CCSBT-ESC/0909/38

Update on the global spatial dynamics archival tagging project - 2009

Marinelle Basson
Paige Eveson
Alistair Hobday
Grant West

Prepared for the CCSBT 14th Meeting of the Extended Scientific Committee 5-11 September 2009
Busan, Korea

Table of Contents

Abstract

As part of the CCSBT Scientific Research Program (SRP), Australia initiated a Global Spatial Dynamics project in 2003. This project involved the archival tagging of juvenile (2–4 year old) SBT throughout their range (i.e. from South Africa to New Zealand) with the objective of estimating movement and mixing rates, and periods of residency in different parts of this range. The project has been implemented as a collaborative project between New Zealand (NZ), Taiwan and Australia. The results of this program to date are described. Archival tags have been released in NZ, Australian, central Indian Ocean and South African waters. A total of 559 tags were released, and to date 61 tags have been recaptured (58 reported). These recaptures include the first recoveries ever from archival tags released in the central Indian Ocean and New Zealand. The fish tagged in 2007 and 2008 have not been at liberty long enough to expect substantial numbers of returns, although the relatively low number to date for the 2007 releases is of some concern. The tag deployment phase of the project has been completed, and the main analysis phase has now commenced. The movement patterns of the archival tags returned to date differs from those seen from the archival tagged fish released during the 1990s in the extent of their eastward and westward movements. In particular, only 2 (7%) of the recaptured fish from tags released in South Australia has moved into the Tasman Sea. This compares with 28% of the recaptures from prior archival releases in the 1990s. Also, none of the recaptured fish from releases after 2000 in SA moved into the more western part of the Indian Ocean (<55°E). This compares with 9% previously. Analyses of the archival data to estimate mixing rates in a spatial mark-recapture model are currently underway. Modelling of movement dynamics and seasonal residence times has also commenced. The approach is based on the integration of position, temperature and depth data from the tags with oceanographic data.

Introduction

As part of the CCSBT SRP, Australia initiated a Global Spatial Dynamics project involving the archival tagging of juvenile (2–4 year old) SBT throughout their range (i.e. from South Africa to New Zealand). The primary objective of the project is the estimation of movement and mixing rates, and periods of residency in different parts of this range. The project has been implemented as a collaborative project between New Zealand (NZ), Taiwan and Australia. This paper presents a summary on activities undertaken in the archival tagging project and planned activities in 2009-2010.

Global Spatial Dynamics Project - Overview

CCSBT-ESC/0309/Info04 provided an overview of the global spatial dynamics project for juvenile SBT. The project is a multi-year, large-scale project that CSIRO initiated to improve our understanding of the global spatial dynamics of juvenile southern bluefin tuna (SBT). Over the first 3 years of the project, the goal was to archival-tag 150 to 200 juvenile SBT per year throughout the range of habitats in which they are exploited. Using information from these archival tags, the project aims to improve our knowledge of the spatial dynamics and habitat utilization of juvenile SBT, and to provide an understanding of the implications of incorporating spatial dynamics and habitat-use information directly into the analyses of conventional tag return data, CPUE standardizations using habitat-based approaches, SBT stock assessments, and management advice. The data collected in this spatial dynamics project are now being used to estimate mixing rates, which should help to provide a robust basis for interpreting the conventional tagging results obtained from the CCSBT Scientific Research Program (SRP) conventional tagging. The project is complementary to the SRP conventional tagging program, and builds upon previous and concurrently running archival tagging projects. The data collected under this project should provide valuable information for the design of any future conventional tagging program for SBT.

Archival tag releases and recaptures

The tag deployment component of the project has now been completed. Although the number of release years was extended from the original goal of 3 years (2004-2006) to 5 years (2004-2008), the project has exceeded its minimum goal in terms of number of archival tag releases, with 559 releases as of February 2009. Archival tags have been released in 5 locations in collaboration with this project:

1. in high seas in the central Indian Ocean
2. off the south west of West Australia (WA)
3. in the Great Australian Bight (SA)
4. off New Zealand
5. off South Africa

A summary of the archival tag releases by year and area is shown in Table 1, together with recaptures to date. Note that a few releases and recaptures may have occurred that were not in the CCSBT tag database at time of data extraction (17 February 2009).

Table 1. Numbers of archival tagged SBT by area and fishing year (1 November year *y* —1 to 31 October year *y*), together with corresponding numbers of recaptures. Data were extracted from the CSIRO tag database as at 17 February 2009.

