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# Commercial spotting in the Australian surface fishery, updated to include the 2009/10 fishing season

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## 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 2009 and February 2010. Spotting data has now been collected over nine fishing seasons (2001-02 to 2009-10). 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). As seen in previous seasons, the standardised index is lowest in 2003 and 2004, and the estimate for 2010 is the highest seen so far and is at a level of about one and a half times the mean.

## Introduction

In the summer of 2001-02 (referred to as “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 7 fishing seasons (2003-2009). Interpretation of the results in terms of how they relate to the actual abundance of juvenile SBT in the GAB is 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, particularly if the series can be maintained in a consistent way over a longer period. It has always been recognised, however, that a scientific survey with consistent design and protocols from year to year is highly preferable relative abundance index. In 2010, 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 9 seasons (2002-2010).

## Field procedures

As for previous years, the field program in 2010 included the collection of spotting data from experienced commercial tuna spotters in the GAB. (Note, in this section we use the terminology ‘spotter’, not ‘observer’). Data were collected on SBT patches (schools) sighted by spotters engaged between December 2009 and February 2010 (referred to as the 2010 fishing season). This year, data were collected by four spotters, all of which had participated in previous seasons. Of these, three contributed 96% of the total search effort recorded (Table 1).

The spotting data collected in 2010 were collected following the protocols used in the previous seven 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 spotter also recorded the type of search effort (intensive or broad scale) undertaken during the flight. 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 (hrs) 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 | - |

## Results

### *Search effort and SBT sightings*

Data were collected for 49 commercial spotting flights in the 2010 fishing season (Table 2). This is substantially less search effort than for previous seasons where often well over 100 flights are recorded. The reduction in spotting days was due to a short fishing season for SBT this year; the fishing season finished in mid-February rather than late-March or even April as has occurred in previous seasons. The details of search effort and SBT sightings are also given in Table 1. SBT were recorded on 83.7% of the 49 commercial flights in 2010 which is about average. 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 3 of the 49 flights were not available in 2010 and thus the proportion of search time and biomass sighted in the ‘core’ fishing are currently unknown - although the total search effort and biomass for the flights are known and are included in the standardisation analysis (below).

Figure 1 shows the spatial distribution of search effort and surface abundance of SBT. In 2002-2007, 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 each season. In 2008, the search effort and SBT biomass recorded within the core area was the highest, although most of it occurred in the south-east corner of the core area. In 2009, however, a significant amount of search effort occurred well outside the core area closer to Port Lincoln. This shift in effort occurred around mid-March as SBT became more difficult to find in the core. In 2010, the percent of search effort in the core area was also relatively low compared to the pre-2009 seasons and again shows a slight shift in search effort to the south-east corner of the core area (towards Port Lincoln). This shift in search effort (~fishing location) could be due to a shift in the location of the SBT schools, a reduced need for the fishing vessels to travel as far west before locating suitable areas of SBT to purse seine, or change in operating behaviour due to economic considerations.

Figure 2 and Figure 3 show the size of SBT schools and fish recorded by Spotter 1 between 2002 and 2010. 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. On average, it appears that the mean size of schools increased between 2004 and 2008, decreased in 2009, but increased again in 2010. The mean size of fish decreased between 2004 and 2006, but has increased gradually since then.

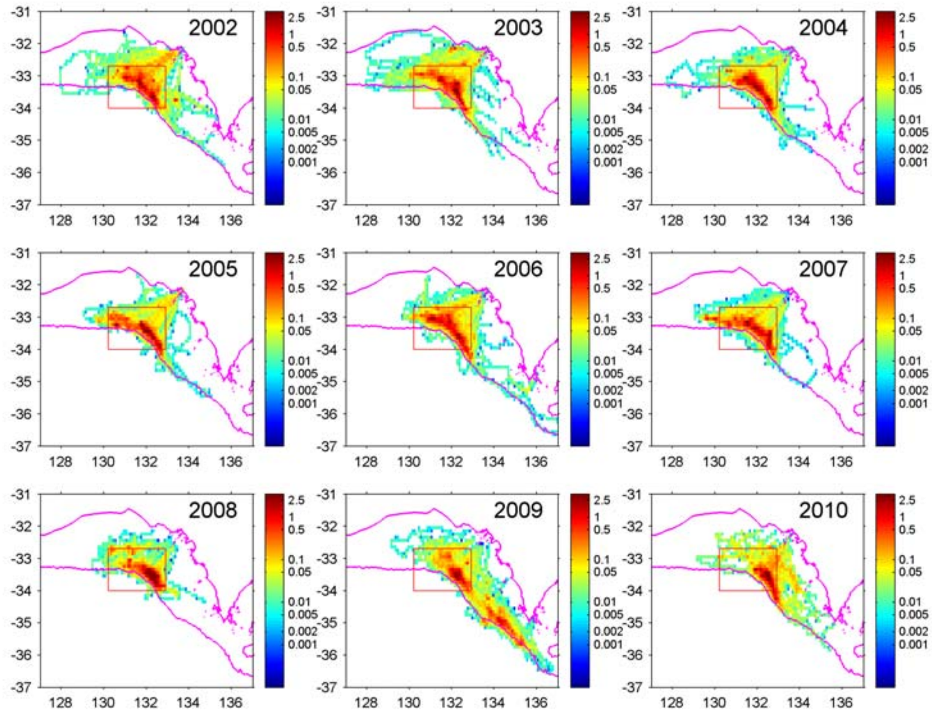
Table 2. Search effort and SBT sighted by commercial spotters in the 2002-2010 fishing seasons.

| 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 |

[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. 3 flights in 2010 (see above).

(a) Search effort (nm flown/0.1º square)




(b) SAPUE (tonnes/nm/0.1º square)

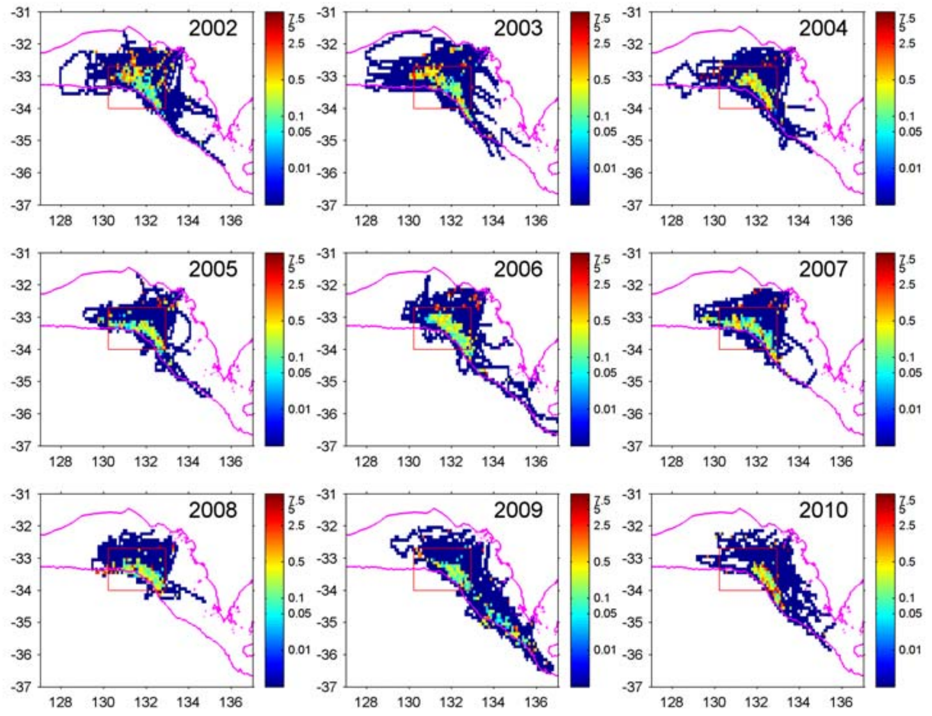



Figure 1. Search effort (a) and SAPUE (b) in the GAB by fishing season. SAPUE data are displayed as the % of total effort for the season. Areas of darkest blue in the SAPUE plot indicate zero SAPUE. Note the log scale for effort and SAPUE. The core fishing area is shown by a red square.

