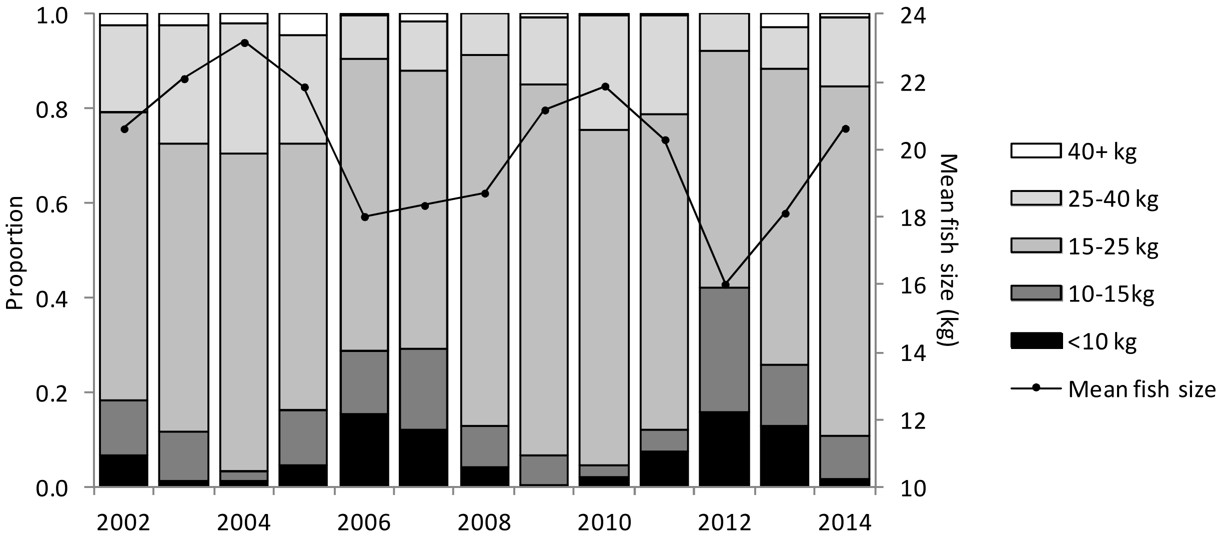

Figure 4. Proportion of SBT by fish weight class (bars) recorded by one commercial spotter in the 2002-2014 fishing seasons. Data are weighted by school size.

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. Three of the indices fluctuate similarly between 2002 and 2014. The 2014 indices were higher than for all previous years. The only index that did not follow the same inter-annual pattern was the index for the core fishing area which was much lower in 2013 and 2014 due to the lack of search effort (and thus SBT sighted) in that region.

