CCSBT-CPUE/0705/BGD03

CSIRO
MARINE RESEARCH

CCSBT-SC/0209/info12

Commercial Aerial Spotting for Southern Bluefin Tuna in the Great Australian Bight by Fishing Season 1982-2000

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April 2002

REPORT R99/1498

CCSBT-SC/0209/Info12

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1 SUMMARY

Since the early 1980s, some commercial aerial tuna spotters supporting surface fishing operations for southern bluefin tuna (SBT) in the Great Australian Bight (GAB) have voluntarily used a commercial spotting log sheet that was developed for recording flight paths and information on schools of SBT detected. Few analyses of the recorded data have been conducted. Little was known about the extent of the available data or the extent and consistencies of the data recording. A pilot study was conducted to evaluate the potential use of these data as an index of abundance. Since no computerized form of the data existed, the primary focus of the study was the computerisation of the data and development of an appropriate database, as this was a prerequisite for their statistical evaluation. The project had four main objectives:

- To create a commercial spotting database that includes all available data
- To evaluate whether the commercial spotting data can provide a useful index of surface abundance
- To calculate a preliminary time series of indices from the available data
- To evaluate these preliminary indices and compare with the aerial survey results

All data that were made available to CSIRO were computerized. The information from the spotting log sheets was entered into an MS Access database. The routes flown were digitised and entered into a Geographic Information System (GIS).

The flight track and spotting data were used to calculate a number of indices of abundance for fishing seasons between 1982 and 2000. Unfortunately and in spite of extensive efforts to obtain historical log sheets, large gaps existed in the time series of data that were made available. There were no data for the 1983, 1986-89 and 1992-98 fishing seasons. Also, the areas and time periods flown show little overlap with the scientific, transect-based aerial surveys conducted since 1991. This prevented any meaningful direct comparison with indices from these aerial surveys. In addition, in constructing the indices of abundance from these commercial data, it was necessary to discard a large percentage of the flights (47%) either because inadequate details were provided or large inconsistencies were evident between the distances flown and flight times recorded.

There are significant technical challenges and difficulties in interpreting commercial spotting data because of the concentrated searching patterns characteristic of commercial spotting, temporal shifts in where searching occurred, and the nature of the data recorded. Many of the problems are analogous to the interpretation of commercial CPUE data compounded by the large variation in the aerial estimation of biomass. The problems and danger of relying on such data as indices of abundance are well known. A further complication in the interpretation of the commercial spotting data is a lack of ability to reliably estimate the size or age distribution of the fish spotted. As such the data cannot be used to provide abundance indices for specific cohorts.

Given the challenges of using data that were not collected to provide a representative sample (e.g. random or uniform coverage of the GAB) and which contained large un-sampled areas and time periods, we calculated several alternative relative abundance indices in which the data are aggregated and weighted differently. The various indices yield different trends. For example, an index weighted according to distance flown showed an increasing trend, while an index weighted according to area searched appeared more flat and variable. Different results were also achieved depending on whether the index used all flight distances or just distances where the flight path indicated searching was occurring. Most indices showed biomass per distance flown

as higher in the most recent two years in comparison to the earlier seasons. However, an index that attempted to determine trends for the area where flights and the purse seining for farming operations fishing have been concentrated in recent years, indicated that the 1999 value was considerably lower than 2000, but comparable to the mid-1980s and early 1990s. All indices consistently place the value from the 2000 season at a high level in relation to other seasons. The 95% confidence interval for the 2000 biomass per distance flown value is also usually large, showing that the estimate is imprecise. There is not a consistent trend shown for the 1982 to 1999 seasons across indices.

In summary:

1. The historical commercial spotting data are not likely to yield an age or size-specific index of abundance;

2. The imprecision found within all the calculated indices means that the available historical commercial data have a low ability to detect changes from season to season; while substantially different trends are seen in different indices.

3. The interpretation of abundance indices based solely on commercial spotting data will likely be highly confounded by the concentrated nature of the searching effort compounded by problems associated with the aerial estimation of biomass.

2 INTRODUCTION

A major difficulty in the stock assessment of southern bluefin tuna (SBT) is the lack of a reliable index of recruitment for the stock. Juvenile SBT are known to assemble in the Great Australian Bight (GAB) during the summer months and form surface aggregations. This area has been a focus for commercial SBT fishing in Australia since the 1970s and currently over 95% of Australian SBT catches are taken from the GAB by purse seiners for farming operations. Since the early 1980s, the commercial fisheries for SBT in the GAB have used airplanes to locate tuna schools. Based on the fact that surface schools of SBT are detectable at times by aircraft, the use of aerial spotting within the GAB has been suggested as a possible approach for developing a recruitment index for SBT. The underlying concept in such an approach is that the rate of detection of SBT per unit of search effort should provide a measure of the relative density of juvenile SBT.

In the early 1980s, a commercial spotting log sheet was developed for recording flight paths and information on schools of SBT detected. Some pilots have used these log sheets to keep records of their commercial spotting activities for SBT in the GAB. Use of these log books was voluntary and the use of them varied over time and among different pilots. Few analyses of these data have been conducted in the past. Given that some data from commercial spotting operations has been collected over a ~20 period, the Australian SBT commercial fishermen suggested that these data might provide a source of information for a relative abundance index for juvenile SBT. However, little was known about the extent of the available data and there was no information on the extent and consistencies to which the various data items had been recorded. In addition, the data from the log sheets had not been computerized. As such, it was not possible to efficiently analyse the existing commercial spotting data or determine the potential information content of these data. In order to undertake an evaluation of the potential use of these data, a pilot study was initiated. The primary focus of the pilot study was the computerisation of the data and development of an appropriate database, as this was a prerequisite for being able to complete any statistical evaluation. In addition, the pilot study sought to undertake some preliminary analyses of the data once a database had been constructed.

It should be noted that beginning in 1989, a large amount of effort has been devoted to developing a fishery independent index of recruitment based on aerial spotting surveys of the GAB. Large-scale surveys based on a consistent survey design and sighting protocols were conducted between 1991-1999 (see Cowling, 2000; Cowling and O'Reilly, 1999; Chen and Polacheck, 1993). After 1993, these aerial surveys were incorporated within the collaborative CSIRO/NRIFSF Recruitment Monitoring Program (Davis, 1999). Among the results, the analyses of the fishery independent aerial surveys found that the distribution of surface schools was highly clustered, that detection probabilities and/or surfacing behaviour varied substantially depending upon environmental conditions, that consistent but considerable differences existed in the estimates of biomass of detected schools among professional spotters and that estimates of fish size appear unreliable in terms of being able to estimate the age of the fish in a school from aerial observations (see Cowling and Millar, 1998). All of these factors indicate that obtaining precise and quantitatively robust abundance indices from aerial spotting data may be problematical. In undertaking this pilot study, it was recognised that these results and problems from the fishery independent aerial surveys would also be encountered in the collection and analyses of commercial aerial spotting information. The primary scientific advantage of commercial spotting data relative to the aerial survey is the longer time series of data and the greater temporal coverage within a season. In addition, the availability and continuity of trained spotters as well as suitable aircraft for conducting the aerial survey has become problematical with the development of commercial farming operations. As such, there may be no alternative to the use of commercial spotting data for producing a future index of SBT in the Great Australian Bight based on aerial spotting.

The main objectives of the project were:

- To create a commercial spotting database that includes all available data
- To evaluate whether the commercial spotting data can provide a useful index of surface abundance
- To calculate a preliminary time series of indices from the available data
- To evaluate these preliminary indices and compare with the aerial survey results

3 DATA SOURCE

Efforts to locate and obtain data from past commercial spotting operations included directly contacting commercial spotters, searching CSIRO and BRS paper files, and inquiries by the head of the Australian Tuna Boat Owners Association. Only data covering the 1982, 1984, 1985, 1990, 1991, 1999 and 2000 fishing seasons in South Australia were locate and made available to this project (Note that a season normally starts in October and finishes the following March - e.g. October 1999 to March 2000 would be called the 2000 season). The data that were located had been recorded on aerial spotting log sheets developed in the early 1980s (Appendix C). These data provide information on flights, environmental conditions and sightings.

Commercial spotting is carried out in small aircraft, usually by an experienced spotter with the assistance of the pilot. A “sighting” of fish is the location of fish visible near the surface of the water. A number of separate “patches” of fish may be present at one sighting. The term “patch” is used by spotters to describe visible separate areas of fish that may be separate schools (patches close together in some cases are potentially continuous beneath the surface). The definition of a what constitutes a separate sighting as well as a “patch” may vary among spotters. The number of patches and the average estimated size in tonnes of the patches is recorded. The objective of commercial spotting is to locate fishable patches of southern bluefin tuna (SBT). Other species may also be present or even mixed with the SBT. Sightings are recorded by filling in commercial spotting log sheets that also allow for the recording of other information such as environmental conditions (see Appendix C). A spotting trip is usually between 4 and 10 hours long, and one spotting trip is normally carried out per aircraft flying day. On completion of the trip, a diagram of the line followed by the aircraft was drawn by hand and kept with the sighting logs. The diagrams are only an estimated schematic representation of the actual flight path. In particular areas in which the plane did intensive searching, there is likely to be an under-representation of the actual flight path (see below).

As part of this project, the information on the spotting log sheets were entered into an MS Access database and the routes flown digitised and geo-referenced for use in a Geographic Information System (GIS).

Participation in the data collection scheme was voluntary and the degree of participation has varied greatly over time. We do not know what fraction of commercial aircraft and pilot-spotter combinations that flew in a year is covered by available flight data – although in most cases it is clear that the coverage is relatively small. We also do not know whether spotters submitted data every flying day, or only on selected days. There are likely to be selection biases in the data set - i.e. the days for which log sheets were completed may not constitute a representative sample of either the pilots and spotters that were flying, or the days on which an individual pilot and spotter flew. However, these are unknown and cannot be assessed.

4 RESULTS

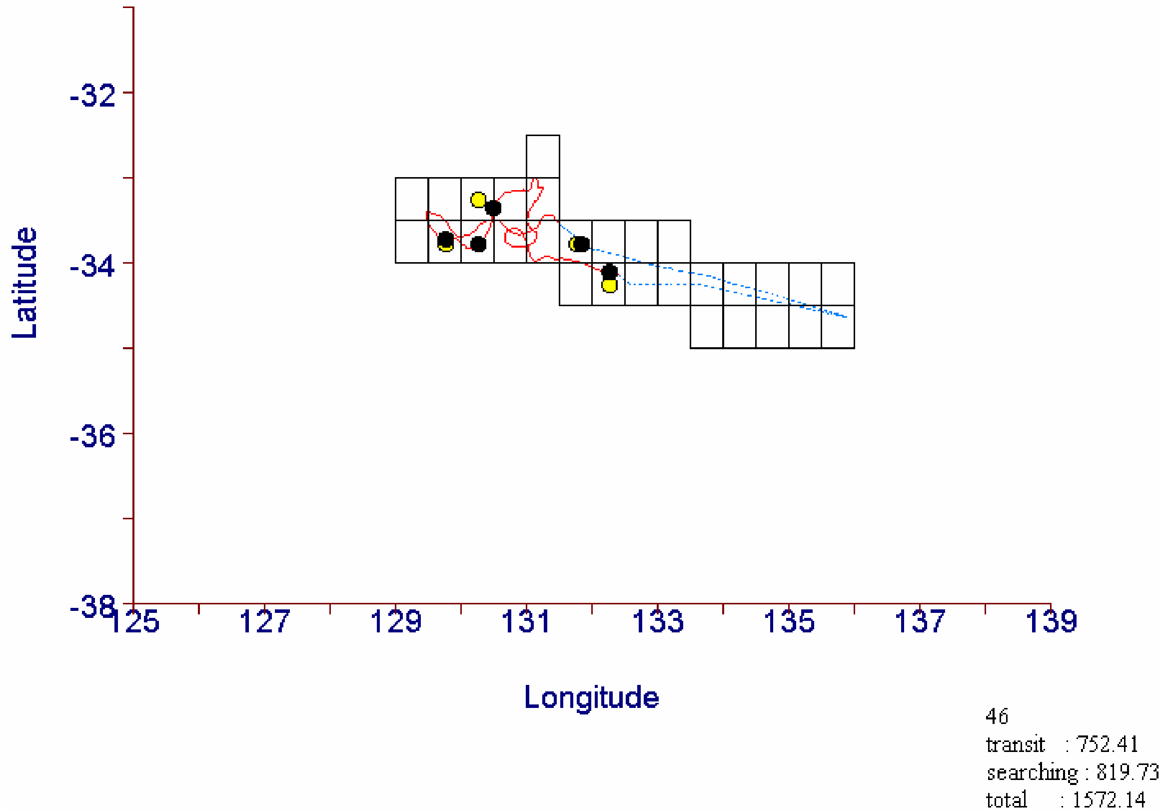
4.1 Determination of flight searching and transit sectors