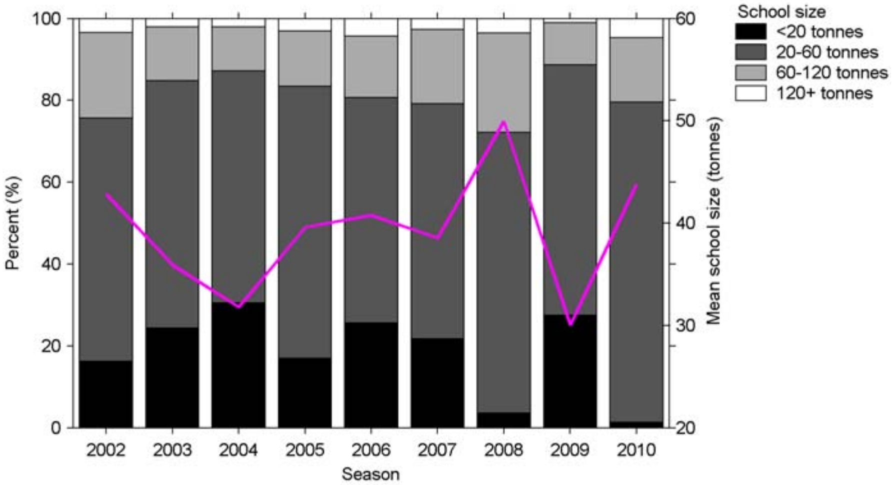



Figure 2. Proportion of SBT schools by size class (bars) and mean school size (line) recorded by one commercial spotter in the 2002-2010 fishing seasons. Total number of school size estimates = 6,544.

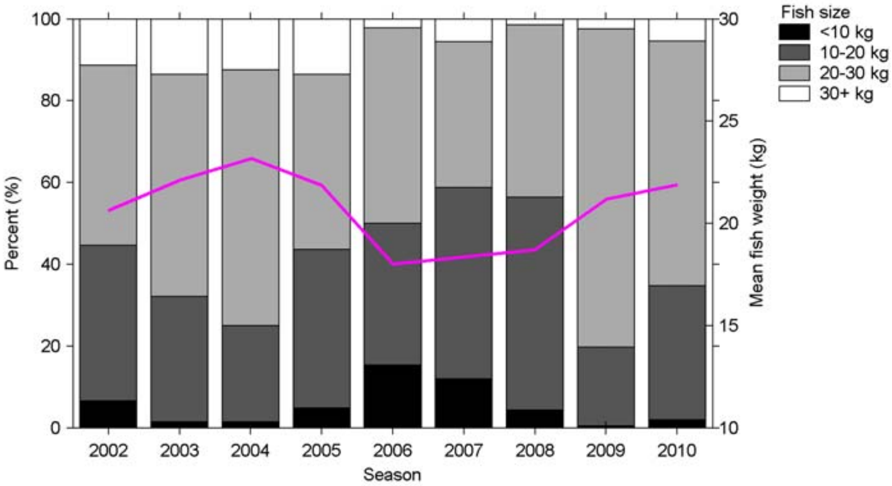



Figure 3. Proportion of SBT by fish weight class (bars) and mean weight in kg (line) recorded by one commercial spotter in the 2002-2010 fishing seasons. Data are weighted by school size. Fish size data collected for 6,414 schools.

## *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), by search type (broad and intensive), and for flights where SBT was/was not targeted.

The four nominal SAPUE indices of juvenile abundance are shown in Figure 4 (top). All four indices fluctuate similarly between 2002 and 2010. The 2010 indices were higher than for 2009, but were similar to the 2002-2010 average. Figure 4 (bottom) shows the comparison of mean SAPUE by search type. Since the type of search effort (broad/intensive) was not recorded in 2002, these indices can only be calculated for eight seasons. In 2010, the SAPUE point estimate for the intensive search effort was much higher than in previous season, while the estimate for the broad search effort was lower. Recording the type of search effort during a flight is very subjective, and it appears that it is not always recorded correctly (e.g. a complete flight is recorded as broad when the track shows that this was not the case). This suggests that indices based on search type are not particularly meaningful.

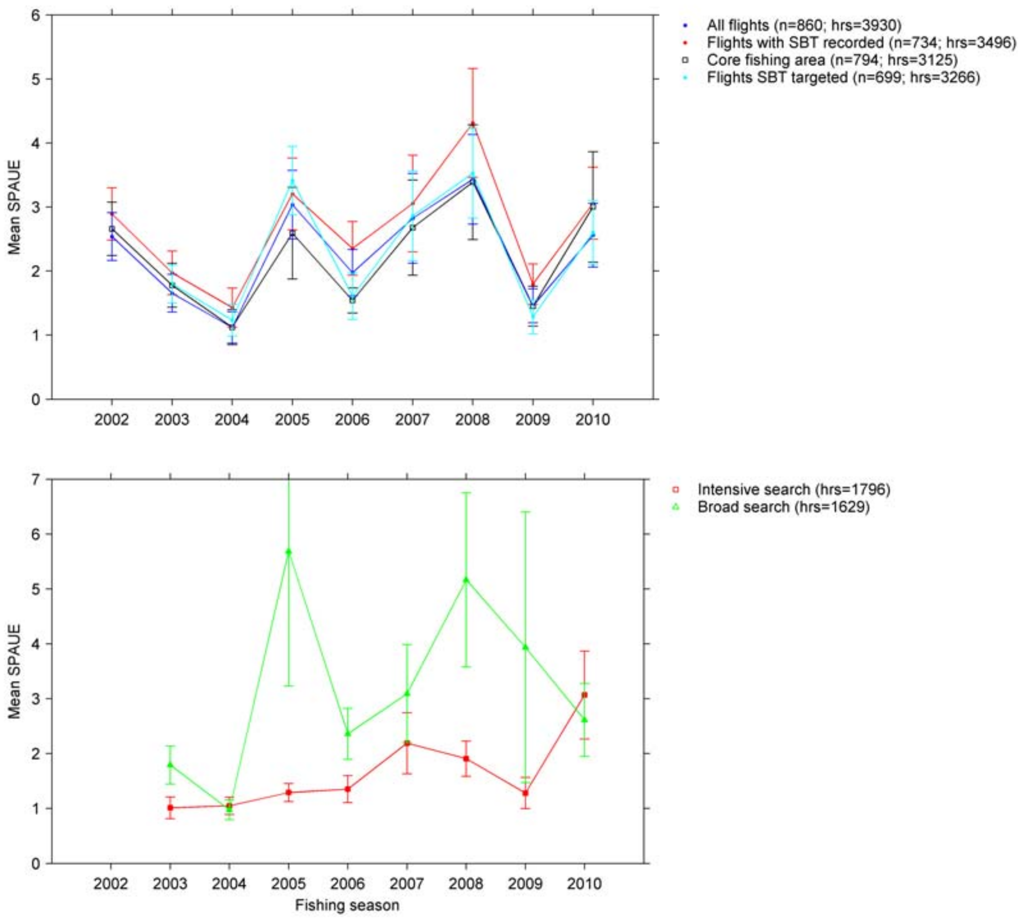



Figure 4. Nominal SAPUE indices (+/-se) (tonnes of SBT sighted per minute searching) for the 2002-2010 fishing seasons for all flights, flights in the core area, or flights that SBT were recorded (top), and by search effort type (bottom). Classifying search effort as either broad or intensive started in 2003 (i.e. the 2002/03 fishing season). 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 eight seasons. These data can potentially be standardised to obtain an index of relative 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 3 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, 2, and 6 were in the updated modelling presented below. Data from four months (Dec, Jan, Feb and March) were included in the analyses, though sensitivity analyses were conducted on data from only January and February (see below).