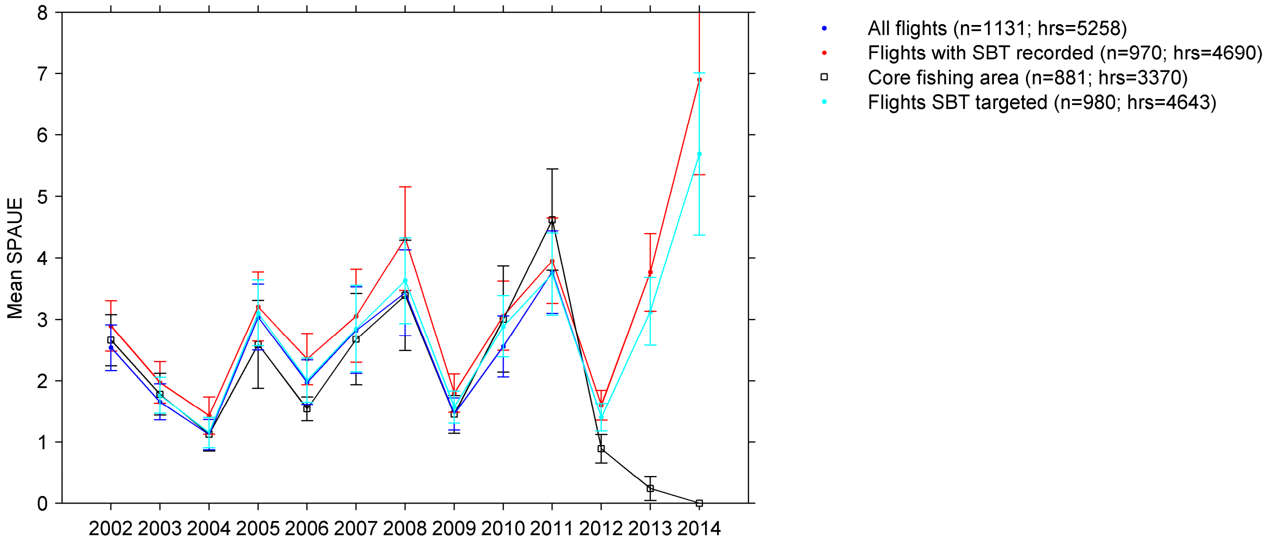

Figure 5. Nominal SAPUE indices (+/-se) (tonnes of SBT sighted per minute searching) for the 2002-2014 fishing seasons for all flights, flights in the core area, and flights that SBT were recorded. Note that only flights in December to March were included, and when search effort was >30 minutes.

Standardised SAPUE

Commercial spotting data are available for 13 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. There have been up to 7 spotters operating at different times since 2002 but unfortunately data were not collected in all months and all years by all spotters (Table 3). 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. In the past, data from only 2 spotters (spotter 1 and spotter 6) were used in standardisation analyses as they had operated in all years (2002-2012; Table 3) (see Farley and Basson, 2012). Last year and again this year, however, only one of these spotters collected data. We have previously 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 (e.g. Farley and Basson, 2008). Given this, and the changes in spotting effort, data from all spotters were included in last year's analyses and again this year.

As we noted last year, the fact that not all spotters operated and therefore have no data for some seasons means that we cannot fit a model with spotter as a fixed effect unless we leave out seasons where not all spotters have data; this would leave hardly any seasons. A solution to this is to treat spotter as a random effect. This allows for differences between spotters and it can manage the missing data. Previous analyses (i.e. Basson and Farley, 2005) showed that interactions (for example between month and season) were important for model fit (residuals were better behaved) though the standardised index itself was not sensitive to the inclusion or exclusion of interactions. The main reason why we chose to exclude interactions in the past is again because of missing data. If we treated the interaction as a fixed effect, the model could not be fitted if there were missing data in some strata. Last year, we modified the model to include interactions and treated them as random effects, which allowed us to handle months and years where data were missing (Farley and Basson, 2013). We apply the same approach again this year (see ”Modelling approach” section below).

Environmental variables

As noted in the past CCSBT reports, 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 2014 commercial spotting flights, environmental conditions were better relative to recent years. Although the wind speed and air temperature were about average, the cloud cover and swell height were well below average while the visibility was above average. In addition, the spotters recorded the overall spotting conditions as the best (highest on average) compared to all previous years.

We have also noted previously (e.g. Basson and Farley, 2006) 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 13 seasons. In 2014, the average temperatures increased from December to February. The December average was relatively cold, January was not particularly unusual compared to previous seasons, while the February average was the highest February temperature.

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	
2013	Dec	13				1		3
2013	Jan	16				11		12
2013	Feb	9				5		7
2013	Mar							

Table 3 continued.

YEAR	MONTH	SPOTTER1	SPOTTER2	SPOTTER3	SPOTTER4	SPOTTER5	SPOTTER6	SPOTTER7
2013	Dec	14			5			
2014	Jan	11			11			12
2014	Feb	2			1			1
2014	Mar							

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
2013	7.34	1.62	19.85	3.46	3.09	8.59
2014	7.49	1.13	23.25	1.80	3.38	10.63