Flying to and from the search area is termed the transit sectors of a flight, and actual searching is termed the search sector. Each flight is therefore made up of an initial transit sector, a search sector, then another transit sector. There may be transit sectors within the search sector but there is no way to determine if and where these occurred. To automate the decision for which parts of the flight was deemed to be transit and which was searching, it was assumed that a flight would normally be composed of a straight flight from the airport to the search area, searching characterised by periods of circling, and then a straight flight back to the airport. The circling could be found by finding points where the flight track deviated by more than a certain number of degrees from the straight transit sectors. After testing a number of values, 30 degrees was chosen as a value that appeared to work for most flights. In a small number of flights there was a short deviation of more than 30 degrees close to the home port, and several flights appear to have returned to the home port and left again within the same flight. It is difficult to decide how these anomalies might be corrected, so no changes were made in these cases.

A computer program was created that takes the digital flight path and sightings records as input. Parts of the flight path were then classified as transit or searching according to the method described above. Sightings were often recorded to the nearest 0.5 degree, so that scale was chosen as the finest level to break down flight searching effort. However, searching effort was generally neither uniform or random within a 0.5 degree square (e.g. Figure 1). The position of any sightings was moved to the closest vertex on the flight path using great circle distance as the distance measure. The measured distance searching and in transit along the digital flight path within 0.5 degree squares, as well as the new locations for sightings within 0.5 degree squares was output by the program. This method ensures that any sightings within a 0.5 degree square have at least some distance flown within that same square.

Processing each flight in this way allowed a database to be constructed that contained distance searched, distance flown in transit and SBT biomass sighted per 0.5 degree square for each flight. The biomass was calculated by multiplying the number of patches of fish seen in one sighting by the recorded average size of the patches in tonnes of fish. Only SBT sightings were examined, and all fish sizes were included (fish size was not analysed).

Figure 1. A typical flight path with associated sightings shown as filled circles (moved from the open circle positions), transit sectors shown as dotted and searching as a solid line.



Additionally, there are a number of rises or 'lumps' in the GAB that fish are known to aggregate around at times. Flights that pass over the areas of these lumps are often also searching, even though they might still be flying a straight path. To account for these areas, searching was deemed to always have occurred for sections of flights that passed through 0.5 degree squares around these lumps as marked in Figure 2. Also, squares near and over the shelf edge are probably always being searched, and these were also deemed to contain searching only. The full set of 0.5 degree squares within which searching was always assumed to occur is shown in Figure 3.

Figure 2. Position of lumps in the GAB and the areas around them where searching was considered to have occurred.

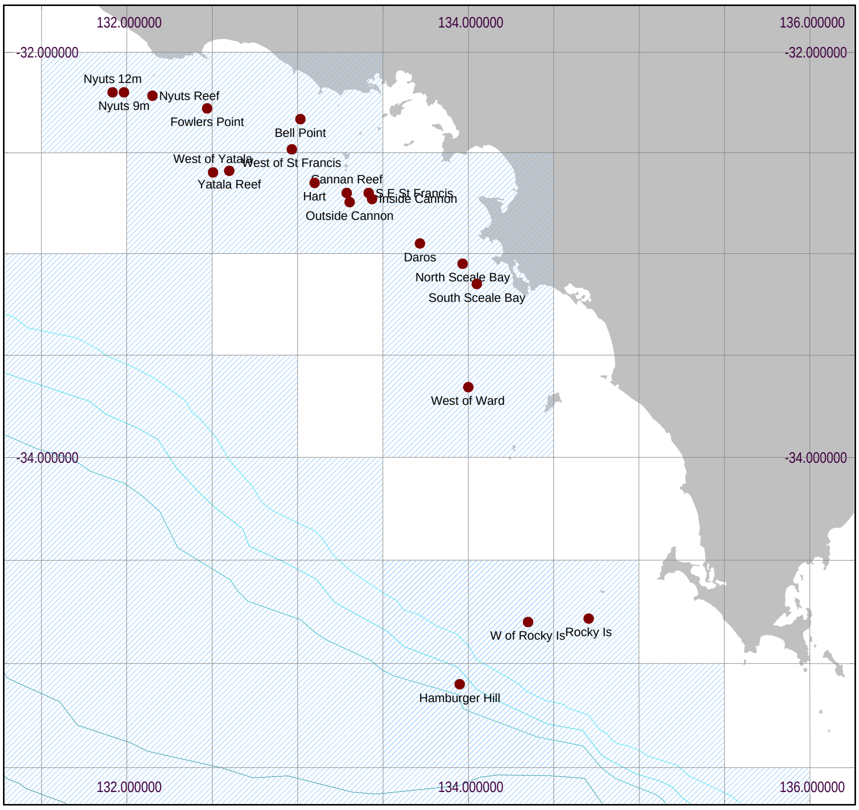


Figure 3. Half degree squares which were always assumed to only contain searching.

A flight departure and return time was recorded for more than half of the flights. Having flight times allows estimation of how many hours each flight took, and given an average flight speed, what distance may have been flown in that time. Average transit speed for Aero Commander aircraft is approximately 160 knots, and Cessna 337 is 150 knots (D. Hayman pers. comm.).

While searching, the average speed is between 120 and 130 knots for the Aero Commander and 100-120 knots for Cessna 337 aircraft (D. Hayman pers. comm.). The average speed within a flight accounting for both transit and searching was assumed to be 130 knots for the Aero Commander and 120 knots for the Cessna 337 (assuming a greater proportion of the time will be searching). The call signs and aircraft types used to collect the available commercial spotting data are given in Table 1. It is not known how searching speed affects efficiency of sighting in tuna spotting. However, it would be expected that sighting efficiency per nautical mile would increase at slower speeds, as has often been found in other line transect search situations. Also, visibility and searching conditions are quite different between a Cessna 337 and an Aero Commander (e.g. a Cessna 337 has a single propeller in front of the cockpit and one behind, while the Aero Commander's twin propeller are located on the wings).

Table 1. Aircraft call signs, type and the number of spotting trips flown.

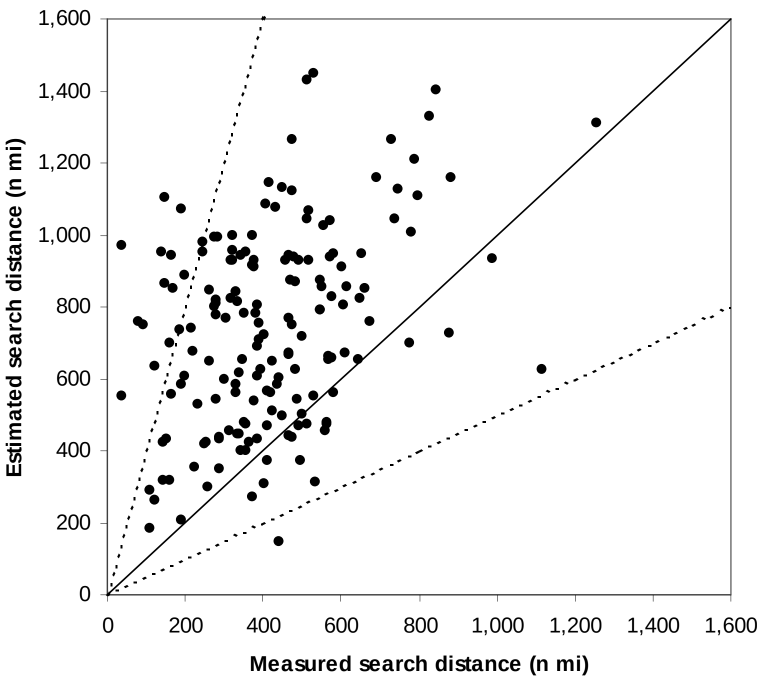
Aircraft	Type	Flights
CHU	Cessna 337	19
EYE	Aero Commander	4
FGS	Aero Commander	36
IBV	Aero Commander	34
JOE	Cessna 337	12
LTP	Aero Commander	111
PLY	Cessna 337	46
TSS	Aero Commander	43

It was assumed that the digital flight path of the transit sectors of each flight would be more accurately represented than the search sector, as this is more likely to be straight rather than turning flight. Any large difference between the estimated distance flown according to the flight time and the distance flown indicated by the digital flight path would most likely be in mis-recording of the flight time, or mis-representation of the true path flown while searching. In two extreme cases (flights 101 and 330), the estimated distance flown was less that the transit distance flown, so the time flown was deemed to be unreliable for these flights.

The recorded flight time can be used as an accuracy indicator for the distance flown according to the flight path. Combined use of both pieces of information can be used to filter out flights where there is too much disparity between the two. For each flight with a valid flight time, the distance of the transit sectors was subtracted from the estimated distance flown assuming the average flight speed of the aircraft. This leaves an estimate of the distance flown during searching (d_e). The measured distance flown during searching (d_m) is also available. The ratio of d_e/d_m can be used as an indicator of the amount of agreement between the two search distance estimates.

The following graph shows the relationship between these two search distance estimates. A ratio in the range of 0.5 to 4.0 was deemed to be acceptable.

Figure 4. Measured distance searched versus estimated distance searched according to the duration of the flight and the average aircraft speed. A ratio of these two measures between the values of 0.5 and 4.0 were deemed acceptable and are indicated by the dashed lines.



Most often, the estimated distance exceeds the measured distance along the flight path.

4.2 Determination of valid sightings

For each sighting of fish, the spotter normally records the position of the sighting, the species, the number of patches, the average patch size, and the average size of fish within patches. For this initial examination we will not look at fish of different average size separately, and do not therefore require complete information on fish size. This was done because independent plane experiments conducted as part of the scientific aerial survey program indicated a lack of consistency among different spotters in their ability to reliably estimate fish sizes from the air (Cowling and O'Reilly 1999). Of 2,166 sightings recorded, 1,938 were identified as SBT. Only one record did not identify the species, and 16 had a species code of 'MIX' referring to mixed species. Only records that specifically identified SBT were used further. Of the sightings of SBT, 1,874 (97%) had complete information on the number of patches seen and the average patch size. A simple estimate of the biomass of SBT observed at one sighting is the number of patches multiplied by the average patch size. As the number of sightings with incomplete information was small, it was considered reasonable to discard flights that did not have complete information for all SBT sightings. Flights that were incomplete in this way were 44, 70, 187, 219, 220*, 221*, 225*, 226*, 240*, 243, 245, 252, 256, 263, 264*, 266, 306, 312*, 315*, 319, 337, 365 and 376* (records marked with * do not have a corresponding flight track recorded).