## *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 5. 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 2010 commercial spotting flights, environmental conditions were not as good as previous years. For example, the average wind speed was the highest recorded for any season, the average swell height was above average, while the spotting conditions and visibility were well below average.
We have noted previously (e.g. CCSBT/ESC/0609/17) that although the mean temperature can be quite similar between seasons, the monthly temperatures can be very different. Figure 6 shows the monthly mean temperatures from the data over the past 9 seasons. In 2010, the average temperatures increased steadily 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 |
| 2010 | Dec | | | | | | 7 | |
| 2010 | Jan | 8 | 5 | | | 1 | 14 | |
| 2010 | Feb | 4 | 3 | | | 3 | 4 | |
| 2010 | 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 |

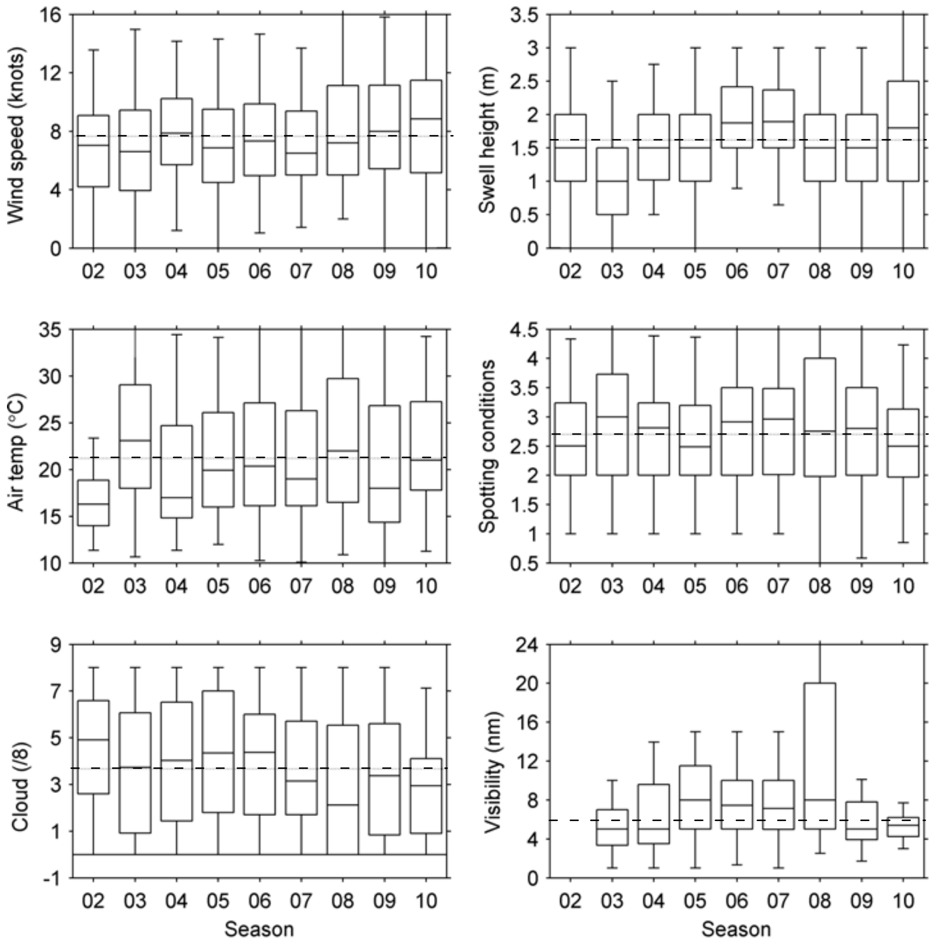



Figure 5. Box plots summarizing the environmental conditions present during search effort on commercial flights by season (all companies, Dec-Mar). The horizontal band through a box indicates the median, the length of a box represents the inter-quartile range, and the vertical lines extend to the minimum 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.

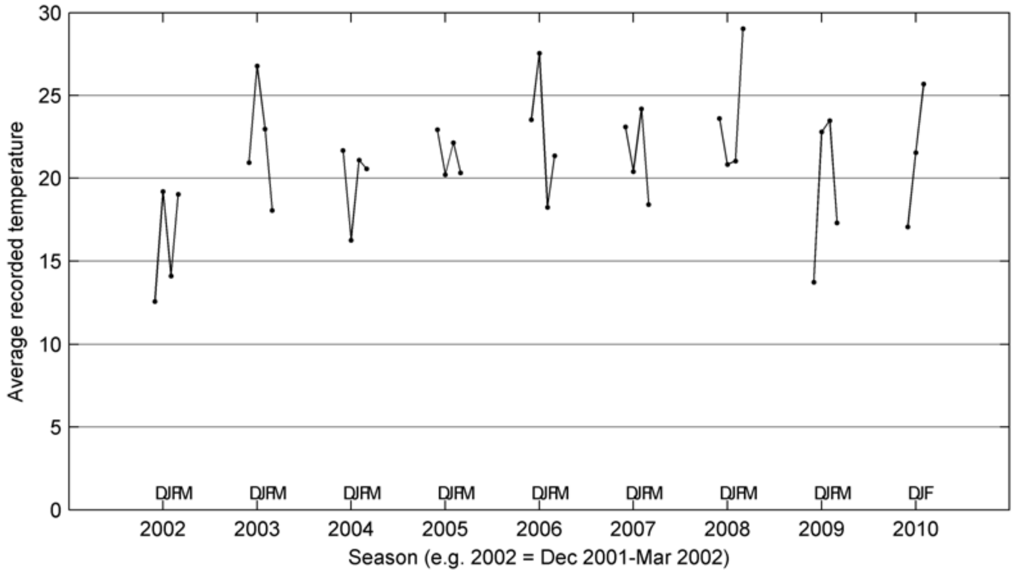



Figure 6. Average monthly temperatures (all companies, Dec to Mar) from the spotting data for the past 9 seasons. DJFM = Dec, Jan, Feb, Mar. Date were only recorded for Dec to Feb in 2010.

## *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 close to average in 2010 (16.3%; the average is 15%).

In the recent two 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 over time (Table 3).

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 |

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)

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|
| SBT | 55.6 | 82.6 | 79.8 | 70.3 | 87.2 | 89.7 | 48.8 | 76.1 |
| 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 |
| 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 |

## *Modelling approach*

We used the same modelling approach as in the past and updated those analyses with data from the 2010 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, 2 and 6 are consistently available in recent years, so only these spotters were included in the analyses presented here. 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 $\Phi$, and for $\Phi<2$ there is no problem with zero observations. When fitting the models, the exponent $\Phi$ 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. Past sensitivity trials with values of 1.2 and 1.7 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 first model that was fitted is the same as that fitted in 2009:

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

Results for this model (see below) indicated that swell and moon illumination were not significant. This was also the case last year, i.e. for data up to the 2009 season, and these variables were dropped from the model, so that the basic model is:

Model 1:
biomass ~ as.factor(season) + as.factor(spotter) + as.factor(month) + wind + spotcon + cloud + temperature + offset(log(effort))

Several sensitivity trials were also conducted:
1. Taking targeting into account two different ways -
    - Target 1: all 7 categories of targeting as factors
    - Target 2: 2 groups of categories, 'SBT' and 'OTH' (other), see text below
2. Excluding December and March data for all years -
    - using Model1
    - using model Target 1

Each sensitivity trial consists of a modification to model 1, either through a change in dataset and/or a change in covariates. The rationale for the sensitivity trials are briefly outlined below.