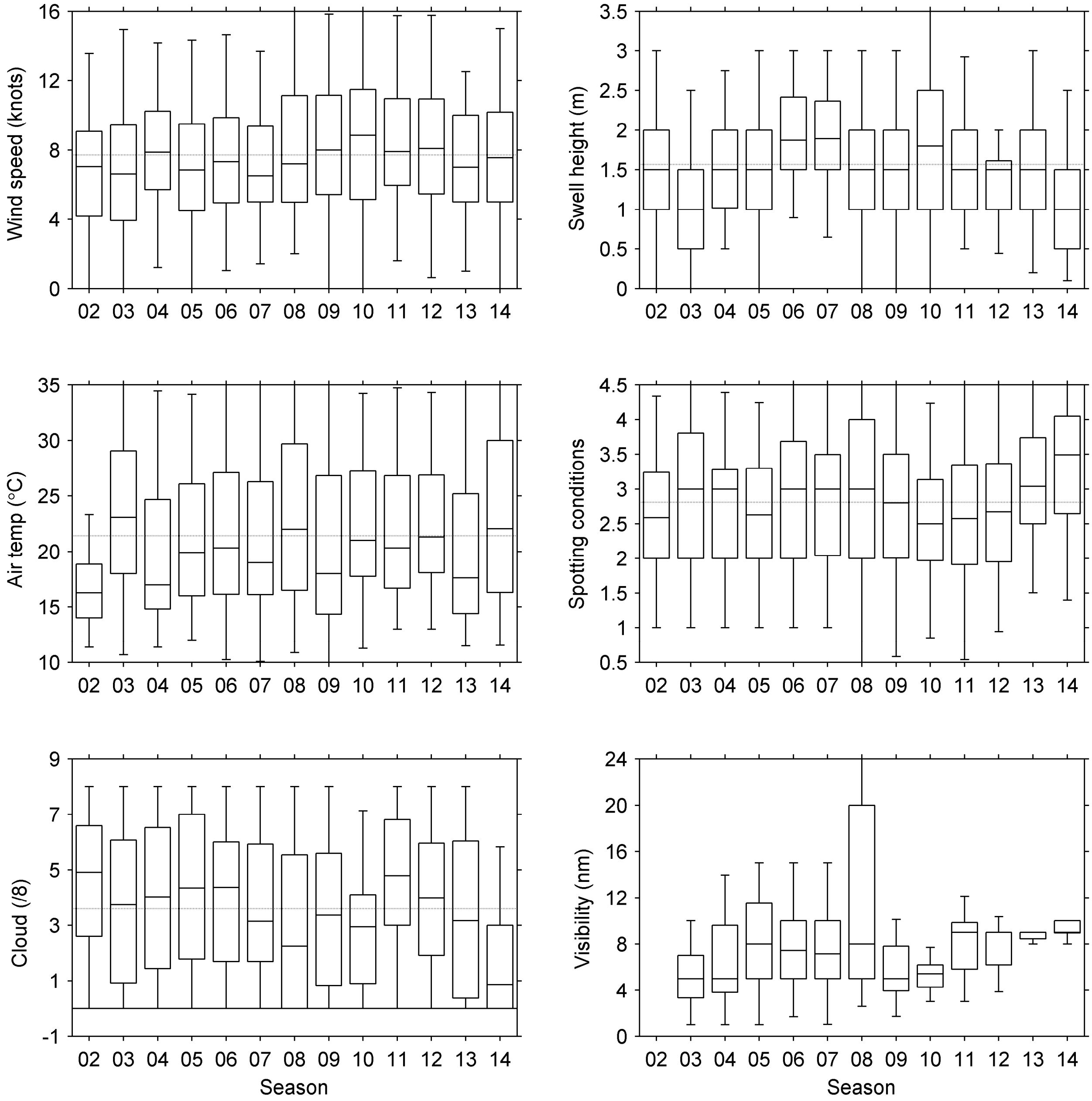

Figure 6. Boxplots summarizing the environmental conditions present during search effort on commercial flights by season (all companies, Dec-Mar). The horizontal band through a box indicates the median, the length of a box represents the inter-quartile range, and the vertical lines extend to the minimum 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.