We will assume for this examination that the flight path more accurately records the positions of sightings than the individual sighting records. For many sightings, the position was recorded to the nearest half degree square. In many cases, the square listed did not have any corresponding flying within it. In almost all cases however, a flight track was within a degree of the recorded sighting. To allow precise matching of searching effort and sightings, the sighting positions were re-calibrated to the nearest vertex on the flight path of the flight that was recorded to have made the sighting. Flight 134 recorded a number of sightings that were all consistently a large distance from the flight path. As there was no means to match the recordings for this flight with any confidence, this flight was also discarded from any further calculations. Of the 1,874 valid SBT sighting records, 1,422 were matched with a recorded flight path. Sightings for flights without flight path records were discarded.

There were three instances of duplicate flight identification numbers for different flights in the GIS track file – track IDs 50, 72 and 114. It was clear from a plot of the flights that each duplicate set should have been one flight (one end of each was the same point in the sea). Each duplicate set was joined to make one track, ensuring that the start and end points of the combined track were on land. Examination of individual plots of all flights showed that each started and ended on land, indicating that digitising of the flights where data was available was complete.

4.3 Supplementary data

The flight record database contains a large number of data fields that can be used to describe conditions during the flight. A total of 307 flights have descriptive details in the flight database. Fields were considered to contain useful additional information for analysis if more than 25% (n=76) of records were filled. There were more than 40 logical fields that could only contain the values of true or false. For these logical fields, it is difficult to determine if a value of false means that the real value is false, or the field simply was not filled. Only 9 of the logical fields contained more than 10 values of true, and only one had more than 25% of records with a value of true, and was the only logical field considered further.

A summary of fields that contained data for more than 25% of records is given in the following table.

Table 2.

Field	Type	Description	% filled
Spotting_qual	Logical		34
Airtemp_F	Number	Air temperature in degrees F (during flight)	27
airtemp_C	Number	Air temperature in degrees C (during flight)	27
wind_max	Number	Wind maximum speed in knots	82
wind_min	Number	Wind minimum speed in knots	67
wind_dir_from	Character	Wind direction from (e.g. SE,NW, etc)	75
cloud1	Character	Cloud description (0-8, 100%, scattered etc)	39
spotting_conditions1	Character	Description of spotting conditions (poor, fair, good etc)	77
Weather	Character	Description of weather conditions (overcast, hot, good etc)	31

4.4 Calculation of seasonal indices of abundance

A number of different approaches were used to calculate annual indices of abundance from the spotting data:

- Index A: Total biomass of fish seen for all flights divided by the total distance flown as directly measured from the flight paths. This index does not discriminate between searching and transit flight, and only excludes flights as invalid if the sightings records were found to be incomplete. Biomass of fish seen is a multiplication of the number of patches by the average patch size for each sighting. This weighted mean version of this index is equivalent to a nominal CPUE index from commercial spotting,

- Index B: The searching portion of each flight as estimated using the flight duration given and the average aircraft speed minus the measured transit distance, as well as areas where searching was deemed to always occur. Only the biomass that was associated with search sectors was included. The index was calculate as the sum of the biomass seen on these searching sector divided by the total estimated distance flown. Also, only flights where the recorded duration of the flight was consistent with the distance and average speed of the aircraft were included. This weighted mean version of this index is equivalent to a nominal CPUE index from commercial spotting but only for the searching sectors.

- Index C: Only search distance and biomass as for index B, but only from within an area bounded by longitude 131˚ to 133˚E, latitude 33˚ to 34˚S. This area has had at least some searching in most years, and appears to be the main area targeted by the fishing vessels in recent years. This weighted mean version of this index is equivalent to a nominal CPUE index for a “core” or “principle” area within a fishery.

- Index D: The sampling unit for this index is a 0.5 degree square instead of the flight as in index A, so the total distance flown and biomass spotted within each square was used instead of the same information per flight. Flights data were still excluded as for index A, with the addition that flights without complete location details for all sightings were also excluded. This index attempts to take into account that searching effort within a flight was not representative or uniformly distributed within the Great Australian Bight.

- Index E: The searching portion of each flight and biomass spotted (as for index B) within each 0.5 degree square. Flight data were excluded as for index B, with the addition that flights without complete location details for all sightings were also excluded.

- Index F: This index is the same as index E, except only using flights that were made during January and February. Flight data were excluded as for index B, with the addition that flights without complete location details for all sightings were also excluded.

Indices A, B and C use the flight as the basic sampling unit and indices D, E and F use 0.5 degree squares.

The standard unweighted mean (μ^s) was calculated for each fishing season as:

$$\mu^s = \frac{\sum_{u=1}^{n} (B_u / D_u)}{n}$$

where u	=	a sampling unit (either a flight or 0.5 degree square)
B_u	=	the biomass of SBT observed within a sampling unit
D_u	=	the distance flown in a sampling unit
n	=	the total number of sampling units.

The standard deviation of the standard unweighted mean σ^s was calculated as:

$$\sigma^s = \sqrt{\frac{\sum_{u=1}^{n} \left((B_u / D_u) - \mu^s\right)^2}{n}}$$

The weighted mean with the weight being the distance flown in a sampling unit was calculated as:

$$\mu^w = \frac{\sum_{u=1}^{n} B_u}{\sum_{u=1}^{n} D_u}$$

and the standard deviation as:

$$\sigma^w = \sqrt{\frac{\sum_{u=1}^{n} D_u \left((B_u / D_u) - \mu^w\right)^2}{\sum_{u=1}^{n} D_u}}$$

The 95% confidence intervals of the mean were calculated using the standard deviation as follows:

$$i^{95\%} = \pm \frac{1.96 * \sigma}{\sqrt{n}}$$

It should be noted that these confidence limits are assume that the estimated indices are normally distributed. However, ratio estimators, such as these indices, can be highly skewed particularly when substantial error is associated with both the numerator and denominator.

It should also be emphasized that these variance and confidence intervals should be considered as minimum estimates. For example, no account is taken of measurement error in either the distance flown, the location of sightings and search effort, and in the estimates of biomass. Substantial measurement error exists (for example see below for analyses of the accuracy of the route maps). Moreover, the sampling units are not independent and substantial co-variances are likely to exist between flights (i.e. pilots go back to areas where they have seen fish previously and to areas where the vessels have been catching fish) and also within flights when the a 0.5 degree square is considered as the sampling unit.

It was not possible to examine in detail the influence of environmental conditions on the abundance of SBT observed because of more than 40 environmental variables that were potentially recorded, only 9 had a coverage of more that 27% of flights. Only two variables were recorded sufficiently often to allow some form of analysis – wind speed and spotting conditions. The spotting conditions variable was a subjective one that had values such as ‘good’, ‘excellent’ or ‘poor’.

5 RESULTS

5.1 Data summary

A summary of the data collected is given in the following table:

Table 3. A summary of the data taken from log sheets and computerised by entry into a database.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Whole season
	1982 season									
# planes					1	1				
# flights					3	7				10
Crews					1	1,2,3				
# sightings					2	10				12
# patches					2	22				24
	1984 season									
# planes	1	1	4	5	3	4		1	1	
# flights	2	2	20	28	9	8		1	1	71
Crews	2	2	2,4,5	2,4,5,6	2,4,5	2,5		6	6	
# sightings	0	3	57	27	6	8		0	0	101
# patches	0	11	203	107	53	23		0	0	397
	1985 season									
# planes			3	2	3	2				
# flights			19	20	10	8				57
Crews			2,4,6,7	6,7	6,7,8	6,8,9				
# sightings			36	25	12	6				79
# patches			165	186	98	28				477
	1990 season									
# planes			2	2						
# flights			7	15						22
Crews			10,11	10,11						
# sightings			16	41						57
# patches			66	215						281
	1991 season									
# planes		1	2	2	2	2	2			
# flights		2	15	23	14	4	8			66
Crews		12	8,13,14	8,13	8,13	8,13	8,13			
# sightings		9	96	60	84	16	34			299
# patches		12	295	216	543	71	105			1242
	1999 season									
# planes			2	1	1	1				
# flights			3	14	15	9				41
Crews			14,15	14	14	14				
# sightings			13	127	163	0				303
# patches			16	228	245	0				489
	2000 season									
# planes		2	2	3	2					
# flights		4	8	14	14					40
Crews		15,16	15,16	14,15,16	14,16					
# sightings		43	97	249	150					539
# patches		88	154	302	314					858

Note: sightings and corresponding patches are only those that were recorded for species “SBT”.

There are clear differences in the temporal coverage of the available data from season to season. There are most flights in December and January. There are very few flights outside the December to March period.

The spotting crews change over the seasons covered by these flights. None of the crews from the 1982 season worked after December 1982, and there are no common crews in 1984, 1990 and 1991.

5.2 Quality of the flight data

Table 4. A summary of available data for spotting flights.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Whole season
	1982 season									
# flights					3	7				10
# flight maps					3	7				10
# flight times					3	5				8
# spotting times					3	7				10
	1984 season									
# flights	2	2	20	28	9	8		1	1	71
# flight maps	2	2	20	27	9	8		1	1	71
# flight times	1	0	11	21	5	7		0	0	45
# spotting times	2	1	17	24	6	8		0	0	58
	1985 season									
# flights			19	20	10	8				57
# flight maps			13	19	8	8				48
# flight times			10	9	8	5				32
# spotting times			19	18	9	5				51
	1990 season									
# flights			7	15						22
# flight maps			7	15						22
# flight times			5	13						18
# spotting times			5	12						17
	1991 season									
# flights		2	15	23	14	4	8			66
# flight maps		0	15	23	14	3	8			63
# flight times		0	0	0	0	0	0			0
# spotting times		0	1	1	1	0	0			3
	1999 season									
# flights			3	14	15	9				41
# flight maps			1	14	15	9				39
# flight times			1	14	15	9				39
# spotting times			1	14	13	9				37
	2000 season									
# flights		4	8	14	14					40
# flight maps		4	8	11	12					35
# flight times		3	8	9	8					28
# spotting times		4	8	6	8					26

Information is available on 307 flights. Of these, there are flight maps for 288 flights (94%).

Flight times are available for 170 flights (55%), and spotting times are available for 202 flights (66%).

5.3 Accuracy of the routes shown on the flight maps

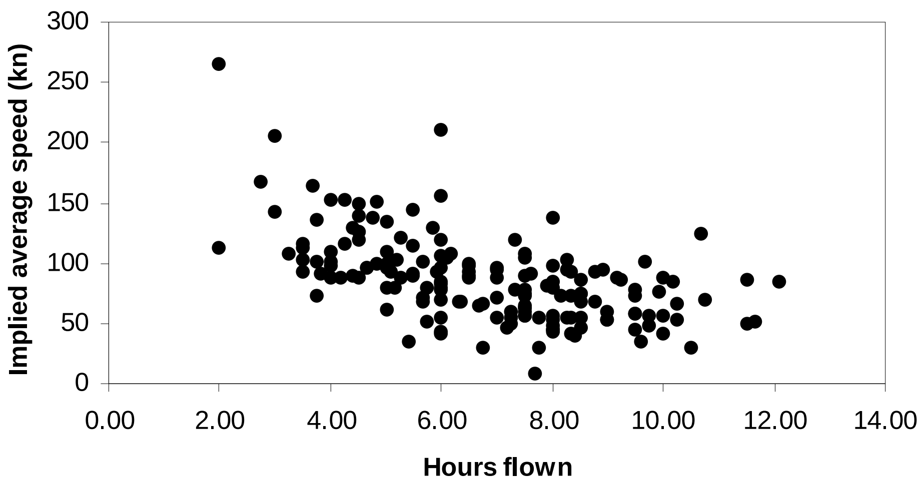
The routes on the flight maps are drawn by hand. After digitisation, the total distance flown shown on the map can be calculated for each flight. One way to check the accuracy of the route is to calculate the speed of the plane implied by the route shown. The implied speed of the plane is plotted against the flight time for each flight in Figure 5.