<u>Target species</u>
In the 2009 and 2010 seasons, some commercial flights were conducted with the aim to spot mackerel ('Mack') or skipjack and mackerel ('SKJ/Mack') rather than SBT. The information on target species has been recorded since the 2003 season, but has not been used in the standardisation prior to 2009, because SBT has usually been at least one of the (if not the only) target species. We started looking at including targeting last year (Eveson et al. 2009), and given the observations of non-SBT targeted flights in the recent two years (see Table 5 and Table 6), sensitivity trials that take targeting into account were again conducted.

There are 7 categories recorded in the data: SBT, SBT/SKJ, SBT/Mack, SBT/SKJ/Mack, SKJ, Mack, SKJ/Mack. One way of taking targeting into account is to leave out data on flights targeted at other species, i.e. 'SKJ', 'Mack' or 'SKJ/Mack'. This is, however, not ideal since SBT are sometimes spotted (and recorded) on such flights. Instead, a model with target as a factor was fitted; this requires one less parameter than the number of categories, i.e. 6 parameters. A more parsimonious approach is to group categories together. Two groups were formed:

'SBT' (containing the target categories SBT, SBT/SKJ, SBT/Mack, SBT/SKJ/Mack) and
'OTH' (for "other", containing the categories SKJ, Mack, SKJ/Mack)
The models fitted with targeting exclude 2002 as targeting was not recorded in that first season.

Months
In 2009, information from Industry indicated that the majority of SBT seemed to have left the GAB in around mid-March. As a result, spotting activities shifted to an area west and southwest of Port Lincoln (see Figure 1). If this departure was substantially earlier (or more complete by mid-March) than in past years, it could affect the standardised index. In 2010, there was limited spotting in December (one spotter only) and spotting was complete by the end of February. It again makes sense to consider the effect of only using data for January and February as a sensitivity trial.

Other covariates
Last year we explored the effect of wind direction in the standardisation (Eveson et al. 2009). Experience in the field suggests that SBT are less likely to be at the surface, and less visible if they are at the surface, when the wind is from the south-east. Wind direction has been summarised as the proportion of time ("day", i.e. during a flight on that day) that the wind was: Northerly (N), South-easterly (SE), other (Oth) or calm. We combined the strength of the wind and direction into new covariates by assigning a single direction for each day, depending on the maximum proportion. Three new variables, windN, windSE and windOth were constructed, setting the value equal to wind speed or equal to 0 depending on the single direction.

Results from last year's analyses found that each of these wind "speed and direction" covariates were significant, but the coefficients were almost identical, and very similar to the single coefficient when just wind speed (no direction) was used. There was also an increase in AIC for the model with wind direction (8037, compared to 8026 for the model with just wind speed). We concluded that this and the similarity among coefficients suggest that 'wind' as a single covariate is preferable. This issue has therefore not been explored again this year.

## *Results*

Diagnostics for Model 1 (Figure 7) shown that residuals are reasonably well-behaved, though the qq-plots are (as in the past) 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. The estimated annual index is shown in Figure 9 below (indicated as 'no target' in the legend). 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 2010 is only significant at the 6.5% level; this coincides with the highest index value seen so far.

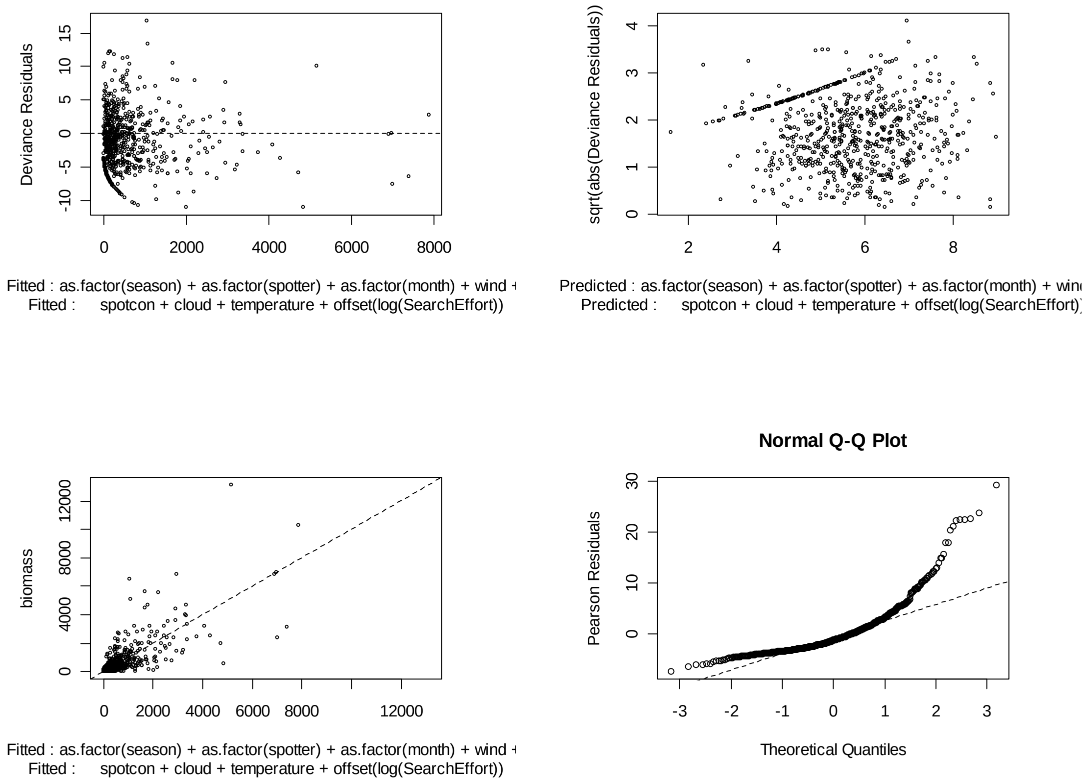



Figure 7. Diagnostics for Model 1 (see text above) with spotters 1, 2, 6.

<u>1. Taking targeting into account</u>

Direct comparison between models with targeting as a covariate and without is simpler when model 1 is run only on the data from seasons 2003 -2010 (since targeting was not recorded in 2002; see Appendix C). Diagnostics for a model which excludes non-SBT targeted effort are very similar to those for model 1 (Figure 8), estimated coefficients are very similar for those covariates or factors that appear in both models (see Appendix C). Only three of the categories in model Target 1 are significant: Mack, SBT/Mack and SKJ. For the 2-category group model the factor is significant. Both models with targeting have lower AIC values (Target 1: 7770.3; Target 2: 7774.4) than the comparable model without targeting (7785.9) - see Appendix C. The model with all categories, Target 1, has the lowest AIC value. The coefficients of the target factors in Appendix C are on the log scale and therefore a little hard to interpret. The exponential values of the coefficients are shown in Table 7. For example, model Target 2 estimates that sightings of SBT under flights targeted at the 'Other' category (SKJ, Mack, SKJ/Mack) is only about half (0.55) that of flights targeted at the SBT category (1.0). Under the Target 1 model, the lowest relative SBT sightings are on SKJ/Mack and Mack targeted flights. The standardisation essentially corrects for these differences.