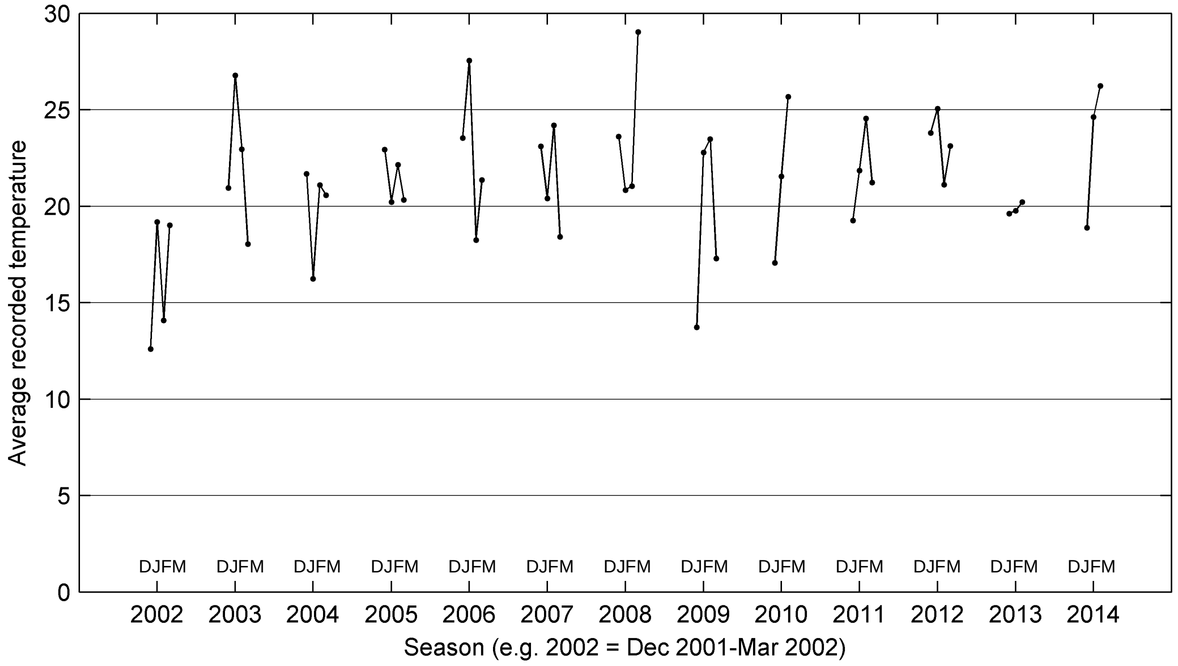

Figure 7. Average monthly temperatures (all companies, Dec to Mar) from the spotting data for the past 13 seasons. DJFM = Dec, Jan, Feb, Mar. Date were only recorded for Dec to Feb in 2010, 2013 and 2014.

The sightings data

The data were compiled as the biomass sighted (tonnes) and search effort flown (hours) 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 (Basson and Farley, 2005). 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 could be treated as a simple 'presence/absence' index. The percentage days with no sightings was notably below the average over all years (14.3%) in 2005 and 2007, and the lowest in 2011 (4.7%). It was slightly above average in 2014 (17.5%).

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 where target was recorded as mackerel, 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 of 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 to 2014 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
2013	13	64	77	16.9	12.3
2014	10	47	57	17.5	17.9

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	2013	2014
SBT	55.6	82.6	79.8	70.3	87.2	89.7	48.8	76.1	93.3	100	100	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			

Modelling approach

We used the same modelling approach as last year (Farley and Basson, 2013), so data for all spotters were included in the analyses. 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 in the past, data for December through March are included in the analysis. Some of the variables (e.g. temperature) most likely only affect surfacing behaviour of tuna, whereas others (e.g. wind, swell) may affect both spotting ability and surfacing behaviour. Recent work has shown that both targeting and visibility are important and have been included in the standardisation. However, moon illumination, cloud cover and swell are not significant and have not been included.

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. Recent work indicated that a value of $\Phi=1.47$ was appropriate, and sensitivity trials conducted last year confirmed this to be true (Farley and Basson, 2013). Thus, we used a value of $\Phi=1.47$ in our analysis this year.

All analyses were done in R using library (Tweedie) to enable use of "family=tweedie()" in the standard GLM routine.

The model fitted can be expressed as:

log(biomass) ~ spotter + season + month + s(wind) + s(spotcon) + s(temperature) + s(visibility) +

target + season:month + spotter:season + offset(log(SearchEffort)),

where season, month and target are factors fitted as fixed effects, and spotter and the two-way interactions between season and month and season and spotter are fitted as random effects. The environmental covariates (wind, spotting conditions, temperature and visibility) are fitted as smooths. We only include data for 2003-2014 since target and visibility were not recorded in 2002.

Model results

Diagnostics for the model fit (Figure 8) show no trends or patterns in the residuals. The smooth (solid red line) in the lower left panel (Figure 8), i.e. the square root of absolute deviance residuals plotted against the linear predictor, is sufficiently flat to indicate an appropriate value of the Φ-parameter (1.47) for the Tweedie distribution.

Estimated model coefficients are given in Appendix A, and the estimated annual index is shown in Figure 10. The environmental variables wind, spotting condition, and temperature were all highly significant (p-value<0.001), whereas visibility was only marginally significant (p-value=0.034). The estimated relationship between biomass per unit effort (on a log scale) and temperature was dome-shaped, while the relationship with visibility was slightly U-shaped (Figure 9). The estimated relationship between the biomass rate and wind speed was negative, and between sightings and spotting conditions was positive (Figure 9). These results are similar to last year except that the relationship between the biomass rate and visibility was closer to linear and slightly positive, but it was also insignificant.