Year	Data	Indian Ocean	WA	SA	Tasman Sea	South Africa	Total
2004	No. released	37	22[a]	23	6	0	88
	No. recaptured	6	6	9	1	-	22
2005	No. released	48	15	40	0	0	103
	No. recaptured	6	3	9		-	18[b]
2006	No. released	25	39	35	30	0	129
	No. recaptured	2	2	11	3	-	18
2007	No. released	49	49	24	19	2	150
	No. recaptured	2	0	1	0	0	3[c]
2008	No. released		49		22	25	90
	No. recaptured		0		0	0	0
Total	No. released	159	174	122	77	27	559
	No. recaptured	16	11	30	4	0	61[d]

a) Deployed in conjunction with CSIRO/NRIFSF Recruitment Monitoring Program (RMP).
b) 2 tags recaptured but not returned, so actual number returned to us is 16
c) 1 tag recaptured but not returned, so actual number returned to us is 3
d) actual number returned to us is 58

A scarcity of suitable fish in New Zealand severely restricted the tagging of juvenile SBT from this area in the first two years of this project. Greater success was achieved during the 2006-2008, resulting in a total of 77 fish released from waters around New Zealand (although some of the recent success was achieved by tagging fish larger than the target range for this project).

As noted previously, the project was unsuccessful in its early attempts to have fish tagged off South Africa (Polacheck et al. 2007). However, during the latter part of 2007 and the early part of 2008, the program was successful in having 27 SBT archival-tagged by observers on Taiwan vessels. In the central Indian Ocean, a total of 159 SBT were archival-tagged between 2004 and 2007.

The total SRP/RMA mortalities in 2005/2006 attributable to the release activities associated with this project were 7 fish or 477kg (CCSBT-ESC/0709/20). No additional SRP/RMA mortalities were attributable to the project since then and no additional ones are anticipated.

A total of 61 tags had been recaptured and entered into the CSIRO tag database as of 17 February 2009, 58 of which have been returned to CSIRO (Table 1). We anticipate that additional archival tags have been recaptured and are in the farms in South Australia and look forward to these being returned during the harvesting operations. As expected, the largest percentage of returns is from the releases in 2004, followed by the 2005 and 2006 releases. It is too early to have had significant numbers of returns from the 2007 and 2008 releases, in particular the latter since fish in the farms from the 2008/09 fishing season in South Australia are still being harvested. From the 88 releases in 2004, 22 or ~25% have been recovered to date. These include 6 from releases in the central Indian Ocean, 6 from releases in Western Australia, 9 from releases in South Australia and 1 from releases in the Tasman Sea (New Zealand). The recoveries from the releases in the Indian Ocean and New Zealand are the first recoveries ever of archival tags from releases in these two areas. For the 2005 and 2006 releases, 17% and 14%, respectively, have been recovered to date. Most of the recoveries have been from the Australian surface fishery, and there has been a paucity of returns from the Japanese (2) and Korean (0) longline fleets. These recovery rates suggest that reporting rates may have declined and that reporting rates may be low in some of the longline fisheries.

Altogether 16 recaptures have been made from the 159 fish tagged by Taiwanese observers in the central Indian Ocean in June-August of 2004-2007 (Table 1). These results, combined with the recapture of 1 out of 6 releases by observers in New Zealand in 2004, demonstrate the feasibility and viability of conducting archival tagging from longline vessels and using trained observers to do the tagging.

As expected, the majority of the (reported) recaptures have come from the GAB (56 of the 61 tags). The remaining 5 recaptures have come from the central Indian Ocean.

Geolocation estimates

Geolocation estimates for archival tags are based on light data – essentially, on the length of day and characteristics of the light curve (over time) at dawn and dusk. In theory this sounds relatively straightforward; in practice it is not, and many different approaches have been developed in attempts to quantify and reduce uncertainty in the estimates. For example, Wildlife Computers (WC) have developed a method based on matching the recorded light curve to theoretical light curves for that day. Other methods are based on estimating when the recorded light reaches a certain threshold level. In general, longitude is better estimated than latitude, but many of the original methods do not estimate the associated uncertainties. Some more recent methods, developed after the start of this project, include the use of covariates to improve estimates; for example Teo et al. (2004) and Nielsen et al. (2006) use sea surface temperature (SST). We will refer to the method of Teo et al. as the ‘Teo adjustment’. Other methods make use of smoothing techniques to reflect the fact that there is a practical limit to the distance an animal can move between one day and the next, and to obtain a relatively ‘smooth’ track (e.g. Nielsen and Sibert 2007; the ‘trackit’ method). The table below shows some of the methods and the type of model each is based on:

	without covariates	with covariates
without smoothing	WC curve matching method	WC method with Teo adjustment for SST Threshold method with Teo adjustment for SST
with smoothing	‘trackit’ method	‘trackit’ method with SST