The average speed of a plane during spotting operations is between about 110 and 140 kn. The majority of the data shows a much lower implied speed, and we can conclude that the hand-drawn routes are generally too short. There may be broad scale or fine scale inaccuracies – the general shape of the route shown may be understated or the amount of circling while fine scale searching may be understated. The distance flown tends to be overstated only on shorter flights (<6 hours).

For flights where the flight time was recorded by spotters, the average flight time was 5.88 hours in the 1982 season, 7.19 in 1984, 7.38 in 1985, 7.42 in 1990, 6.46 in 1999 and 5.79 in 2000. This does not therefore indicate any strong potential source of bias through time, although the lower averages for 1982 and 2000 should be noted.

Another way of assessing the accuracy of the routes is to compare the location of recorded sightings and the route. On several occasions sightings are recorded at least 60nm from the recorded flight path. This impossible event also shows inaccuracy in the flight paths.

Figure 5: Average speed implied by route drawn on spotting map (knots) against flight time (hours).



5.4 Quality of the sightings data

Table 5. A summary of available data for individual SBT sightings.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Whole season
	1982 season									
SBT sightings					2	10				12
Incomplete biomass					0	0				0
Mixed species					0	0				0
Missing positions					0	0				0
No flight					0	0				0
Valid SBT sightings					2	10				12
	1984 season									
SBT sightings	0	3	57	27	6	8		0	0	101
Incomplete biomass	0	0	5	0	0	0		0	0	5
Mixed species	0	0	0	0	0	0		0	0	0
Missing positions	0	0	0	0	0	0		0	0	0
No flight	0	0	2	0	0	0		0	0	2
Valid SBT sightings	0	3	50	27	6	8		0	0	94
	1985 season									
SBT sightings			36	25	12	6				79
Incomplete biomass			1	0	0	0				1
Mixed species			0	1	0	0				1
Missing positions			0	0	0	0				0
No flight			0	0	0	0				0
Valid SBT sightings			35	24	12	6				77
	1990 season									
SBT sightings			16	41						57
Incomplete biomass			0	0						0
Mixed species			0	0						0
Missing positions			0	0						0
No flight			0	0						0
Valid SBT sightings			16	41						57
	1991 season									
SBT sightings		9	96	60	84	16	34			299
Incomplete biomass		0	46	22	26	15	0			109
Mixed species		0	11	22	0	0	0			33
Missing positions		0	0	0	0	0	0			0
No flight		9	0	0	0	0	0			9
Valid SBT sightings		0	50	16	58	1	34			159
	1999 season									
SBT sightings			13	127	163	0				303
Incomplete biomass			12	26	0	0				38
Mixed species			0	0	0	0				0
Missing positions			0	0	0	0				0
No flight			0	0	0	0				0
Valid SBT sightings			1	101	163	0				265
	2000 season									
SBT sightings		43	97	249	150					539
Incomplete biomass		0	8	53	8					69
Mixed species		0	0	0	0					0
Missing positions		0	0	0	0					0
No flight		0	0	0	0					0
Valid SBT sightings		43	89	196	142					470

For each sighting of fish, the spotter is asked to record the position of the sighting, the species, the number of patches and the average patch size. If all this information was not present, the sighting was assessed to be incomplete in terms of biomass details and marked as invalid. In some cases the species was recorded as “MIXED”. As there was no indication of how much

SBT was observed in these cases, these sightings were marked as invalid. Sightings that had no recorded position, or that could not be matched with an identified flight record were also marked as invalid. As the biomass per distance flown in a flight is generally affected by invalid sightings, flights that contained invalid sightings were discarded from biomass calculations. Of the 243 flights with sighting records, 39 were discarded because of invalid sightings. Of the 1,390 sightings of SBT, 1,134 (82%) were determined to be valid.

Many more sightings were recorded in 1991 than in the 4 years between 1982 and 1990. None of these sighting records are complete as a different form was used in that year. The missing data is the time of each sighting, and in many instances, the species.

In most cases, sightings are close to vessels. Few sightings are recorded while in transit to and from the fishing area. It may be the case that sightings were only recorded close to the fishing ground. The greater speed in transit mode would also be a factor reducing sighing efficiency. It is noted on the sighting forms sometimes that fish have been seen that were not recorded.

5.5 Other data Issues

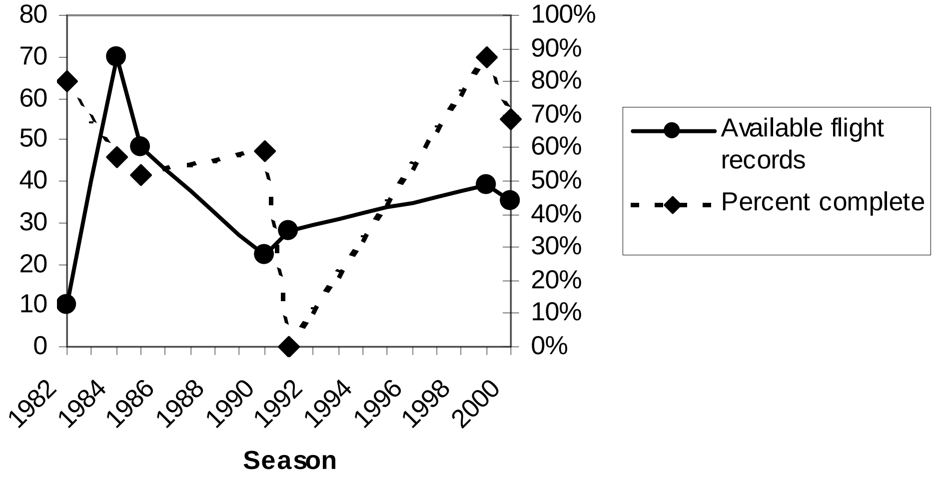
There are large gaps in time series – no data for 1983, 1986-89 and 1992-98 fishing seasons. The areas flown show little overlap with the aerial survey. There were also a number of recording problems and inconsistencies in the sightings details and flight records. In sightings records, for example, the species of fish sighted was not recorded in some instances. In others, an estimate of the average patch size was not given, so a biomass estimate could not be calculated. The following table summarises the major data recording problems and shows the number of flights that were discarded because of them. One flight was found to be composed of two flight records that were combined. In the 1991 season, 35 records were found to have been part of the formal aerial survey (Cowling, 2000). As this investigation is of commercial spotting records alone, these aerial survey records were excluded from further analyses. A total of 14 flight records were excluded because the ratio of estimated and measured search distances was outside the deemed acceptable range of 0.5 to 4.0.

Table 6. Summary of flight data recording problems.

	1982	1984	1985	1990	1991	1999	2000	Total
Flights with maps	10	71	48	22	63	39	35	288
Combined	0	1	0	0	0	0	0	1
Aerial survey flights	0	0	0	0	35	0	0	35
Flights available for use	10	70	48	22	28	39	35	252
Invalid sightings	0	3	3	0	9	4	5	24
No time details	2	26	16	4	28	1	7	84
Invalid distance ratio	0	3	6	5	0	0	0	14
Valid flights	8	40	25	13	0	34	24	144
Percent valid flights	80%	57%	52%	59%	0%	87%	69%	57%

The number of flight records available for use each season, and the percentage that had complete associated information, are shown in Figure 6. There was a high percentage of useable records for the 1982 season, a period where the percentage dropped below 50% (none in 1991 because of lack of flight times), and then an improvement in the 1999 and 2000 seasons.

Figure 6. The number of flight records available for each season, and the percentage that had complete associated information.



There was considerable year-to-year variability in where searching occurred and where SBT were detected. Figure 7 shows an area that was commonly searched in most years overlayed on all flights. Figure 8 shows the percentage of total search distance flown each season that was within the box. This clearly shows how much variability there was between years in the areas searched. There is very little overlap, for example, between the 1990 season and the 2000 season.

Figure 7. Track paths of all flights in all years, overlayed with a box bounding an area commonly searched in most years.

Figure 8. The percentage of total search distance flown each season that was in the box shown in Figure 7.

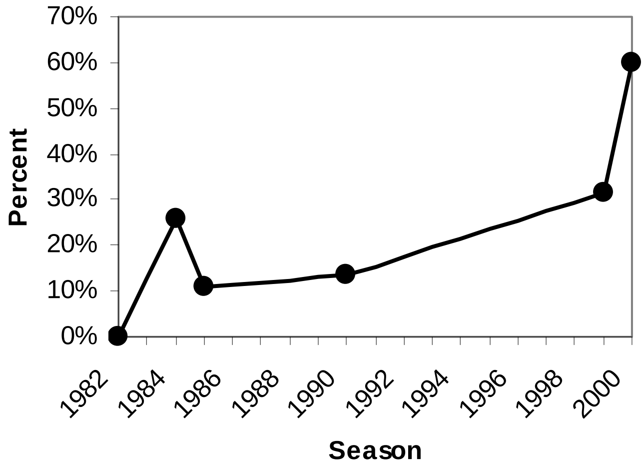
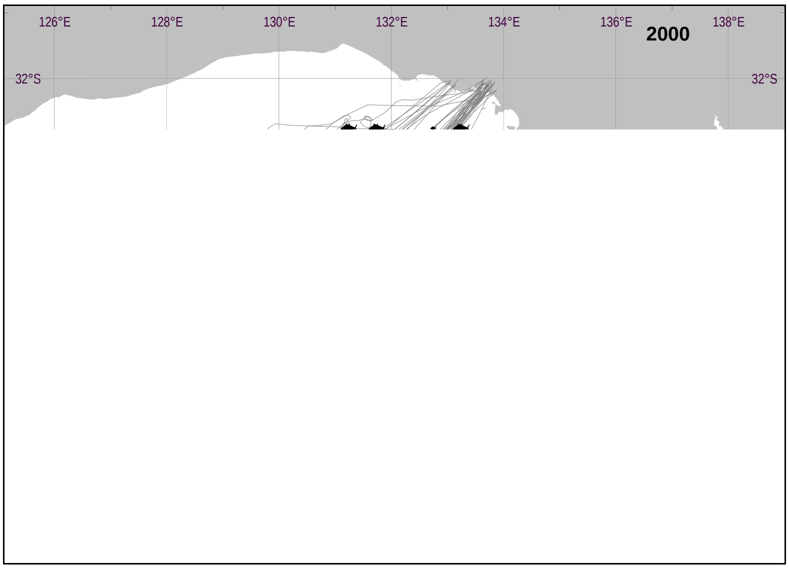


Figure 9. The flight tracks for the 2000 season showing a concentration of search effort in the box area shown in Figure 7.



5.6 Relative Indices

Results of index calculations using the methods for Index A and Index D are compared Figure 10. While Index A appears to show an increasing trend, this is not as clear for index D. Figure 11 shows similar comparison for indices B and E. In this case, substantive differences are seen for between the indices in 1999, which would in turn have substantial consequences for any interpretation of the indices as measures of abundance. Confidence intervals for mean index values using the method for Index E, as well as the means are shown in Figure 12. This shows that the index values are very imprecise. Detailed results for all indices are shown in Appendix B.

Figure 10. Results of calculations using total distance flown for index A and index D by fishing season.