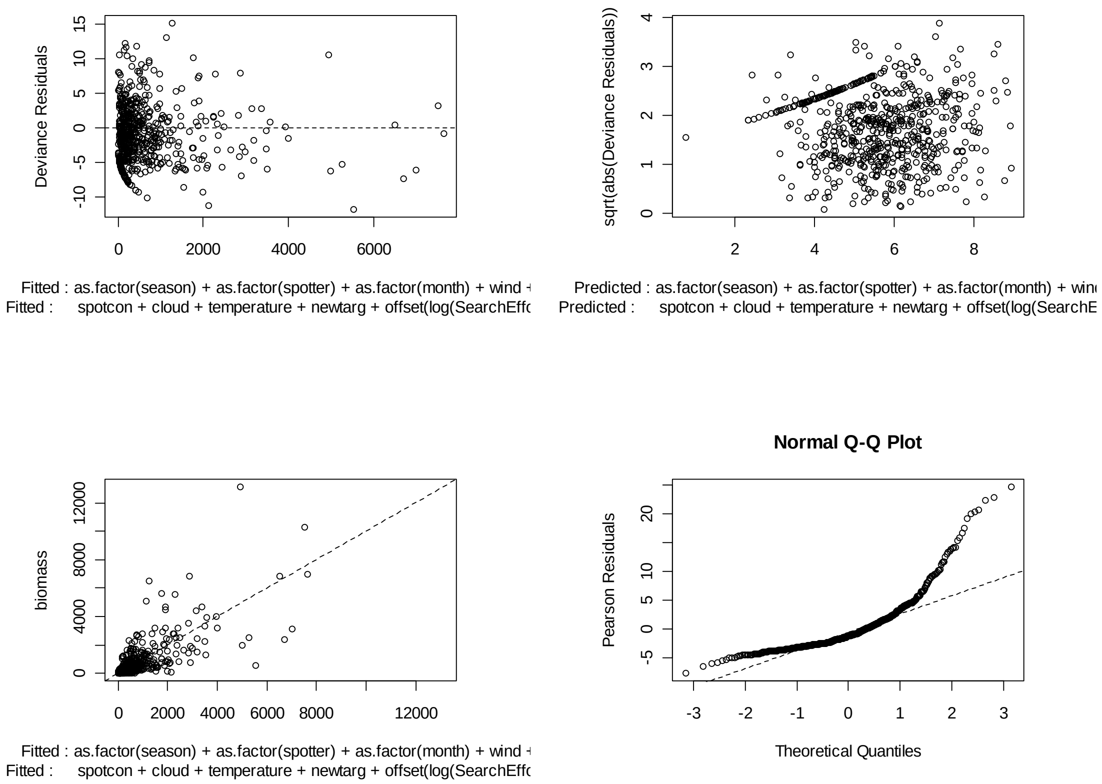



Figure 8. Diagnostics for model (see text above)

Table 7. Implications of estimated coefficients for the different targeting categories. For model Target 1, the effects are given relative to the 'SBT' category; for Target 2 it is relative to the 'SBT' group of categories (i.e. combined SBT, SBT/SKJ, SBT/Mack, SBT/SKJ/Mack). For example, under model Target 2, sightings of SBT under the 'Other' category (SKJ, Mack, SKJ/Mack) is only about half (0.55) that of the SBT category (1.0). Under the Target 1 model, the lowest relative SBT sightings are on SKJ/Mack and Mack targeted flights.

| Model: Target 1 | | Model: Target 2 | |
|---|---|---|---|
| Category | effect | Group | effect |
| SBT | 1 | SBT | 1 |
| Mack | 0.36 | Other | 0.55 |
| SBT/Mack | 0.55 | | |
| SBT/SKJ | 0.96 | | |
| SBT/SKJ/Mack | 0.67 | | |
| SKJ | 0.61 | | |
| SKJ/Mack | 0.17 | | |

The index for model 1 with and without the 2002 data is very similar, so when comparing the actual indices, the full time-series has been used. The resulting indices for the models with and without targeting are also very similar in terms of the patterns of trend over time (Figure 9).

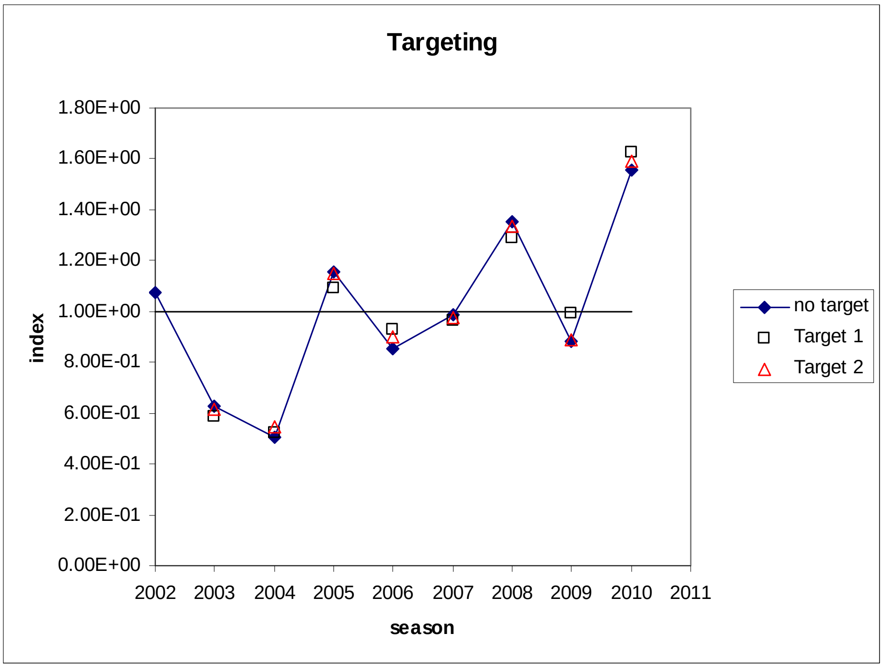



Figure 9. Standardised index for (a) model 1, indicated as 'no target' in the legend (all seasons), (b) model Target 1 with targeting as a covariate for all categories (excluding season 2002) and (c) model Target 2 with two targeting categories (see text; excluding season 2002). Each index is standardised to its mean.

It is important to interpret the target information with some care. The main difference between flights targeted at non-SBT species versus those targeted at SBT, appears to be the locations or areas searched and, presumably, what the spotters are looking for. The raw data on sighting rate (SBT biomass / Search effort) by target category, relative to the target category 'SBT' shows very little pattern (see e.g. Table 5.6 in Eveson et al. 2009). Targeting, particularly of Mackerel flights is also not evenly spread over time, but this may be an important factor to consider in the standardisation of the index.

<u>2. Excluding December and March data for all years</u>

This sensitivity trial was run on Model 1 and model Target 1. Most of the estimated coefficients are very similar between the two pairs of comparable models (Appendix C). There are some differences between the season-effects. The biggest difference between the indices for both Model 1 and Target 1 is in 2008 (Left panel, Figure 10 below), but the overall patterns over time are very similar. Since different datasets are used in the models with or without Dec and March, goodness of fit comparisons (e.g. via AIC) are invalid.