For the archival tags released under this project, the database currently contains estimates of location from the threshold method with Teo adjustment for SST (for 50 tags), and the ‘trackit’ method without SST (for 40 tags). There are several reasons why position estimates do not exist for all 58 tags that have been returned to us. For instance: the light sensor failed for a few tags; the sensor data for a few recent tag returns still needs to be downloaded into the database; there were problems with downloading the data for a few tags (sometimes these problems can be resolved, but it requires sending the tags to Wildlife computers for processing and can take significant time). Also, the ‘trackit’ method, which involves a fairly sophisticated Kalman filter, does not always converge; although the default settings can be adjusted to try and achieve convergence, this is time-consuming and does not always lead to convergence.

Work is underway to estimate ‘trackit’ locations with SST, but some technical problems that require input from the authors of the software have been encountered. The estimates we have to date are, however, a good starting point for further analyses. We note that one strength of the ‘trackit’ method is that it provides estimates of uncertainty for each latitude-longitude pair; none of the other methods provide this. A potential weakness (depending on how the information is subsequently used) is the fact that smoothing introduces additional autocorrelation. Another weakness is the fact that land is not taken into account in ‘trackit’, so that parts of the tracks (or their uncertainty envelopes) sometimes fall on land. Appendix A contains some example tracks and their uncertainty obtained from the ‘trackit’ method, as well as some plots illustrating the differences between methods.

We have also developed an in-house method of geolocation (under a CSIRO-funded project; the work is in the process of being written up for publication). This method uses the light data at dawn and dusk to construct a Gaussian likelihood which can then be used in subsequent modelling or filtering. A distinguishing feature of this approach is that the Gaussian likelihoods for each dawn and each dusk event are independent, thus making it ideal for use in a subsequent modelling frameworks, such as Kalman filters or Hidden Markov models. It is not ideal to use the maximum likelihood estimates of latitude and longitude from this approach directly since the uncertainties of the estimates are relatively large, particularly for latitude. We are currently in the process of developing a relatively simple filter based on the likelihood, but with the option for incorporating additional information, such as limits on movement and covariates like sea surface temperature, to generate more realistic movement tracks. A planned refinement of this track filter is to incorporate land boundaries to avoid tracks (or their uncertainty envelopes) being on land. Such a refinement is clearly desirable when analysing SBT movement, particularly around the GAB and Tasman Sea.

Change in east-west movement

As noted in previous reports on this project, the movement patterns of the archival tags returned to date continue to differ from those seen from the archival tagged fish released during the 1990s in the extent of their eastward movements (Polacheck et al. 2006a). This analysis has been updated for this report. Only 2 (7%) of the recaptured fish from tags released since 2000 in the GAB have moved into the Tasman Sea (>145°E). This compares with 28% of the tags recaptured from prior releases (Table 2). Based on a chi-square test, this difference is highly significant ($p<0.01$). Also, none of the recaptured fish from releases since 2000 in the GAB have moved into the more western part of the Indian Ocean (< 55°E[1]); this compares with 17% previously (Table 3). The contraction in east-west movement between these time periods is evident in plots showing longitude over time (Figure 1).

A number of factors, including age, month, latitude and longitude of release, were considered to investigate whether the changes in movement were due to some of these factors. However, the changes in movement were apparent even when these factors were taken into account. Such changes in movement and habitat use can have significant implications for the fishery, the interpretation of abundance indices and for management of the stock.

Table 2. The number of recovered archival tags by release year which had a maximum longitude less than or exceeding 145°E. Only fish released in the GAB are included. (Updated with data as at February 2009)