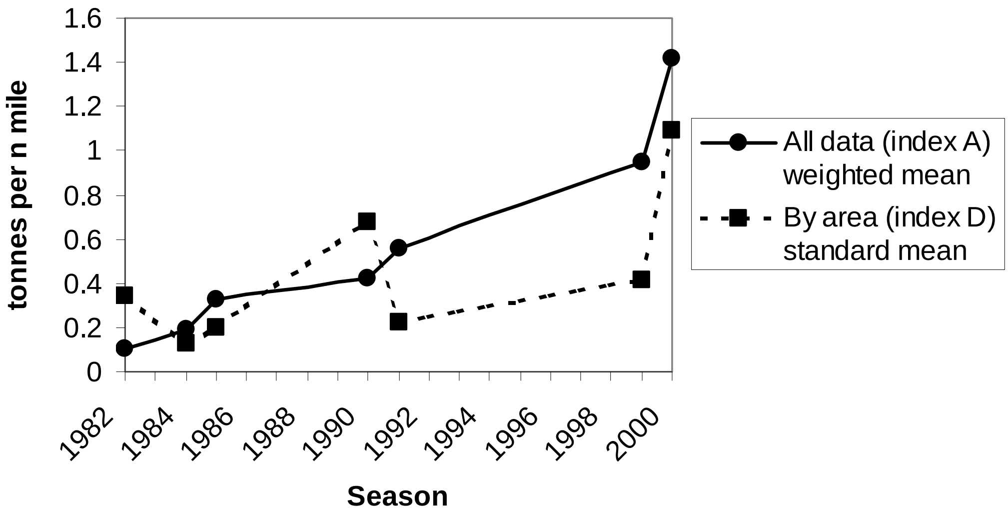


Figure 11. Results of calculations using search time only for index B and index E by fishing season.

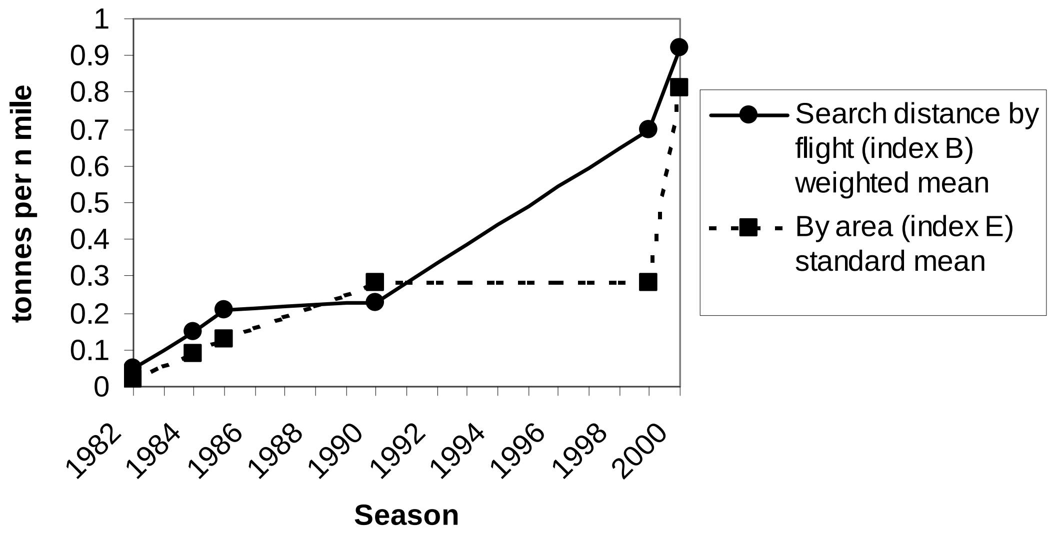


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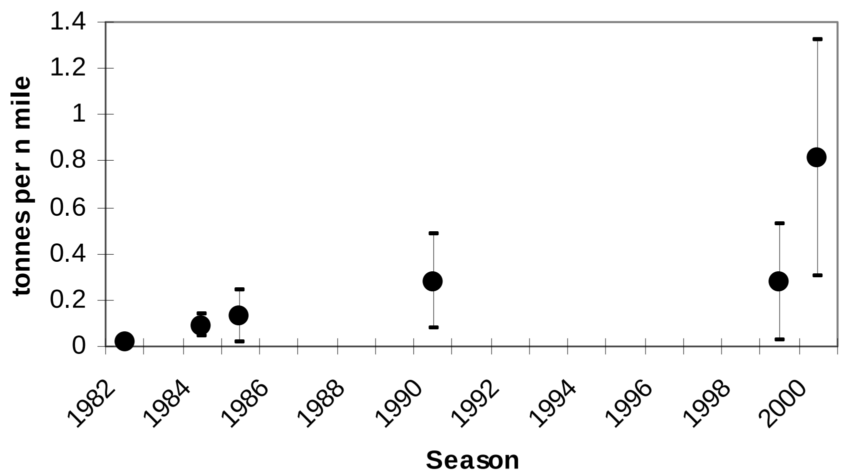
Figure 12. Results for calculating Index E (standard mean), including 95% confidence intervals of the mean.



6 DISCUSSION

A number of flights were discarded from further analysis because they did not contain complete details for all patches of fish observed. As this only affects flights with fish observed, and not those without, a bias is introduced in the absolute value calculated for biomass observed per distance flown, leading to a degree of underestimation. However, as the cases of such incomplete details were spread across most years, there should not be a strong bias in relative biomass observed per distance flown comparisons among years. For the years where results have been shown, more than 50% of records have been available for use in index calculations, which also reduces the impact of such a bias.

6.1 Evaluation of the potential usefulness of the historical commercial spotting data

Data collection

Participation in this data collection scheme was voluntary. We do not know whether there were any systematic differences between the spotters who chose to participate and those who chose not to participate. We also do not know whether the participating spotters submitted flight data every flying day, or only on selected days. There are likely to be selection biases in the data set, but these are unknown and cannot be assessed.

To assess the reliability of spotters' patch size estimates in the aerial survey, in 1998 and 1999 ground-truthing experiments were conducted in which spotters in separate planes observed the same patches almost simultaneously (Cowling and O'Reilly 1999). These experiments showed differences in average estimated patch size among crews of up to 53%. It is not possible to assess the variation among different crews in patch size estimates for the historical commercial spotting data. Nor is it possible to assess the difference in estimated patch size versus the tonnage of fish in the school of fish as caught by commercial vessels as this information has not been recorded. Both these sources of variability are expected to be significant, but have not been evaluated here. We do not know if there is any bias due to trends in these factors over time – for example, commercial spotters overestimating in early years and correcting in later years. If there is no bias, this at least means that the variance around annual abundance levels is underestimated in the results given in this report.

Completeness of the sightings data

Only 34% of the SBT sighting records we had to work with were complete. This obviously constrained our ability both to estimate abundance trends and to evaluate the usefulness of commercial spotting data.

An added constraint was that in most cases, sightings were close to vessels, and few sightings were recorded while planes were in transit to and from the fishing area. It may be the case that only sightings close to the fishing ground were recorded. In the data, it is stated several times that not all the sightings were recorded.

Completeness of the search effort data

The area actively searched on a flight is not accurately known. The duration of active searching is known for only 62% of the flights. Even in these cases, what has been classified as active searching will contain periods of time when a plane may be circling to assist a vessel in locating and setting on fish. The flight paths shown on the forms are clearly inaccurate, generally understating the distance flown. All of these factors mean that the basic measure of nominal search effort is not consistent among flights. This adds additional, but inestimable variance to all of the indices. Also, there are potential biases that may be related to SBT abundance and changes in fishing strategy (e.g. transit time may be greater when density is low, the number of secondary sightings when circling would be expected to increase with circling, etc).

Year to year comparability

The time period covered by the available data by season are non-continuous, with no data for the 1983, 1986-98 and 1991-98 seasons. This compromises the temporal comparability of any indices developed from these data. The number of flights made varies considerably by season. There is little consistency in the spotting crews among seasons in both personnel or proportion of total flight time flown within a season. Considerable differences in sighting efficiency (i.e. the ability to detect schools) exists among different spotters. Physical differences in the design of the two aircraft used in commercial spotting would also be expected to affect sighting efficiency, and there are differences among seasons in the proportion of flights made by different aircraft. There is no information that would allow for inter-seasonal calibration to correct for what are potentially large differences in sighting efficiencies between seasons. Therefore, it is not possible to determine to what extent change (or lack there of) in average sightings rates between years reflected difference abundance of SBT in the GAB compared to differences in sighting efficiency. .

Another factor that affects the year to year comparability of the indices is the estimation of the biomass of a patch. As noted, large and apparently consistent differences exists among spotters in their biomass estimates for the same patch of fish (Cowling and O'Reilly 1999). Since there are no data to calibrate the biomass estimates from different spotters, and the contribution of different spotters to the data has change markedly over time, it is not possible to assess the extent to which year to year changes reflect actual changes in abundances relative to differences among spotters in their estimates of biomass.

Indices based on patches/time flown

Indices based on patches/time flown (corrected for differences in airplane speeds) would appear to provide a more appropriate measure of effort then those based on distance derived from the route maps. This is because of the greater accuracy with which time is recorded. However, flying time is only available for 67% of the flights and there are no flights with flying times for the 1991 season. Thus, indices based on time flown as the underlying effort measure will have poorer coverage and thus large variances associated with them.

Indices based on patches/distance flown

Indices based on patches/distance flown will be inaccurate, as the routes have not been accurately recorded. Generally the routes are too short (giving low speeds), and a CPUE index developed from uncorrected data would be overestimated. The extent to which this varies with density is not clear, but could potentially bias any index from these commercial spotting data. Some form of adjustment of the distances is required. The assumptions made here to estimate the true search distance flown are strong and assume that the flight path is accurately located on the map. We know that this is probably not the case because a number of recorded sightings more than 1 degree or about 60 n miles from the flight path.

Indices based on all effort versus active searching

Indices based that are based on all effort provide substantially broader coverage of the Great Australian Bight then those based on periods of active searching. Thus, areas of active searching tend to be located along the shelf edge break and around specific inshore features (Appendix A). Excluding effort and sightings during transit results in substantially poorer coverage of the more inshore and middle portions of the bight. Moreover, effort during transit mode is not directed to areas where fish are thought to be highly concentrated and thus could potentially provide important information about the non-representativeness of searching effort. Using all of the effort data would be preferable. However, sighting rates are generally substantially lower during transiting and few sightings are made during this time. About 15% of the total distance flown was calculated to be during transit. About 6% of the total observed SBT biomass was recorded during transit. It is not clear the extent to which this is due to the lower sighting efficiency during transiting (e.g. high plane speeds, less focussed/not searching, etc) and to what extent this is due to the fact that there are low density of SBT patches in the areas being transited.

Differences among the weighted and unweighted indices

The weighted mean gives more weight to those flights or squares in which greater distances were flown. As the weighted mean is determined by the sum of the biomass divided by the sum of the distance flown over all sampling units, the results are independent of what the sampling unit was. That means that the results for the weighted mean are similar for indices (A,D) and (B,E). The only differences are due to some flights being rejected from the 0.5 degree square calculations because some observations in those flights did not have location information.

The unweighted indices give equal weight to the index values obtained within each sampling unit. This means that all flights are treated equally for the standard mean calculations for indices A, B and C, and all 0.5 degree squares are treated equally for indices D, E and F.

If sampling effort within a sampling unit is representative or random with respect to the underlying population, weighted and unweighted indices are both unbiased estimates of the actual quantity being measured and should provide similar estimates. In this situation, the weighted mean should yield lower variances (e.g. those units with higher sampling effort provides a more accurate estimates). However, when sampling effort within a sampling unit is not representative or random with respect to the underlying population, weighted indices can provide highly biased estimates. This is a particularly important issue in the analyses of CPUE and commercial spotting data where searching effort is often highly concentrated and aggregated in space and time. Since fishermen and commercial spotters are interested in locating fish, they will tend to concentrate their effort in areas of highest fish density. If data are aggregated into sampling units without any consideration of the spatial/temporal coverage, areas and time periods with the most effort will dominate the index. Thus, the index will reflect the sighting rates areas/times of concentrated effort and not reflect the overall fish population abundance. As such, unweighted indices which disaggregate the data spatially (such as indices

D, E and F) and temporally are preferable for commercial fishing and spotting data as they attempt to correct for some of the non-representativeness and aggregated nature of the sampling effort.