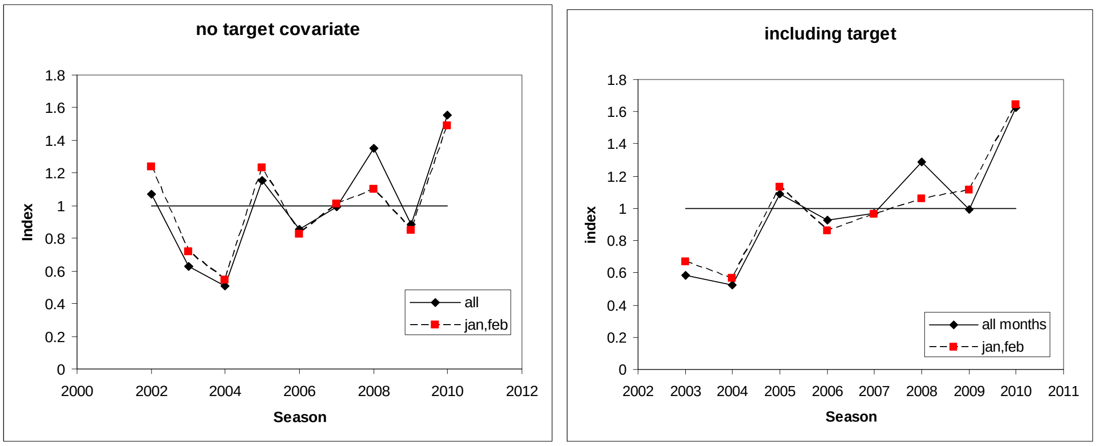



Figure 10. Comparisons between the standardised index for all months and for just January and February data. The left panel is for Model 1 which does not take targeting into account. The right panel is for the model Target 1 with all 7 target categories as covariate.

## 3. Other considerations

In the past, most recently in 2009, we explored the effect of using a different assumption about the mean-variance relationship through different values of the Tweedie parameter, Φ. Those results suggested a value of 1.5 is still appropriate. Given the consistency of this result, we have not revisited this in the most recent analyses, but should obviously be checked again in future as the time series is extended.

Comparisons between estimated standard errors from the GLM model and estimates from bootstrap analysis, as described in Basson and Farley (2005), were made in the past. These comparisons showed that the model estimates of standard deviations were no smaller than the bootstrap estimates (from 500 replicates). We have not redone this analysis here under the continued assumption that the standard errors from the model can be used to indicate the uncertainty in the index. This assumption should be rechecked in future. As in the past, we note that the standard errors describe only the uncertainty about the season level given the available data; there is an extra layer of [process] uncertainty, about how many SBT were in the GAB outside the area covered by the SAPUE, that the model cannot reveal.

## 4. Summary of results

Results of the standardised index for model 1 and Target 1 are shown in Figure 11. The ranges shown in Figure 11 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. Also note that the index for model 1 is scaled to the mean over 2002-2010; model Target 1 is scaled to the mean over 2003-2010. Results of the estimated index value and standard error are shown in tabular form in Table 8. Note that since the index for both models is scaled to their respective series mean, values for earlier years will change as new seasons' data are added to the analysis, even if the model does not change.

Given the small differences between the index based on Model 1 and Target 1 (particularly when the standard errors are taken into account), the fact that Model 1 results start in 2002 rather than 2003, and that this is the same model as used last year, we suggest that the index from Model 1 be used in the next data exchange for the SAPUE index. The issue of targeting should, however, be explored regularly since it can have an impact on the patterns over time.

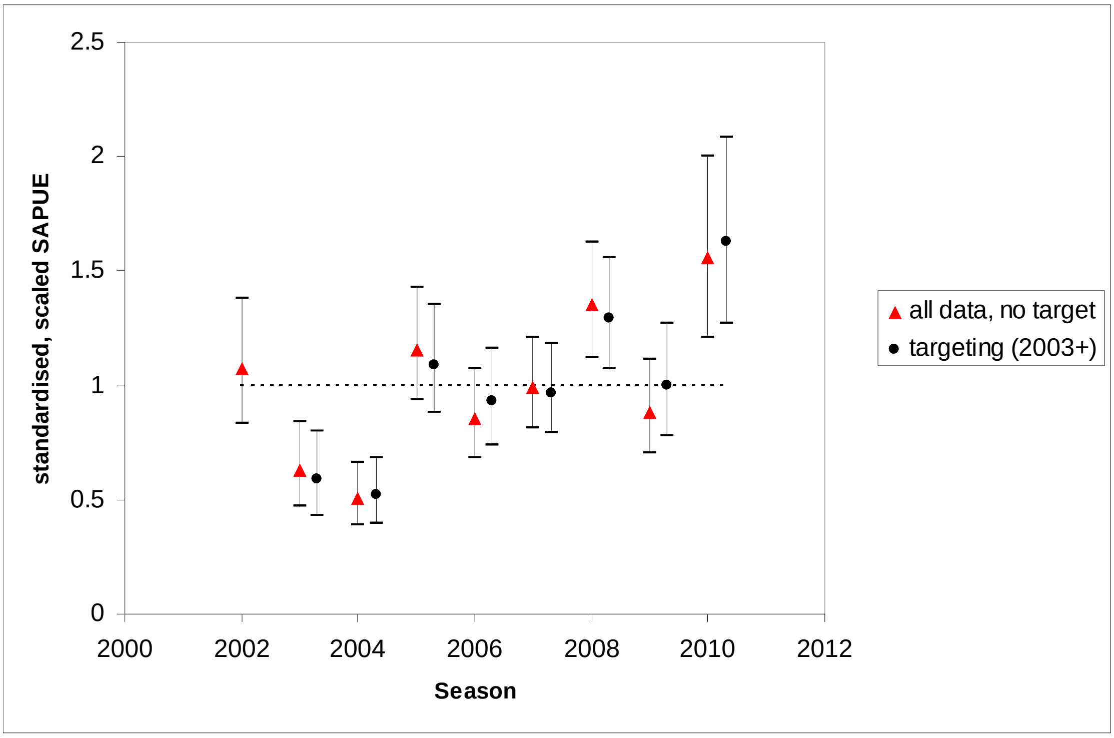



Figure 11. Estimates of standardised relative surface abundance, scaled to the mean over the relevant period, for model 1 (red triangles; all data, no target; scaled over 2002-2010) and Target 1 (black dots; targeting (2003+); scaled over 2003-2010). Both models used data from spotters 1,2 and 6 only, and data for all months (December – March). 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 8. Standardised SAPUE index of juvenile SBT in the GAB for model 1 and model Target 1. Both models use data from all months (December – March) and spotters 1,2,and 6 (see text for further detail). Season refers to the second year in a split year, i.e. 2002 = the 2001/2002 season. Targeting data were not collected in the 2002 season. The estimated values are also illustrated in Figure 11 above.

| Season | Model 1 | | Target 1 | |
|---|---|---|---|---|
| | Estimate | SE | Estimate | SE |
| 2002 | 1.07 | 0.14 | | |
| 2003 | 0.63 | 0.09 | 0.58 | 0.09 |
| 2004 | 0.51 | 0.07 | 0.52 | 0.07 |
| 2005 | 1.15 | 0.12 | 1.09 | 0.12 |
| 2006 | 0.86 | 0.10 | 0.93 | 0.10 |
| 2007 | 0.99 | 0.10 | 0.97 | 0.10 |
| 2008 | 1.35 | 0.13 | 1.29 | 0.12 |
| 2009 | 0.88 | 0.10 | 0.99 | 0.12 |
| 2010 | 1.55 | 0.20 | 1.63 | 0.20 |

## 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 continue to be spotter 1, 2 and 6. Extensive trials with different combinations of spotters included in analyses were conducted in the past (e.g. CCSBT-ESC/0809/25) and we have not reconsidered the choice of spotter given the unbalanced nature of the dataset for combinations other than spotter 1, 2, and 6. Past work also showed that the general temporal patterns, particularly in recent years, are not sensitive to the choice of spotters. We have, however, conducted 2 sets of sensitivity trials associated with targeting and choice of months to include in the analysis.