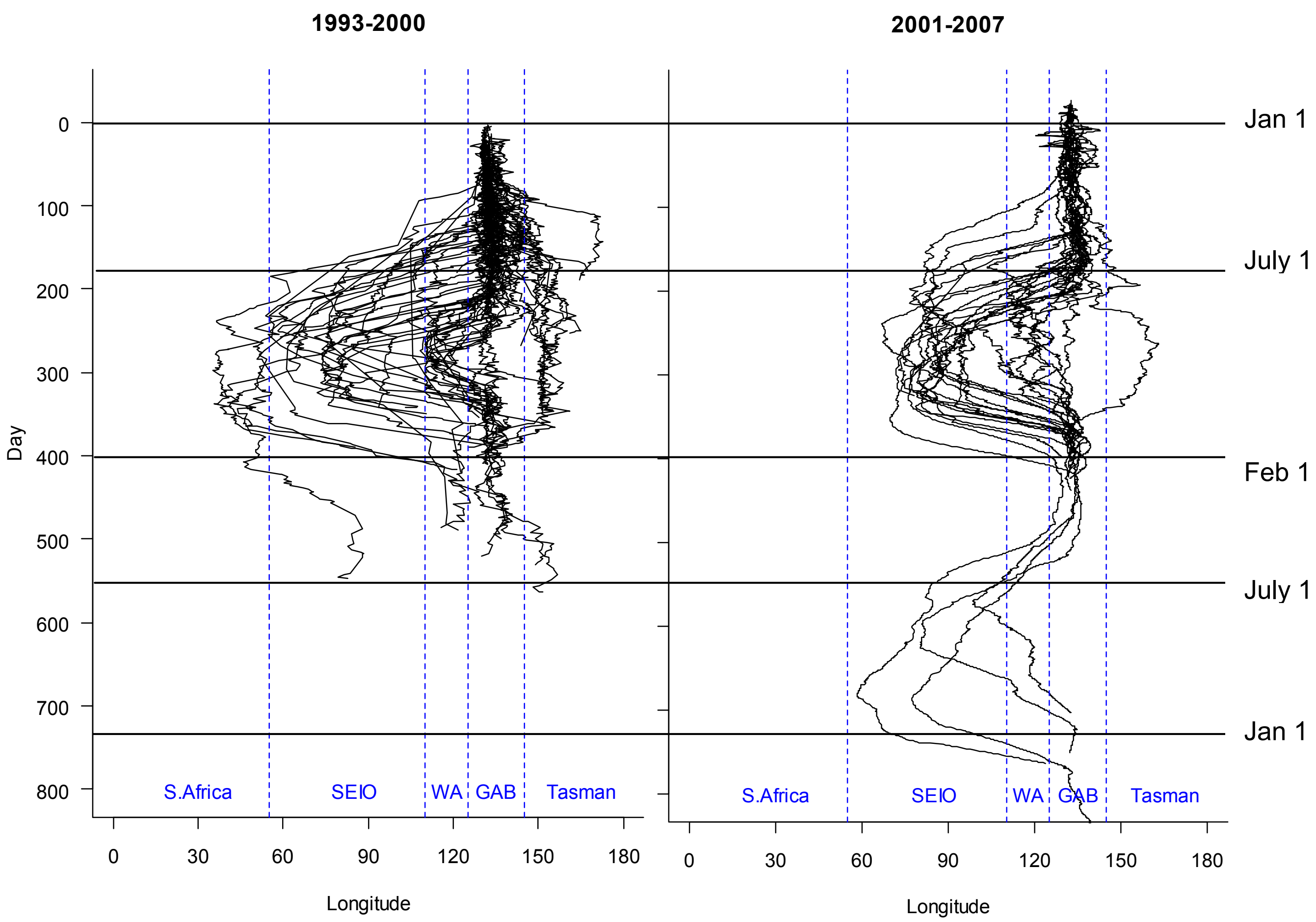
	Maximum Longitude	
Year	≤145	>145
1993	2	0
1994	6	2
1995	12	4
1998	17	7
1999	5	3
2000	6	3
2002	2	0
2004	10	0
2005	13	2
2006	1	0
2007	1	0
Total	75	21

[1] In the past, this analysis was based on 65°E. Further analyses of improved position estimates suggested that 55°E would be more appropriate. The overall result of a change in movement dynamics between the 1990s and 2000s persists using both values of longitude.

Table 3**.** The number of recovered archival tags by release year which had a minimum longitude less than or exceeding 55°E. Only fish released in the GAB are included. (Updated with data as at February 2009)

	Maximum Longitude	
Year	≤55	>55
1993	0	2
1994	1	7
1995	0	16
1998	1	23
1999	2	6
2000	2	7
2002	0	2
2004	0	10
2005	0	15
2006	0	1
2007	0	1
Total	6	90

Figure 1. Longitude estimates plotted against number of days since January 1 of the year of release for fish tagged in the GAB in years 1993-2000 versus 2001-2007.