The year effect was significant (p-value < 0.05) for 2005, 2008, 2010, 2011 and 2014, which coincide with above average standardised index estimates (Figure 10, Table 7). The index value for 2014 is above average for the period 2003-2014, and second highest over that period (with 2011 being highest). It is important, however, to keep in mind that the standard error (SE) estimates for the index values are often quite high, with the SE for 2014 being the second highest (Table 7, Figure 10). Note that the ranges shown in Figure 10 were obtained by taking the predicted values ± 2 SEs on the log scale and then converting to the normal scale, where the SEs themselves take into account the fact that the index has been scaled to the mean.

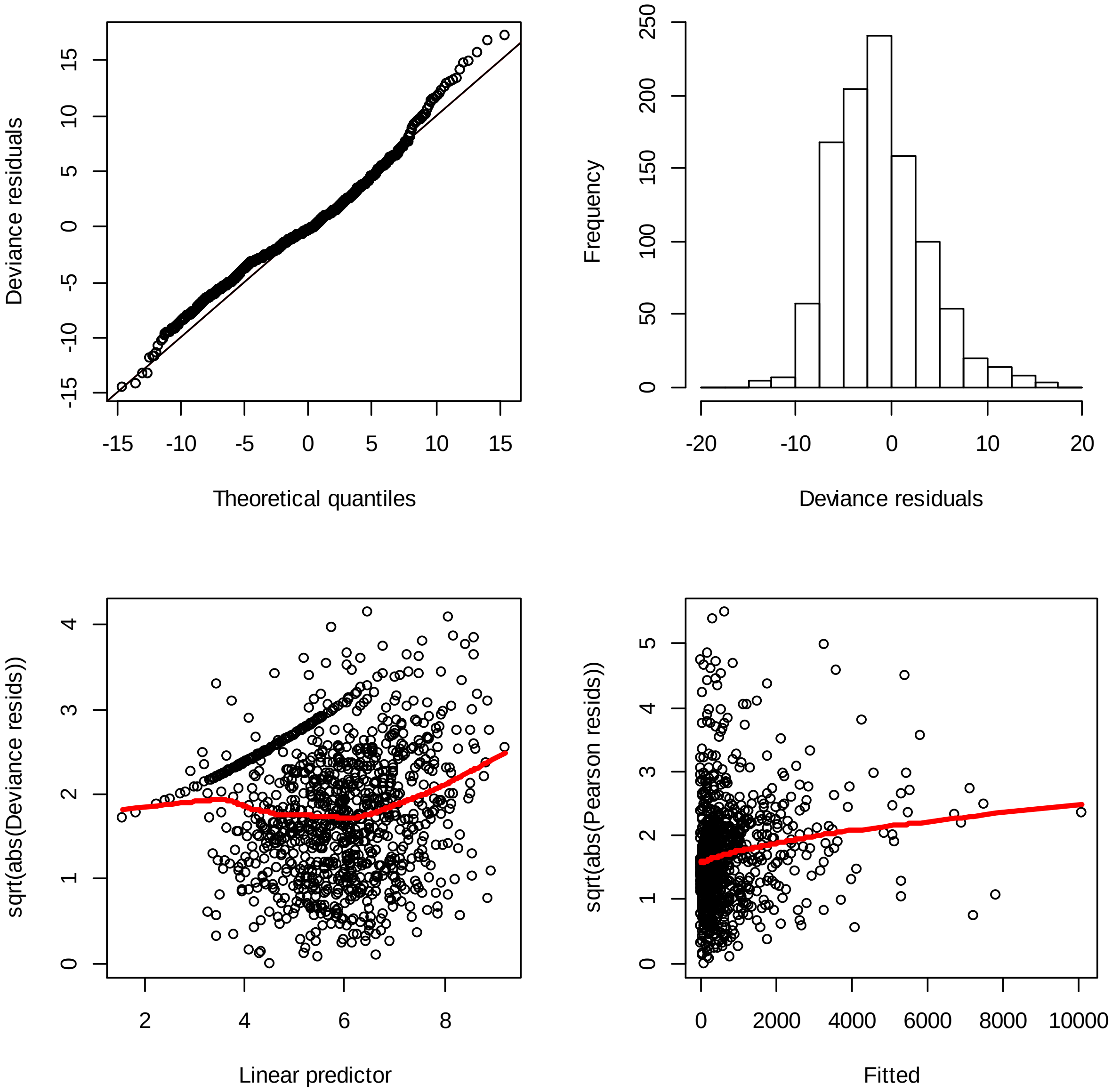

Figure 8. Diagnostic plots for the fitted model (see text above).