Most of the sensitivity trials made very little, if any, difference to the estimated index of abundance. Including targeting reduces the AIC. In the model with 7 targeting categories (Target 1) only two target categories are significant at the 1% level; one at the 5% level. In the more parsimonious model which has two groups of categories ('SBT' and 'Other'=non-SBT) the term is highly significant (0.15%). A summary of the frequency of different targeting categories by season (Table 6) shows that there were some changes in 2009 and 2010; for example, a larger number of flights targeting Mackerel (or Mackerel with skipjack/SBT) than in previous years. As noted in the past, such changes can complicate standardisation and even the recorded 'target' information may not fully capture changes in spotting activity between seasons. We suggest that this information continue to be recorded, so that the sensitivity of results to this covariate can continue to be considered.

Indices based only on data from January and February are very similar to those based on December through March, with the exception of 2008 when the standardised index is markedly lower (when based only on January and February). There is currently no strong reason for excluding December or March, though this issue needs to be checked annually. 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). Estimated coefficients are very consistent between the different models considered here; this has also been the case in past analyses.

The standardised SAPUE index for 2010 is the highest seen so far – at a level of about one and a half times the mean – and is consistent with Industry's impressions of the "quality" of the 2010 fishing season. The index is still lowest in 2003 and 2004 (only about half the mean level), and close to average in 2009 (Figure 11). The index reflects the abundance of 2, 3 and 4 year olds combined. The two low years would therefore represent 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). We reiterate the caveat that it is well-known that not all juveniles spend their summers in the GAB. Unfortunately, there is not yet any direct information about the proportion of the total juvenile population in the GAB each year. This is not a major problem if the proportion has remained approximately constant over time. If, however, there have been substantial changes in the proportion (e.g. through changes in movement dynamics) then it becomes more difficult to know how to interpret this index.

## *Acknowledgements*

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.

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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 and sensitivity trials.**

Estimates of coefficients, standard errors and related 'significance' quantities for model 1 and sensitivity trials.

**Model 1: basic model with no targeting.**

```
summary(wd10mod1)
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 = tempdat)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-11.102   -4.441   -1.279    1.328   16.805

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)            0.268701   0.349735   0.768  0.44258
as.factor(season)2003 -0.534068   0.206027  -2.592  0.00975 **
as.factor(season)2004 -0.747845   0.189781  -3.941 8.99e-05 ***
as.factor(season)2005  0.073676   0.175098   0.421  0.67406
as.factor(season)2006 -0.225516   0.177818  -1.268  0.20516
as.factor(season)2007 -0.080362   0.168251  -0.478  0.63307
as.factor(season)2008  0.231138   0.168068   1.375  0.16951
as.factor(season)2009 -0.194921   0.181156  -1.076  0.28232
as.factor(season)2010  0.370938   0.200906   1.846  0.06529 .
```

```
as.factor(spotter)2   -1.678779   0.141265 -11.884  < 2e-16 ***
as.factor(spotter)6   -0.679236   0.093732  -7.247 1.19e-12 ***
as.factor(month)2     -0.234927   0.104199  -2.255  0.02448 *
as.factor(month)3     -0.795819   0.117733  -6.760 3.03e-11 ***
as.factor(month)12     0.294582   0.116954   2.519  0.01201 *
wind                  -0.102906   0.017028  -6.043 2.52e-09 ***
spotcon                0.381081   0.070508   5.405 9.06e-08 ***
cloud                 -0.037929   0.017454  -2.173  0.03012 *
temperature            0.027431   0.006542   4.193 3.13e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Tweedie family taken to be 21.52439)

    Null deviance: 30639  on 681  degrees of freedom
Residual deviance: 13288  on 664  degrees of freedom
AIC: 8613.2

Number of Fisher Scoring iterations: 6
```

### Targeting 1: all data, including 'target' as a covariate using all categories. Coefficients are relative to target category 'SBT'

(Note: 2002 is excluded because target information was not recorded)

```
sapu> summary(ttry)

Call:
glm(formula = biomass ~ as.factor(season) + as.factor(spotter) +
    as.factor(month) + wind + spotcon + cloud + temperature +
    newtarg + offset(log(SearchEffort)), family = mvb.tweedie(1.5,
    0), data = tempdat10)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-11.870   -4.493   -1.428    1.333   15.084

Coefficients:
                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                   -0.334335   0.414363  -0.807  0.42007
as.factor(season)2004         -0.114525   0.212101  -0.540  0.58943
as.factor(season)2005          0.623213   0.194339   3.207  0.00141 **
as.factor(season)2006          0.461781   0.200760   2.300  0.02178 *
as.factor(season)2007          0.503703   0.195026   2.583  0.01004 *
as.factor(season)2008          0.792818   0.187392   4.231 2.69e-05 ***
as.factor(season)2009          0.531822   0.205323   2.590  0.00983 **
as.factor(season)2010          1.025205   0.221107   4.637 4.35e-06 ***
as.factor(spotter)2           -1.780068   0.146840 -12.122  < 2e-16 ***
as.factor(spotter)6           -0.593486   0.105446  -5.628 2.80e-08 ***
as.factor(month)2             -0.300567   0.109240  -2.751  0.00611 **
as.factor(month)3             -0.774591   0.122245  -6.336 4.64e-10 ***
as.factor(month)12             0.186248   0.127469   1.461  0.14451
wind                          -0.105809   0.017586  -6.017 3.11e-09 ***
spotcon                        0.389353   0.072674   5.358 1.21e-07 ***
cloud                         -0.033187   0.018270  -1.816  0.06980 .
temperature                    0.029807   0.006712   4.441 1.07e-05 ***
Mack                          -1.026158   0.397259  -2.583  0.01003 *
SBT/Mack                      -0.604982   0.225334  -2.685  0.00746 **
SBT/SKJ                       -0.037062   0.169220  -0.219  0.82671
```

```
SBT/SKJ/Mack              -0.397183   0.264125  -1.504  0.13317
SKJ                       -0.491455   0.214093  -2.296  0.02205 *
SKJ/Mack                  -1.761361   1.188734  -1.482  0.13894
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Tweedie family taken to be 20.90025)

    Null deviance: 28748  on 619  degrees of freedom
Residual deviance: 11681  on 597  degrees of freedom
AIC: 7770.3

Number of Fisher Scoring iterations: 6
```