Mixing rates for use with conventional tag data

One of the objectives of this project is to use the information provided by archival tags on the mixing rates of juvenile SBT between the major SBT fishing areas to inform the analyses of the conventional tagging data. A fundamental assumption in estimation of mortality rates and abundance from tag data is that tagged and untagged animals are fully mixed throughout the range of the population. For SBT, this can be difficult to achieve since they are distributed over such a large geographic area. If complete mixing is not achieved, then spatial heterogeneity in survival and capture probabilities can lead to biased estimates of mortality rates and abundance if not accounted for. This is particularly relevant in the case of SBT since conventional tagging primarily occurred off western and southern Australia, rather than over the full distributional range of juveniles. We know that capture rates differ significantly between major fisheries/fishing regions for juvenile SBT, so it is important to consider a tagging model that takes spatial heterogeneity into account.

As part of a previous FRDC project, Polacheck et al. (2006b) developed a discrete-space, discrete-time spatial model for estimating mortality rates (both fishing and natural), abundance and movement probabilities from conventional tag-return data. The model was initially developed under a general framework, but was subsequently modified to accommodate spatial and temporal dynamics resembling those of juvenile SBT (see Appendices 11 and 16 of Polacheck et al. 2006b for details). We refer to this as the spatial SBT model.

Having position estimates from archival tags that were released at the same time as conventional tags can improve the spatial SBT model in a number of ways. First, archival tag data can provide valuable information about the appropriateness of the spatial and temporal structure being assumed; e.g., are the area and season definitions reasonable? The archival tag data collected to date have already highlighted the need for some changes to the structure of the model. In particular, the model has an area referred to as South Australia, where juvenile fish are present only in summer, after which they migrate to one of three longline regions. Originally we thought fish of ages 1 and 2 were found off of Western Australia predominantly in the summer, so this area was included with the GAB as part of the summer South Australia region. The archival tag tracks show that, in fact, quite a few fish spend their winter in waters around WA before going back into the GAB (e.g. Figure A1 of the Appendix A), so it would make sense to have WA as a separate region that can have juvenile SBT present in both summer and winter.

Second, the spatial SBT model has difficulty separating fishing mortality from movement with conventional tagging data alone. The information provided by archival tag data on fish location/movement can be very useful in this regard. Two general approaches for including this information in the model are: i) use the information to estimate the movement probabilities, which can then be plugged directly into the model as known or as priors (i.e., with uncertainty), or ii) directly incorporate the information within the model through an additional likelihood component. We are currently exploring both approaches, and applying them to archival data from the 1990s and 2000s. Good progress has been made to date, and we anticipate providing results of these analyses to the CCSBT SC in 2010.

Plans for 2009–2010

The archival tag releases intended for this project have now been completed. There are no plans for further releases, and only if additional tags were made available would additional releases be possible. The focus of the work in 2009-2010 includes: completion of the in-house geolocation method and track-filter (under a CSIRO funded project) to use with the archival tag data from the "Global Spatial" project; continued work on using archival tag data to improve the conventional tag model for estimating movement rates, mortality rates and abundance; and integrating position, temperature and depth data from the tags with oceanographic data to develop a seasonal model of residence times and habitat use for regions with consistent temporal patterns across years.

Acknowledgements

We wish to acknowledge and thank the collaboration provided by New Zealand and Taiwan fishing industry and observers for assistance and collaboration with tag deployments. We also wish to thank the fishery administrations in these two countries for their cooperation and help in facilitating the work. We wish to thank the crew of the *ATU-S* for their enthusiasm and support during the charter of South Africa and for the efforts of Thor Carter and Mark Rynar (from CSIRO) to tag SBT during this cruise. Brian McDonald of the CCSBT Secretariat provided invaluable logistic assistance with the vessel charter for the surface fishery. Funding for this project is being provided by the Australian Fisheries Research and Development Corporation (FRDC), the Australian Department of Agriculture, Forestry and Fisheries (DAFF), CSIRO Marine and Atmospheric Research and CSIRO's Wealth from Oceans Flagship. Mr. Yan Feng-lung has provided invaluable assistance in facilitating arrangements with the Taiwanese scientific observers. Geoff Campbell and the crew of FV Quadrant were invaluable during tagging of SBT in southern Western Australia for 2007/08.

References

Polacheck, T., J. Gunn, and A. Hobday. 2003. Global Spatial Dynamic Project for Juvenile SBT. CCSBT-ESC/0309/Info 4.