Index D shows substantial difference between the time trends when based on weighted or unweighted mean. Index D stratifies the data by 0.5 degree squares and uses all the effort and sighting data. The unweighted mean in this case does not clearly indicate any trend, whereas the weighted mean continuously increases from season to season. Substantive difference between the weighted and unweighted means, as seen in this case, is what would be expected if in fact searching effort is concentrated in areas of high abundance. These results demonstrate the importance of stratifying effort by appropriate spatial units and not simply aggregating the data over all areas if unbiased time trends are to be obtained.

For the other indices, the differences are not great between trends shown by the weighted and unweighted means. This is not particularly surprising for indices which use a flight as the basic sampling unit. A large difference between the weighted and unweighted means would only be expected if the length of a flight were highly correlated (either positively or negatively) with the number of sightings. However, the factors determining the duration of a flight are complex, so it is not surprising there is not a strong relationship. The other indices which involve spatial stratification (i.e. E and F) are based on areas where planes are actively searching. The fact that the unweighted and weighted means are similar suggests that in the areas where active searching takes place there is not a strong relationship between the amount of effort and number of sightings. We suspect that this is due to a combination of factors including the inaccuracy with which searching effort has been recorded, the fact that spotters use prior information for selecting areas to search and that there may be substantial amount of “non-search” time in areas with high effort associated with assisting fishing activities.

Index trends

There is a considerable difference in the trends shown by an index depending on whether search flight time only is included, whether it is weighted or unweighted, or whether only a spatial or temporal subset of the data is considered.

It is clear from examination of seasonal plots of all flights (see Appendix A) that spotting flights in the last two seasons (1999 and 2000) concentrated more heavily in a much smaller region of the GAB. This means that it not possible to say from the available data what the abundance of SBT was in those areas not covered recently that did have spotting activity in most of the earlier years.

Most indices show biomass per distance flown as higher in the most recent two years in comparison to the earlier seasons. However, interpretation of this as reflecting a possible change in abundance is highly confounded by changes in spatial cover and lack of sufficient information to separate factors related to changes in abundance from the large number of other factors that can affect detection rates. For example, indices D and E are the only indices which attempt to take into account the concentrated and highly non-random distribution of searching effort.

Index C attempts to look at trends just within the area where flights have recently concentrated, and this places the 1999 value considerably lower than 2000, and comparable to earlier years.

All indices consistently place the value from the 2000 season at a high level in relation to other seasons. The 95% confidence interval for the 2000 biomass per distance flown value is also usually large, indicating that the 2000 season estimate is not very precise (e.g. see Figure 12). There is not a consistent trend shown for the 1982 to 1999 seasons across indices.

There are difficulties in interpreting commercial spotting data because of the concentrated searching and lack of consistency in where searching occurs and what data are recorded. Because of the imprecision and inability to resolve additional detail, the historical spotting data are not likely to yield an age or size-specific index. The interpretation of index calculations has very similar problems to those encountered with CPUE analyses. There is no apparent increase in biomass shown by the index that is averaged over the areas searched. Because of the imprecision of the indices, they have a low ability to detect changes from season to season.

Comparison with the aerial survey

One of the objectives of this project was to compare any preliminary indices derived in this project with indices derived from the aerial survey. However, meaningful comparisons were not possible because of the temporal incompleteness of the aerial survey data. Thus, the commercial spotting data available for this project provided only two years of overlap with the aerial survey (the 1999 and 2000 seasons). Given the high CVs associated with both the preliminary commercial spotting indices and the aerial survey, any comparison of trends based on only two data points from two successive years would be meaningless. Additionally, the 1999 and 2000 aerial surveys are also the most problematical and uncertain within the aerial survey time series because of the unavailability of experienced spotters. Two of the four spotters in each of these years were trainees with no previous experience (Cowling 2000).

7 REFERENCES

Chen, S.X. and Polacheck, T. 1993. Report on the 1993 aerial surveys for juvenile Southern Bluefin Tuna in the Great Australian Bight. RMWS/93/8.

Cowling, A. and Millar, C. 1998. Data analysis of the aerial surveys (1991-1998) for juvenile Southern Bluefin Tuna in the Great Australian Bight. RMWS/98/xx.

Cowling, A. and O'Reilly, J. 1999. Data analysis of the aerial surveys (1993-1999) for juvenile Southern Bluefin Tuna in the Great Australian Bight. RMWS/99/xx.

Cowling, A. 2000. Data analysis of the aerial surveys (1993-2000) for juvenile Southern Bluefin Tuna in the Great Australian Bight. CSIRO Division of Marine Research Report.

Davis, T.L.O. 1999. Southern Bluefin Tuna Recruitment Monitoring Program (1993-1998) Final Report. CSIRO Division of Marine Research Report.

APPENDIX A – Maps of flight paths and SBT sightings by season

Figure A.1. Flight paths and sightings of SBT in the 1982 fishing season.

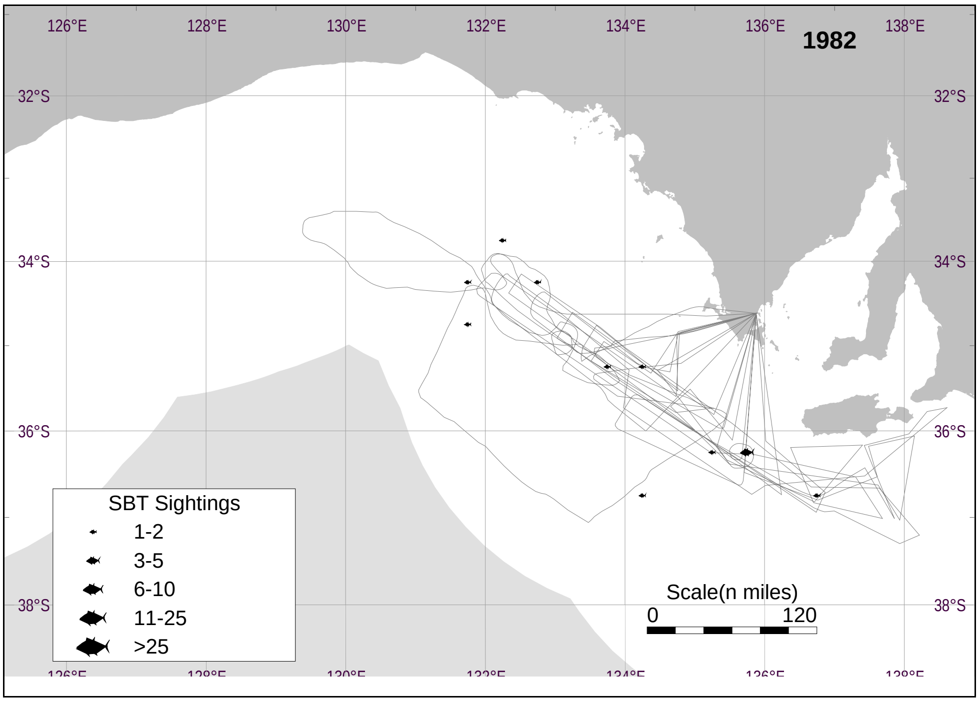


Figure A.2. Flight paths and sightings of SBT in the 1984 fishing season.

Figure A.3. Flight paths and sightings of SBT in the 1985 fishing season.

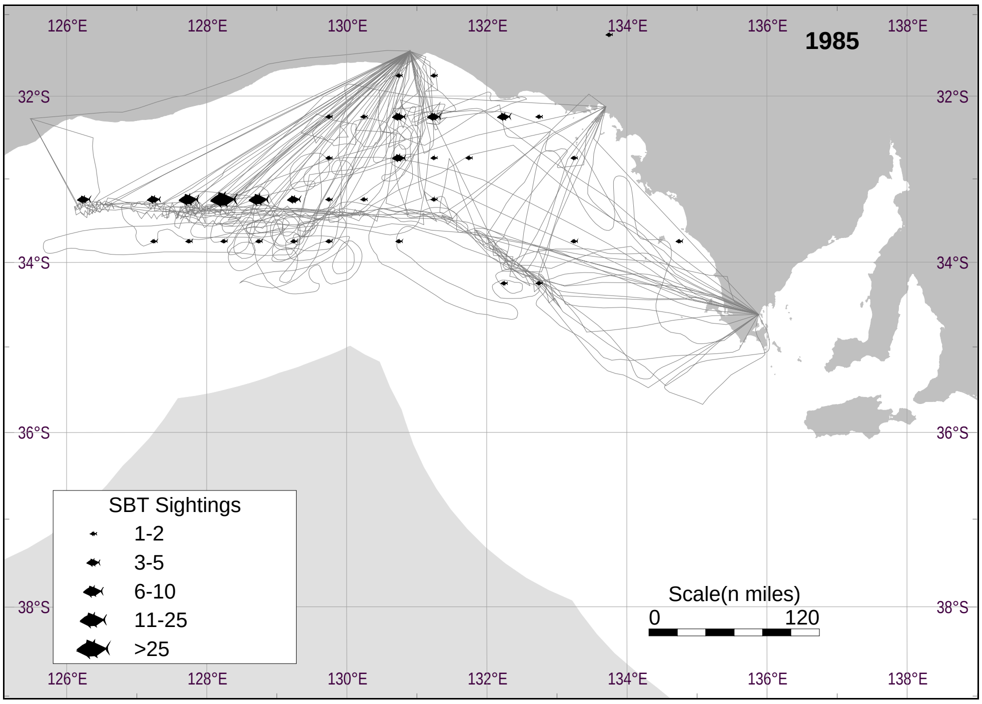


Figure A.4. Flight paths and sightings of SBT in the 1990 fishing season.

Figure A.5. Flight paths and sightings of SBT in the 1991 fishing season.

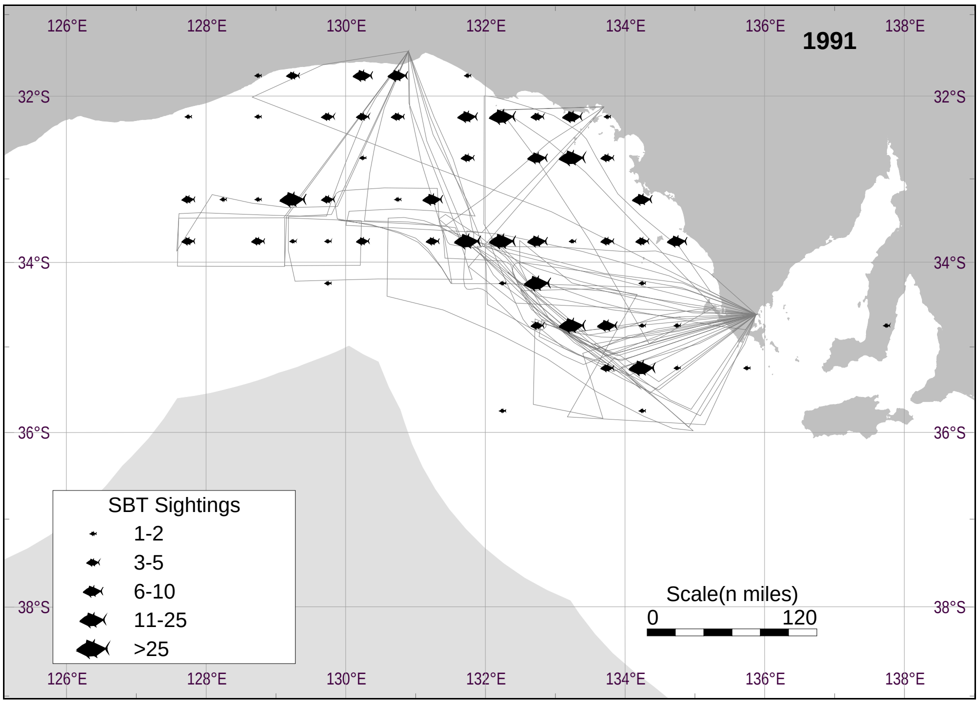


Figure A.6. Flight paths and sightings of SBT in the 1999 fishing season.