**Targeting 2: Parsimonious version with 2 categories ‘SBT’ = (SBT, SBT/SKJ, SBT/Mack, SBT/SKJ/Mack) and ‘OTH’= (SKJ, Mack, SKJ/Mack); excluding data for the 2002 season.**

```
sapu> summary(wd10mod1.t2)

Call:
glm(formula = biomass ~ as.factor(season) + as.factor(spotter) +
    as.factor(month) + wind + spotcon + cloud + temperature +
    as.factor(sumtarg) + offset(log(SearchEffort)), family =
mvb.tweedie(1.5,
    0), data = workdat10, subset = (sumtarg != "NA          "))

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-11.394   -4.523   -1.429    1.265   16.256

Coefficients:
                          Estimate Std. Error t value Pr(>|t|)
(Intercept)               -0.92016    0.44221  -2.081 0.037873 *
as.factor(season)2004     -0.11816    0.20217  -0.584 0.559146
as.factor(season)2005      0.62682    0.18771   3.339 0.000892 ***
as.factor(season)2006      0.38010    0.18979   2.003 0.045655 *
as.factor(season)2007      0.46484    0.18133   2.563 0.010605 *
as.factor(season)2008      0.77723    0.17492   4.443 1.05e-05 ***
as.factor(season)2009      0.36597    0.19084   1.918 0.055629 .
as.factor(season)2010      0.95001    0.20791   4.569 5.94e-06 ***
as.factor(spotter)2       -1.76448    0.14693 -12.009  < 2e-16 ***
as.factor(spotter)6       -0.67179    0.09783  -6.867 1.64e-11 ***
as.factor(month)2         -0.26301    0.10869  -2.420 0.015828 *
as.factor(month)3             -0.75937    0.12161  -6.244 8.04e-10 ***
as.factor(month)12             0.26018    0.12545   2.074 0.038504 *
wind                          -0.10460    0.01763  -5.933 5.03e-09 ***
spotcon                        0.39342    0.07325   5.371 1.12e-07 ***
cloud                         -0.03058    0.01838  -1.664 0.096629 .
temperature                    0.02836    0.00669   4.240 2.59e-05 ***
as.factor(sumtarg)SBT          0.59465    0.18638   3.191 0.001494 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Tweedie family taken to be 21.23264)

    Null deviance: 28748  on 619  degrees of freedom
Residual deviance: 11901  on 602  degrees of freedom
AIC: 7774.4
```

```
Number of Fisher Scoring iterations: 6
```

Model **without targeting** for direct comparison with Target 1 and Target 2 (above). This is also needed for model selection purposes because 2002 data need to be excluded since targeting was not recorded for that season.

```
WITHOUT targeting
sapu> summary(ttry0)

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 = tempdat10)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-11.181   -4.454   -1.350    1.292   16.388

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)           -0.339205   0.406695  -0.834  0.40458
as.factor(season)2004 -0.191811   0.202835  -0.946  0.34471
as.factor(season)2005  0.617736   0.188444   3.278  0.00111 **
as.factor(season)2006  0.321309   0.190017   1.691  0.09136 .
as.factor(season)2007  0.463399   0.182051   2.545  0.01116 *
as.factor(season)2008  0.771335   0.175636   4.392 1.33e-05 ***
as.factor(season)2009  0.354282   0.191503   1.850  0.06480 .
as.factor(season)2010  0.928604   0.207717   4.471 9.32e-06 ***
as.factor(spotter)2   -1.719777   0.146921 -11.705  < 2e-16 ***
as.factor(spotter)6   -0.647542   0.098053  -6.604 8.79e-11 ***
as.factor(month)2     -0.238756   0.108994  -2.191  0.02887 *
as.factor(month)3     -0.781147   0.122064  -6.399 3.13e-10 ***
as.factor(month)12     0.297308   0.125545   2.368  0.01819 *
wind                  -0.106550   0.017683  -6.026 2.93e-09 ***
spotcon                0.394519   0.073482   5.369 1.13e-07 ***
cloud                 -0.034917   0.018489  -1.888  0.05944 .
temperature            0.028436   0.006728   4.226 2.74e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Tweedie family taken to be 21.44254)

    Null deviance: 28748  on 619  degrees of freedom
Residual deviance: 12112  on 603  degrees of freedom
AIC: 7785.9
Number of Fisher Scoring iterations: 6
```

### Using only months 1 and 2 (January & February)

```
Model 1 variation with only Jan, Feb
sapu> summary(wd10mod1.jf)

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 = workdat10, subset = (month != 12 & month != 3))

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-10.938   -4.505   -1.272    1.400   15.988

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)            0.125147   0.451325   0.277  0.78170
as.factor(season)2003 -0.541900   0.262101  -2.068  0.03930 *
as.factor(season)2004 -0.821952   0.248086  -3.313  0.00100 **
as.factor(season)2005 -0.002612   0.226080  -0.012  0.99079
as.factor(season)2006 -0.406747   0.246858  -1.648  0.10017
as.factor(season)2007 -0.200741   0.224609  -0.894  0.37198
as.factor(season)2008 -0.116368   0.235973  -0.493  0.62217
as.factor(season)2009 -0.375585   0.242992  -1.546  0.12294
as.factor(season)2010  0.186340   0.244756   0.761  0.44689
as.factor(spotter)2   -1.664922   0.147503 -11.287  < 2e-16 ***
as.factor(spotter)6   -0.543359   0.115252  -4.715 3.30e-06 ***
as.factor(month)2     -0.248463   0.103976  -2.390  0.01731 *
wind                  -0.084019   0.020385  -4.122 4.54e-05 ***
spotcon                0.398787   0.087829   4.541 7.35e-06 ***
cloud                 -0.050938   0.021795  -2.337  0.01990 *
temperature            0.031883   0.008078   3.947 9.28e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Tweedie family taken to be 20.90436)

    Null deviance: 17541  on 434  degrees of freedom
Residual deviance:  8447  on 419  degrees of freedom
AIC: 5429.4

Number of Fisher Scoring iterations: 6
```

<u>Target 1 model variation with only Jan, Feb</u>

```
sapu> summary(ttry.jf)

Call:
glm(formula = biomass ~ as.factor(season) + as.factor(spotter) +
    as.factor(month) + wind + spotcon + cloud + temperature +
    newtarg + offset(log(SearchEffort)), family = mvb.tweedie(1.5,
    0), data = tempdat10, subset = (month != 12 & month != 3))

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-11.963   -4.396   -1.433    1.404   13.931

Coefficients:
                            Estimate Std. Error t value Pr(>|t|)
(Intercept)               -0.586234   0.534520  -1.097 0.273444
as.factor(season)2004     -0.162523   0.268574  -0.605 0.545451
as.factor(season)2005      0.528818   0.237733   2.224 0.026705 *
as.factor(season)2006      0.252876   0.253265   0.998 0.318688
as.factor(season)2007      0.366559   0.243218   1.507 0.132608
as.factor(season)2008       0.461018   0.253524   1.818 0.069782 .
as.factor(season)2009       0.513260   0.265802   1.931 0.054226 .
as.factor(season)2010       0.901755   0.263312   3.425 0.000683 ***
as.factor(spotter)2        -1.767985   0.155355 -11.380  < 2e-16 ***
as.factor(spotter)6        -0.392549   0.132039  -2.973 0.003137 **
as.factor(month)2          -0.328852   0.110361  -2.980 0.003069 **
```

```
wind                          -0.082949   0.021382  -3.879 0.000123 ***
spotcon                        0.438173   0.089721   4.884 1.53e-06 ***
cloud                         -0.042730   0.022786  -1.875 0.061524 .
temperature                    0.032782   0.008343   3.929 0.000101 ***
Mack                          -1.995865   0.522128  -3.823 0.000154 ***
SBT/Mack                      -0.744334   0.273642  -2.720 0.006825 **
SBT/SKJ                       -0.072526   0.208434  -0.348 0.728066
SBT/SKJ/Mack                  -0.453130   0.294300  -1.540 0.124467
SKJ                           -0.518061   0.282198  -1.836 0.067165 .
SKJ/Mack                      -1.857423   1.180976  -1.573 0.116598
---Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Tweedie family taken to be 20.29884)

    Null deviance: 16863  on 401  degrees of freedom
Residual deviance:  7353  on 381  degrees of freedom
AIC: 4977.4

Number of Fisher Scoring iterations: 6
```