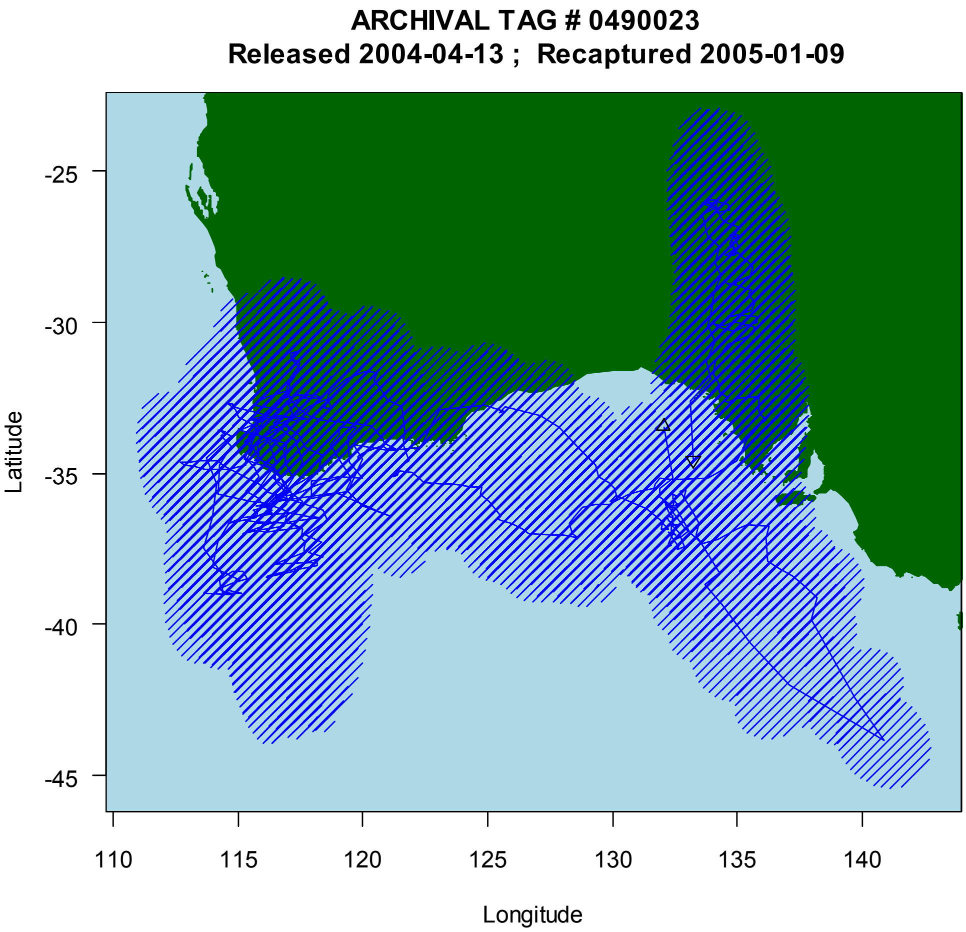
Polacheck, T., A. Hobday, S. Bestley, J. Gunn. 2006a. Comparison of East-West Movements of Archival Tagged Southern Bluefin Tuna in the 1990s and early 2000s. CCSBT-ESC/0409/28.

Polacheck, T., Eveson, J.P., and Laslett, G.M. 2006b. Estimation of mortality rates from tagging data for pelagic fisheries: analysis and experimental design. Final report. FRDC project 2002/015.

Polacheck, T., S.K. Chang, A. Hobday and G. West. 2007. Update on the Global Spatial dynamics Archival Tagging project - 2007. CCSBT-ESC/0709/20.

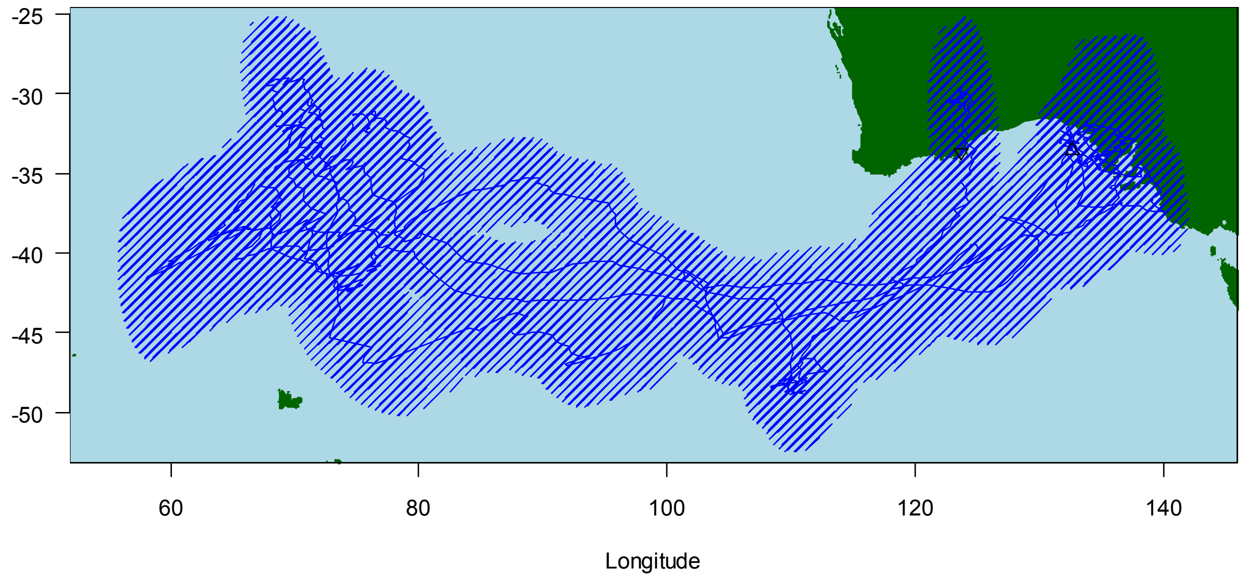
Appendix A: Geolocation – examples of estimated tracks