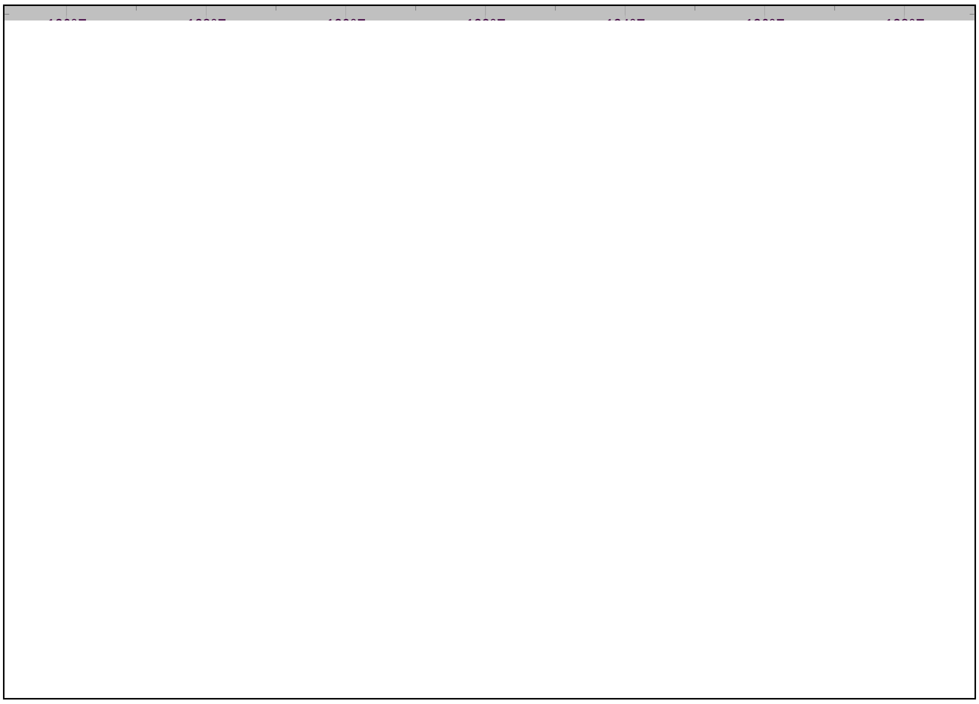
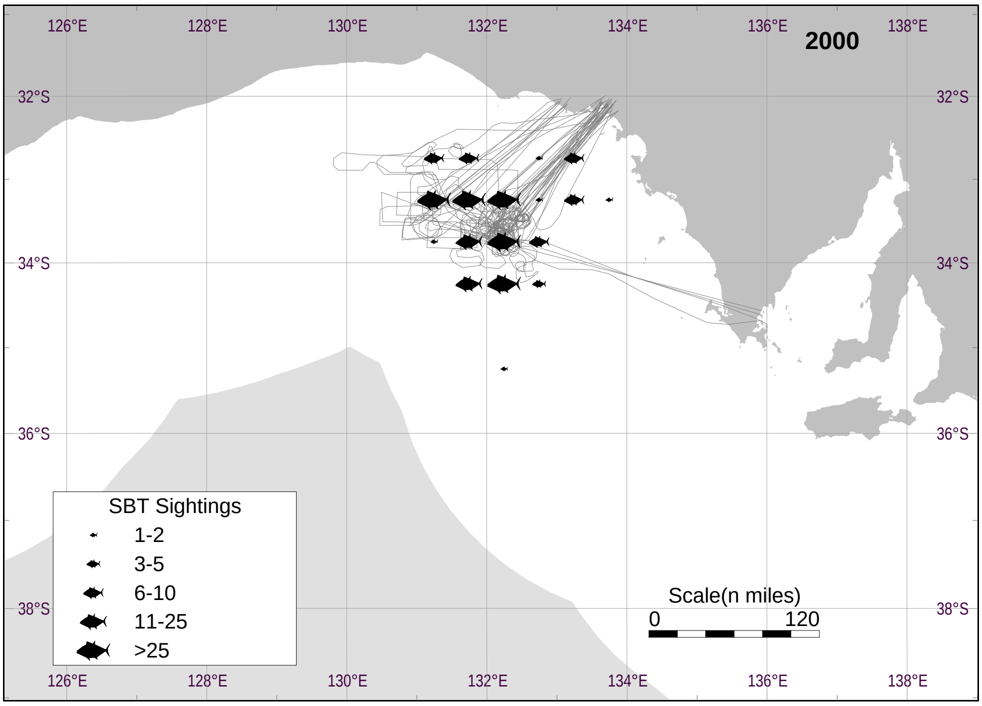


Figure A.7. Flight paths and sightings of SBT in the 2000 fishing season.



APPENDIX B – Detailed results for each index

Index A – all data

Total biomass of fish seen for all flights based on distance flown in transit and searching directly measured from the flight paths. Biomass of fish seen is multiplication of number of patches by average patch size for each sighting. No adjustment according to time of flight.

Table B.1. Weighted and standard mean index values per fishing season with 95% confidence intervals for index A.

				Weighted			Standard		
Year	Flights	Biomass (t)	Distance (n mi)	Mean	95%+	95%-	Mean	95%+	95%-
1982	10	830	7,941	0.10	0.21	0.00	0.08	0.17	0.00
1984	67	8,027	41,927	0.19	0.27	0.11	0.20	0.28	0.12
1985	45	8,000	24,392	0.33	0.42	0.24	0.31	0.40	0.22
1990	22	4,195	10,094	0.42	0.73	0.11	0.57	1.01	0.13
1991	19	5,042	8,938	0.56	1.12	0.00	0.60	1.18	0.02
1999	35	19,362	20,400	0.95	1.46	0.44	1.05	1.58	0.52
2000	30	20,118	14,208	1.42	1.97	0.87	1.41	1.96	0.86

Figure B.1. Weighted mean and 95% confidence intervals by fishing season for index A.

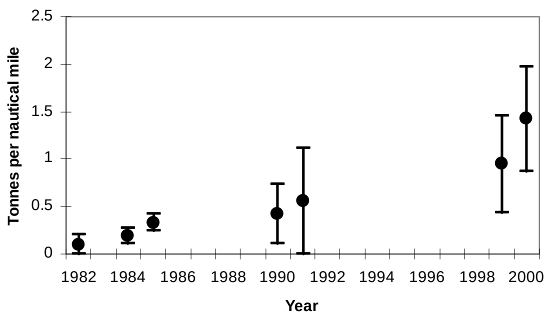
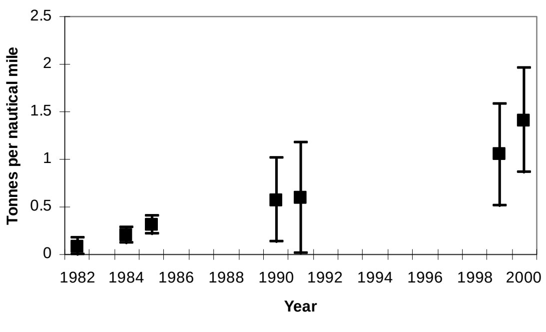


Figure B.2. Standard mean and 95% confidence intervals by fishing season for index A.



Index B – searching portion of flights only

The searching portion of each flight was separated from transit to and from the base airfield by assuming that when the flight path has deviated by more than 30 degrees from the path flown to and from the airfield. It was also possible to adjust the distance flown during searching according to the time the flight took, assuming an average speed of 140 knots. Only the distance of the search sectors of each flight were adjusted, as it was assumed that transit would be reasonably straight, and therefore more correctly described than search sectors on the drawn flight paths. Only the biomass that was associated with search sectors was included.

Note that 1991 is not shown here but is in index A, as no flight times were given for any flights during that year.

Table B.2. Weighted and standard mean index values per fishing season with 95% confidence intervals for index B.

				Weighted			Standard		
Year	Flights	Biomass (t)	Distance (n mi)	Mean	95%+	95%-	Mean	95%+	95%-
1982	8	280	5,295	0.05	0.09	0.01	0.04	0.09	0.00
1984	40	4,545	30,066	0.15	0.24	0.06	0.17	0.26	0.08
1985	25	3,925	18,492	0.21	0.31	0.11	0.23	0.35	0.11
1990	13	2,498	10,670	0.23	0.33	0.13	0.20	0.31	0.09
1999	34	18,012	25,601	0.70	1.15	0.25	0.80	1.32	0.28
2000	24	13,767	15,030	0.92	1.25	0.59	0.92	1.30	0.54

Figure B.3. Weighted mean and 95% confidence intervals by fishing season for index A.

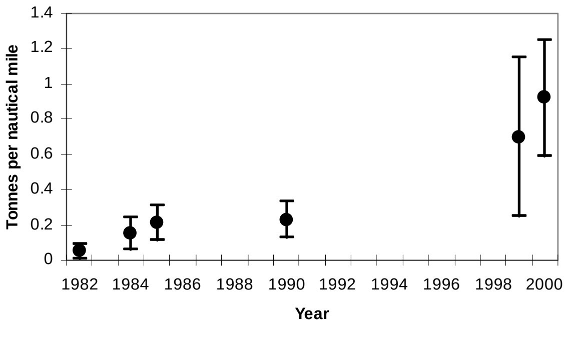
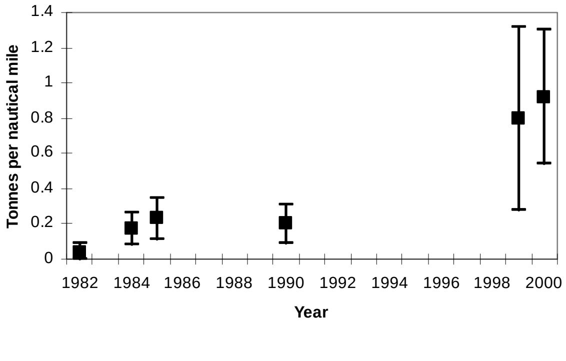


Figure B.4. Standard mean and 95% confidence intervals by fishing season for index A.



Index C – searching portion of flights in box longitude 131° to 133°E, latitude 33° to 34°S only

Only search distance and biomass as for index B was included, also only from within the specified area. This area has had at least some searching in most years, and appears to be the main area targeted by the fishing vessels.

Table B.3. Weighted and standard mean index values per fishing season with 95% confidence intervals for index C.

				Weighted			Standard		
Year	Flights	Biomass (t)	Distance (n mi)	Mean	95%+	95%-	Mean	95%+	95%-
1984	24	860	7,718	0.11	0.19	0.03	0.11	0.19	0.03
1985	10	300	1,986	0.15	0.36	0.00	0.09	0.26	0.00
1990	7	0	1,445	0.00	0.00	0.00	0.00	0.00	0.00
1999	27	3,922	8,019	0.49	0.74	0.24	0.30	0.52	0.08
2000	24	9,884	9,010	1.10	1.42	0.78	1.03	1.40	0.66

Figure B.5. Weighted mean and 95% confidence intervals by fishing season for index C.