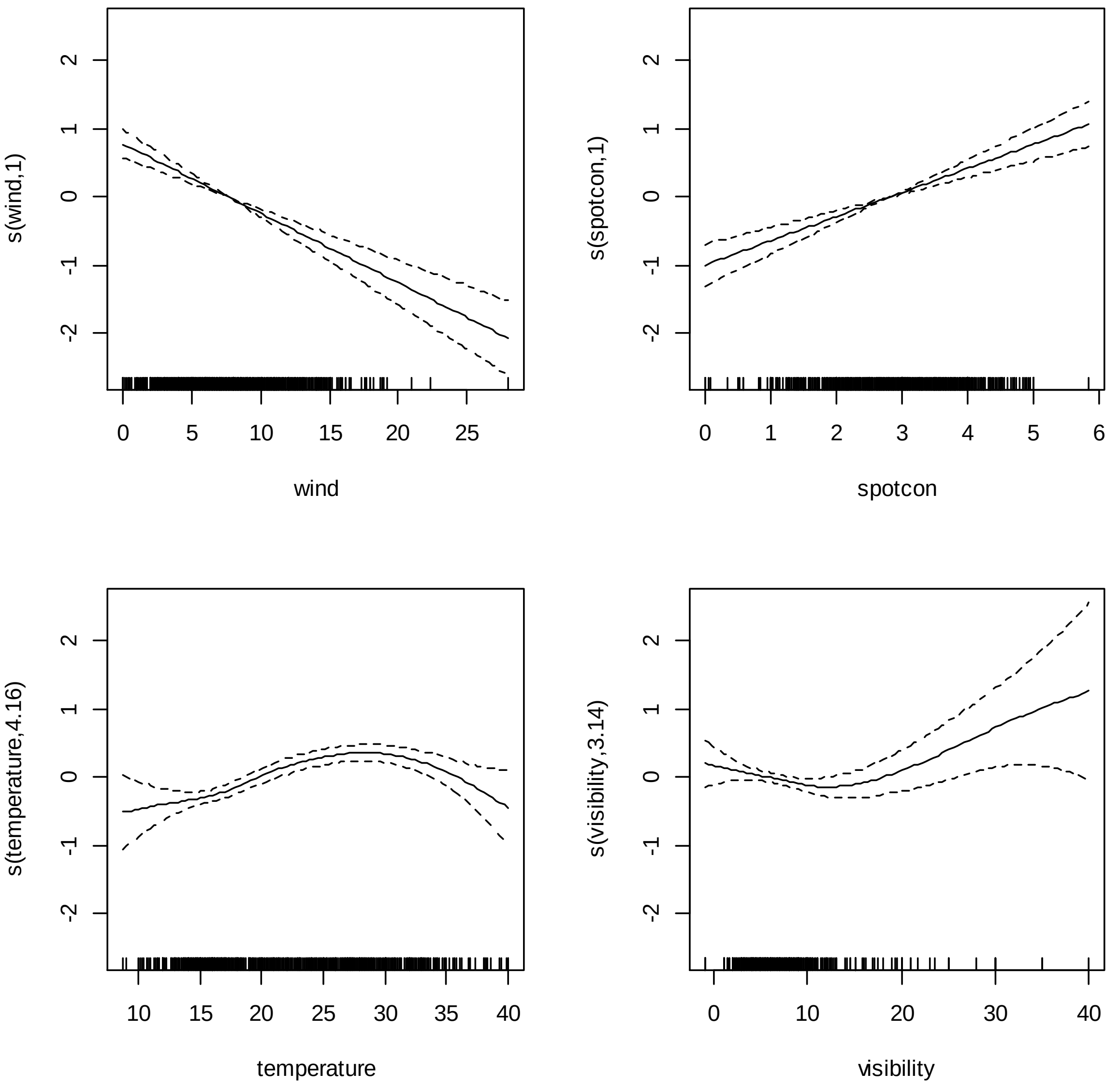

Figure 9. Estimated smooth relationships with 95% CI's between log(biomass/SearchEffort) and covariates 'wind' (windspeed in knots), 'spotcon' (spotting condition between 0 and 5), 'temperature' (air temperature in °C) and 'visibility' (in nautical miles). The 'rug' on the horizontal axis shows where data points are located.