Figure A1. Tracks estimated using the software package “trackit” for a few selected archival tags. The solid line shows the most probably track, and the shaded area shows the 95% confidence region.
a)



b)

ARCHIVAL TAG # 0490376
Released 2005-03-02 ; Recaptured 2007-03-14



c)

ARCHIVAL TAG # 0490516
Released 2005-12-19 ; Recaptured 2007-01-27

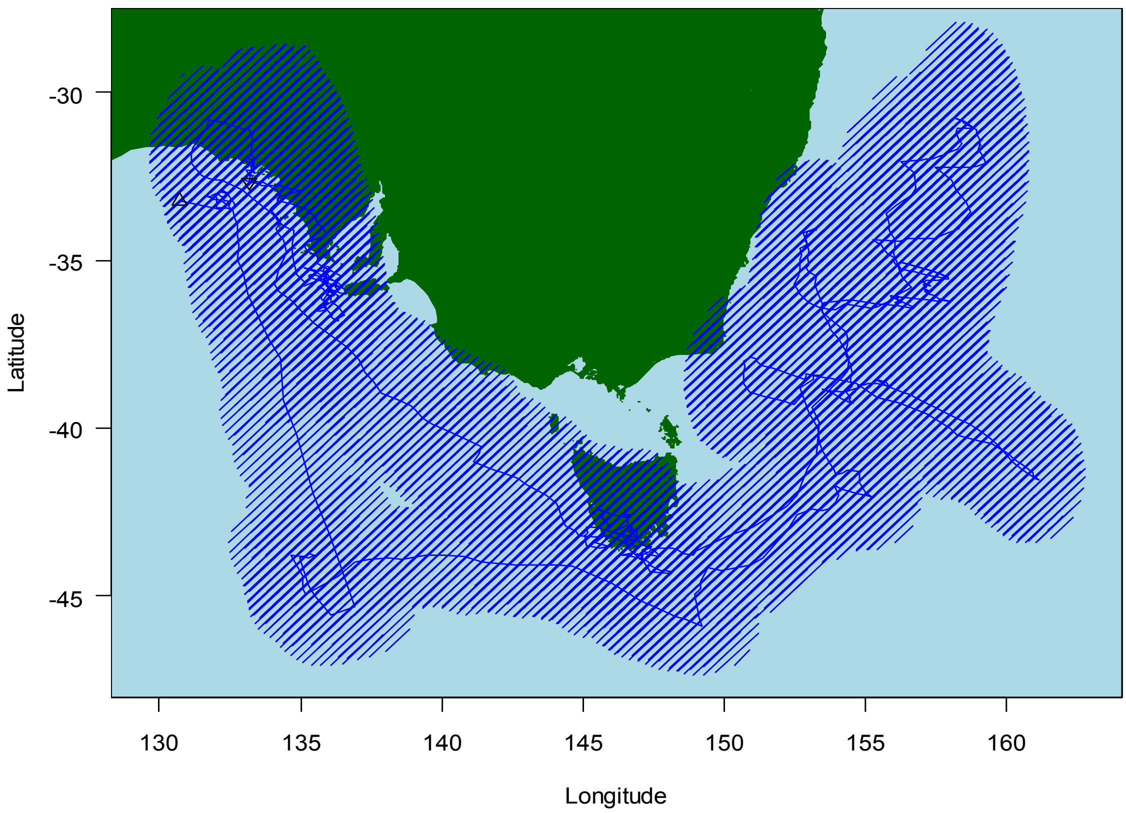
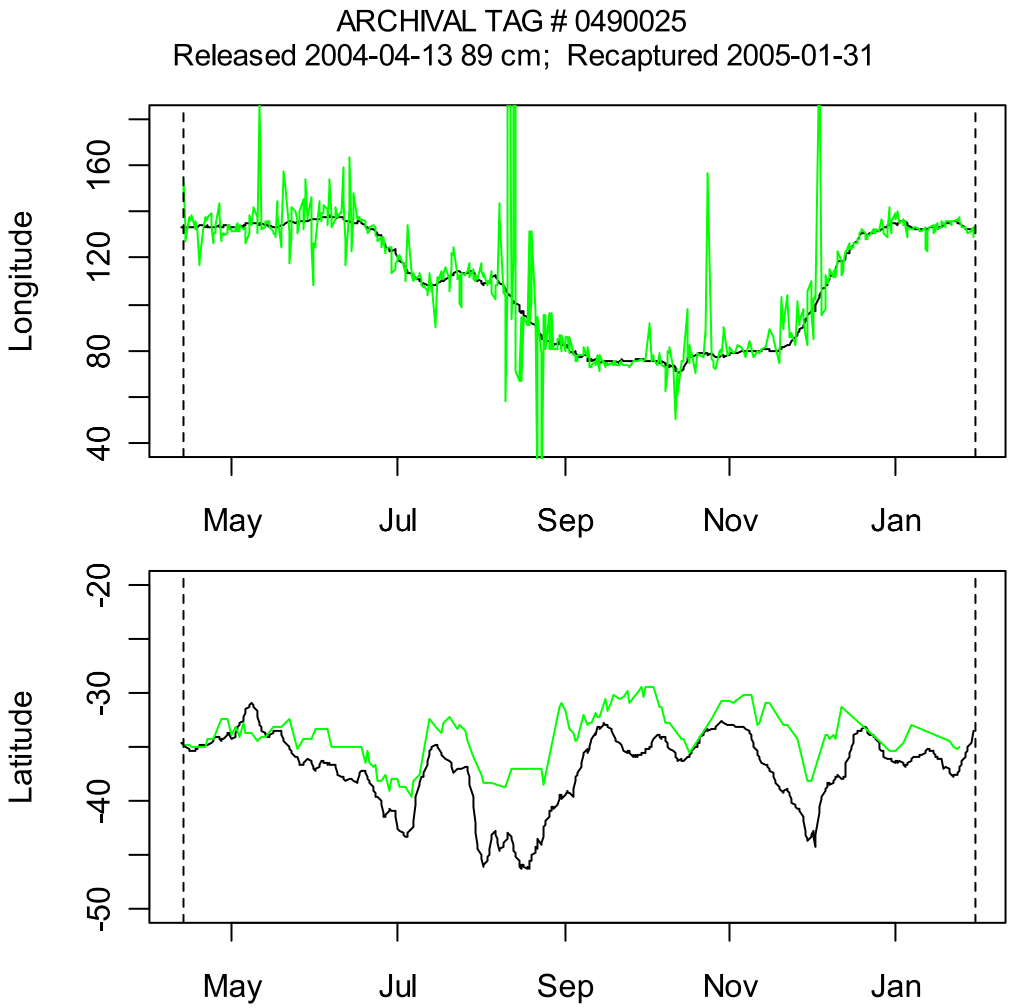


Figure A2. Longitude and latitude estimates obtained using a) the threshold light method with Teo adjustment for SST (green lines), and b) trackit software (black lines).



Longitude estimates tend to be very similar across methods. Even though the longitude estimates from the threshold method (green line in top of Figure) are highly variable, if a smoother was applied to the estimates they would be very similar to the estimates from trackit (black line). As for the latitude estimates, the threshold method with Teo adjustment produces quite different latitude estimates than the trackit method (green line vs. black line in bottom of Figure). If the reasons for these large differences cannot be determined and we have no way to resolve which are most reliable, then it may be necessary to consider the estimates from several methods in any analyses which require latitude.

Note that Figure 3 gives no indication of the uncertainty in the estimates. The only method that provides estimates of uncertainty is trackit. It is well documented that the uncertainty in latitude tends to be much larger than the uncertainty in longitude, and this is supported by the estimates produced by trackit. However, even though the estimates of uncertainty in latitude from trackit are quite large, they still do not cover the range of latitude estimates produced by the different methods.