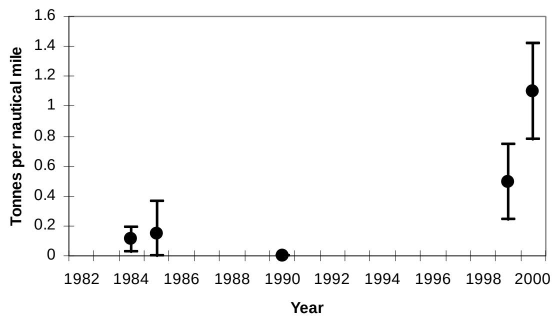
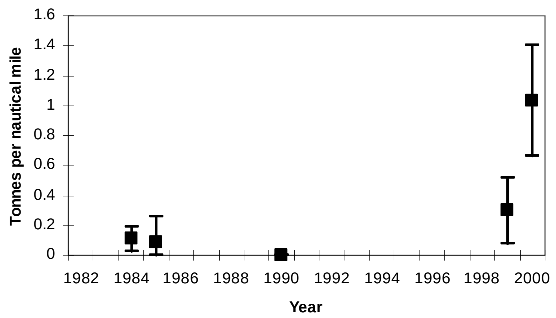


Figure B.6. Standard mean and 95% confidence intervals by fishing season for index C.



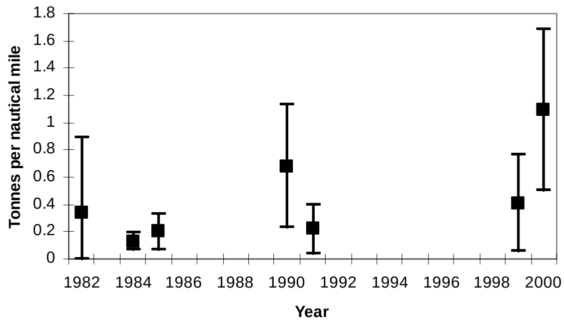
Index D – all data with sampling unit as 0.5 degree square

The distance flown and biomass spotted (as for index A) within each 0.5 degree square was used as the basis for statistics for this index. Weighted results are not given as they are the same as for Index A – the sampling unit does not affect the totals used in the weighted index calculations.

Table B.4. Standard mean index values per fishing season with 95% confidence intervals for index D.

Year	Squares	Biomass (t)	Distance (n mi)	Standard Mean	Standard 95%+	Standard 95%-
1982	71	830	6,936	0.34	0.89	0.00
1984	123	8,027	41,620	0.13	0.19	0.07
1985	117	8,000	24,076	0.20	0.33	0.07
1990	87	4,195	9,349	0.68	1.13	0.23
1991	63	5,042	7,847	0.22	0.40	0.04
1999	51	19,362	20,137	0.41	0.76	0.06
2000	38	20,028	13,561	1.09	1.68	0.50

Figure B.7. Standard mean and 95% confidence intervals by fishing season for index D.



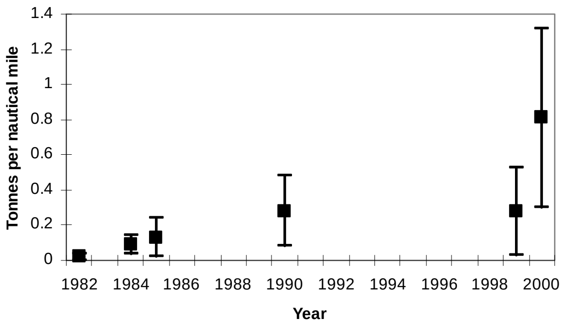
Index E – searching portion of flights only with sampling unit as 0.5 degree square

The search distance flown and biomass spotted (as for index B) within each 0.5 degree square was used as the basis for statistics for this index. Weighted results are not given as they are the same as for Index B – the sampling unit does not affect the totals used in the weighted index calculations.

Table B.5. Weighted and standard mean index values per fishing season with 95% confidence intervals for index E.

				Weighted			Standard		
Year	Squares	Biomass (t)	Distance (n mi)	Mean	95%+	95%-	Mean	95%+	95%-
1982	41	280	5,283				0.02	0.04	0.00
1984	108	4,545	30,081				0.09	0.14	0.04
1985	99	3,925	18,486				0.13	0.24	0.02
1990	75	2,498	10,679				0.28	0.48	0.08
1999	51	18,012	25,598				0.28	0.53	0.03
2000	36	13,767	15,030				0.81	1.32	0.30

Figure B.8. Standard mean and 95% confidence intervals by fishing season for index E.



Index F – searching portion of flights only with sampling unit as 0.5 degree square in January and February only

This unweighted index is the same as index E, except only using flights that were made during January and February. The weighted index is the same as unweighted index B except only using flights that were made during January and February.

Table B.6. Weighted and standard mean index values per fishing season with 95% confidence intervals for index F.

				Weighted			Standard		
Year	**Squares**	**Biomass (t)**	**Distance (n mi)**	**Mean**	**95%+**	**95%-**	**Mean**	**95%+**	**95%-**
1982	25	90	1,266	0.07	0.16	0.00	0.04	0.11	0.00
1984	87	2,535	18,874	0.13	0.20	0.06	0.08	0.14	0.02
1985	73	2,655	9,960	0.27	0.38	0.16	0.08	0.14	0.02
1990	67	1,644	6,412	0.26	0.43	0.09	0.31	0.56	0.06
1999	44	19,662	20,849	0.94	1.51	0.37	0.68	1.23	0.13
2000	28	10,381	11,627	0.89	1.20	0.58	0.65	1.09	0.21

Figure B.9. Weighted mean and 95% confidence intervals by fishing season for index F.

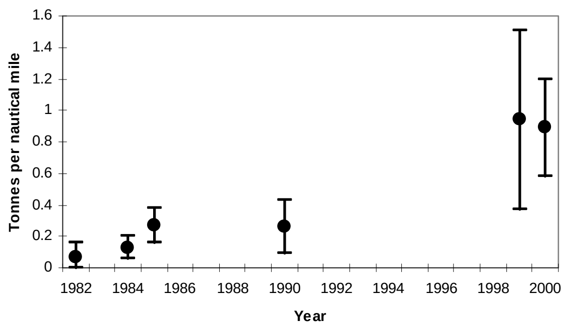
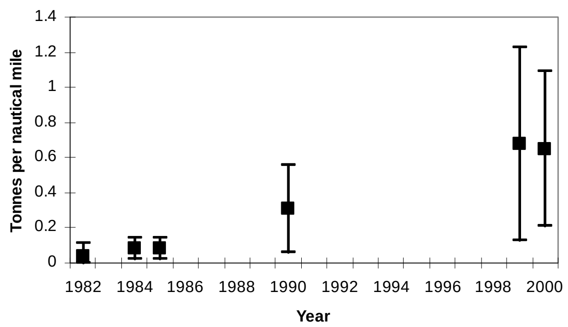
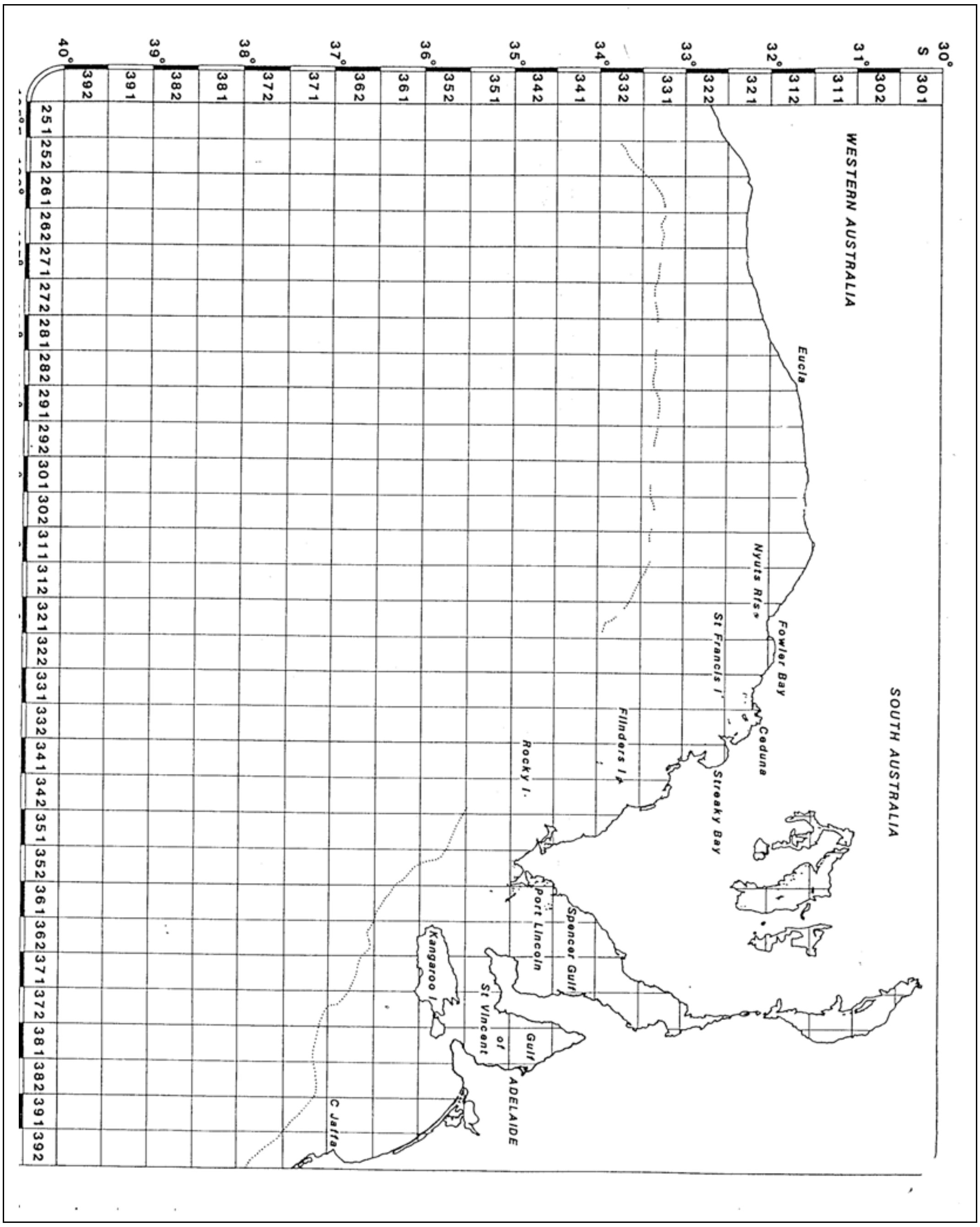


Figure B.10. Standard mean and 95% confidence intervals by fishing season for index F.



APPENDIX C – Aerial spotting data forms



A (1) DATE D D M M Y Y (2 3 4 5 6 7) AIRCRAFT REG. VH ___ (8 9 10) COMPANY ___ (11)

PILOT ___ (12 13) SPOTTER ___ (14 15)

DEPART ___ TIME ___ (16 17 18 19) HRS

ARRIVE ___ TIME ___ (20 21 22 23) HRS

ACTUAL SPOTTING TIME ___ (24 25) HRS ___ (26 27) MINS

WEATHER :- ___ (28 29)

GENERAL SPOTTING CONDITIONS :- ___ (30 31)

SIGHTINGS

1	MAP REF SYMB ETC. (2 21 40 59)	GRID POSN.	SPEC CODE	APPROX. TIME	(14 33 52 71) No. OF SCH	AVERAGE SCHOOL SIZE (TONNES)	FISH SIZE (S.M.L)	COMMENTS	(20 39 58 77)
B									
C									
D									
E									
F									
G									