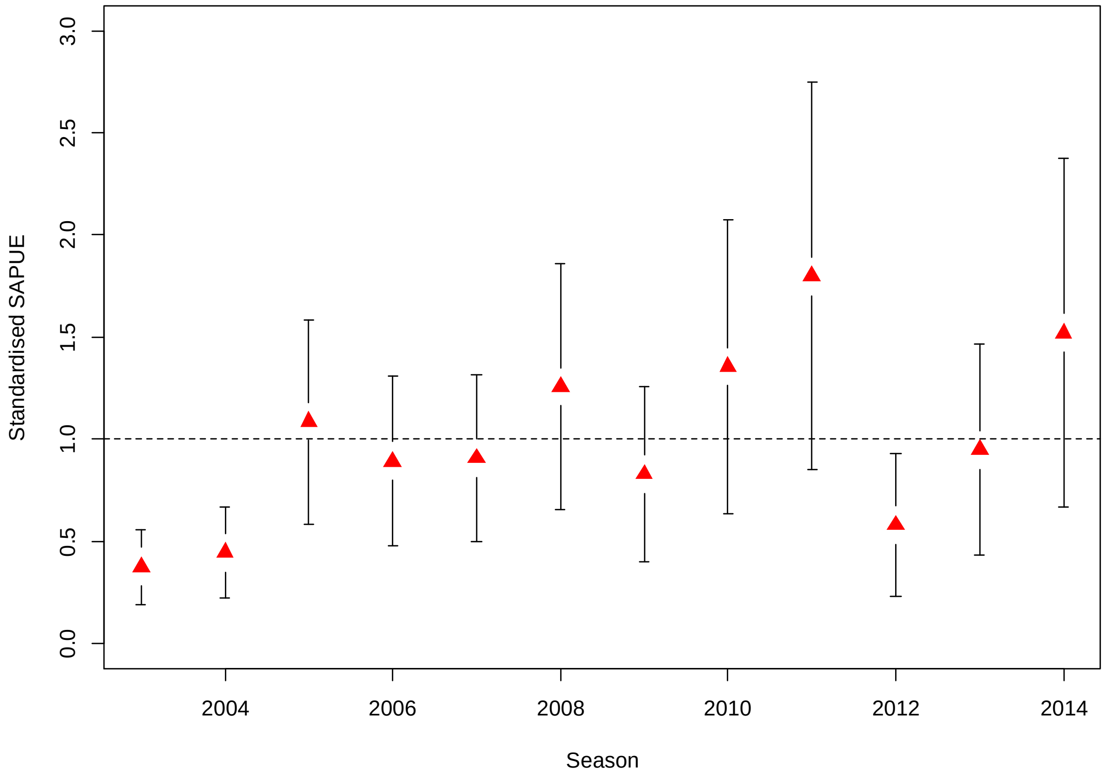

Figure 10. Estimates of standardised surface abundance per unit effort (SAPUE), scaled to the mean over the relevant period (see text for details). Data from all spotters, and months December – March were used. The median and exp(predicted value ± 2 standard errors) are shown. The horizontal line at 1 indicates the mean. Season refers to the second year in a split year, e.g. 2002 refers to the 2001/2002 season.

Table 7. Standardised SAPUE index of juvenile SBT in the GAB. Data from all months (December – March) and all spotters were used. Season refers to the second year in a split year, e.g. 2002 refers to the 2001/2002 season. The estimated values are illustrated in Figure 10 above.

SEASON	SAPUE ESTIMATE	SE
2003	0.38	0.09
2004	0.45	0.11
2005	1.09	0.25
2006	0.89	0.21
2007	0.91	0.20
2008	1.26	0.30
2009	0.83	0.21
2010	1.36	0.36
2011	1.80	0.47
2012	0.58	0.17
2013	0.95	0.26
2014	1.52	0.43

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 in the past, it is most appropriate to include data for all spotters in the analysis, rather than just spotters 1 and 6 (i.e. Farley and Basson, 2012). We have previously 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. The most important environmental variables for this dataset were wind speed, spotting condition, and temperature.

The data suggests that during the 2014 commercial spotting flights, environmental conditions were better relative to recent years. Although the wind speed and air temperature were about average, the cloud cover and swell height were well below average while the visibility was above average. In addition, the spotters recorded the overall spotting conditions as the best (highest on average) compared to all previous years. This resulted in a significant decrease in the standardized index estimate compared to the raw estimate.

The 2012 standardised SAPUE index was the lowest since 2004, but the index increased in 2013 and again in 2014. The 2014 estimate is substantially higher than the long-term (2003-2014) average, and just slightly below the 2011 estimate, which was the highest for all years. The drop in the index between 2011 and 2012 is difficult to explain given that it represents the combined abundance of ages 2-4 years (see Farley and Basson, 2012). Without additional information it was impossible to establish the reason, or reasons, for the drop.

As noted in the past, the index should be treated with caution. We have noted 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 (e.g. Eveson et al., 2013), 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).

References

Basson, M., Farley, J. 2005. Commercial spotting in the Australian surface fishery, updated to include the 2004/5 fishing season. CCSBT-ESC/0509/23.

Basson, M., Farley, J. 2006. Commercial spotting in the Australian surface fishery, updated to include the 2005/6 fishing season. CCSBT-ESC/0609/17.

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., Farley, J., Bravington, M. 2013. The aerial survey index of abundance: updated analysis methods and results for the 2012/13 fishing season. CCSBT-ESC/1309/10.

Farley, J., Basson, M. 2008. Commercial spotting in the Australian surface fishery, updated to include the 2007/08 fishing season. CCSBT-ESC/0809/25.

Farley, J., Basson, M. 2012. Commercial spotting in the Australian surface fishery, updated to include the 2011/12 fishing season. CCSBT-ESC/1208/15.

Farley, J., Basson, M. 2013. Commercial spotting in the Australian surface fishery, updated to include the 2012/13 fishing season. CCSBT-ESC/1309/09.

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

Appendix A: Model output

```
Family: Tweedie(1.47)
Link function: log

Formula:
biomass ~ spotter.re + season + month + s(wind) + s(spotcon) + s(temperature) +
s(visibility) + Target + season.month + spotter.season + offset(log(SearchEffort))

Parametric coefficients (fixed effects only)
                                    Estimate Std. Error t value Pr(>|t|)
(Intercept)                       -2.625e-01  4.834e-01  -0.543 0.587216
season2004                         1.869e-01  4.474e-01   0.418 0.676206
season2005                         1.036e+00  4.407e-01   2.351 0.018926 *
season2006                         8.036e-01  4.515e-01   1.780 0.075406 .
season2007                         8.120e-01  4.475e-01   1.815 0.069891 .
season2008                         1.156e+00  4.611e-01   2.506 0.012362 *
season2009                         7.394e-01  4.622e-01   1.600 0.110008
season2010                         1.244e+00  4.882e-01   2.548 0.011000 *
season2011                         1.419e+00  4.905e-01   2.892 0.003912 **
season2012                         4.013e-01  4.969e-01   0.808 0.419518
season2013                         8.916e-01  4.982e-01   1.789 0.073860 .
season2014                         1.309e+00  5.015e-01   2.609 0.009214 **
month2                            -2.624e-01  1.961e-01  -1.338 0.181144
month3                            -8.622e-01  2.252e-01  -3.829 0.000137 ***
month12                            6.448e-02  2.014e-01   0.320 0.748889
TargetMack/SBT                    -5.941e-01  3.555e-01  -1.671 0.094999 .
TargetMAK/SKJ/SBT                 -2.325e+02  7.048e+04  -0.003 0.997369
TargetSBT/Mack/SBT                -5.510e-01  2.145e-01  -2.569 0.010351 *
TargetSBT/SKJ/SBT                  1.763e-01  1.717e-01   1.027 0.304888
TargetSBT/SKJ/Mack/SBT            -3.653e-01  3.400e-01  -1.074 0.283022
TargetSKJ/SBT                     -3.495e-01  1.781e-01  -1.962 0.050025 .
TargetSKJ/Mack/SBT                -7.592e-01  1.545e+00  -0.491 0.623303
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                 edf Ref.df      F  p-value
s(wind)        1.002  1.004 57.369 7.67e-14 ***
s(spotcon)     1.002  1.003 41.870 1.48e-10 ***
s(temperature) 4.158  5.172 11.959 1.86e-11 ***
s(visibility)  3.145  3.929  2.636    0.034 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.457   Deviance explained = 61.9%
REML score =   6789  Scale est. = 25.107    n = 1038
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