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Report of the global spatial dynamics project: Non-Technical Summary

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Important disclaimer

Abstract

This document consists of the Non-technical summary of a recently completed project titled: "Spatial Interactions Among Juvenile Southern Bluefin Tuna at the Global Scale: A Large Scale Archival Tag Experiment". The full report should soon be available on the FRDC website under 'recently completed reports' (http://www.frdc.com.au/research/recent-final).

1 Non-technical Summary

2003/002. Spatial Interactions Among Juvenile Southern Bluefin Tuna at the Global Scale: A Large Scale Archival Tag Experiment

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OBJECTIVES:

The final set of objectives is listed here; the rationale for changes during the project is discussed in **Section 5**.

Objective 1: Tag 150-200 juvenile southern bluefin tuna (SBT; *Thunnus maccoyii*) per year for 3 years with archival tags throughout the full range of spatial habitats in order to provide a comprehensive understanding of their spatial dynamics;

Objective 2: For each tag returned (expected to be ~20-30%) estimate daily position based on the stored light and temperature data and develop a database for the storage and analysis of all relevant location, temperature and depth data;

Objective 3 (revised): Provide a comprehensive analysis of the evidence for temporal changes in the spatial dynamics of juvenile SBT, and analyse the implication of the information provided on mixing rates between the major SBT fishing grounds and their changes over time for the use of combined archival and conventional tagging data to provide fishery independent estimates of fishing mortality for monitoring the SBT fishery.

Objective 4: Provide critical information and contribute to developing a framework for incorporating the archival tag and conventional tagging data within the SBT stock assessment model;

Objective 5 (revised): Integrate the position, temperature and depth data provided by the tags with oceanographic data to develop a seasonal model of residence times and habitat use for regions with consistent temporal patterns across the years.

Objective 6 (revised): Evaluate the implication from the seasonal habit model for the interpretation of future catch and effort data and monitoring strategies.

Objective 7: Evaluate implications of the spatial dynamics of juvenile SBT for the management of the SBT resource (e.g. the potential consequences and benefits of either ignoring or using spatially explicit management actions).

OUTCOMES ACHIEVED TO DATE

This project has led to substantial improvement in our current understanding of southern bluefin tuna (SBT) movements and spatial dynamics, which should form the basis for improved models, including spatial population dynamics models to underpin future assessments and management procedures for SBT. Uptake of results has been delayed by the CCSBT's (Commission for the Conservation of Southern Bluefin Tuna) recent focus on developing a management procedure for SBT.

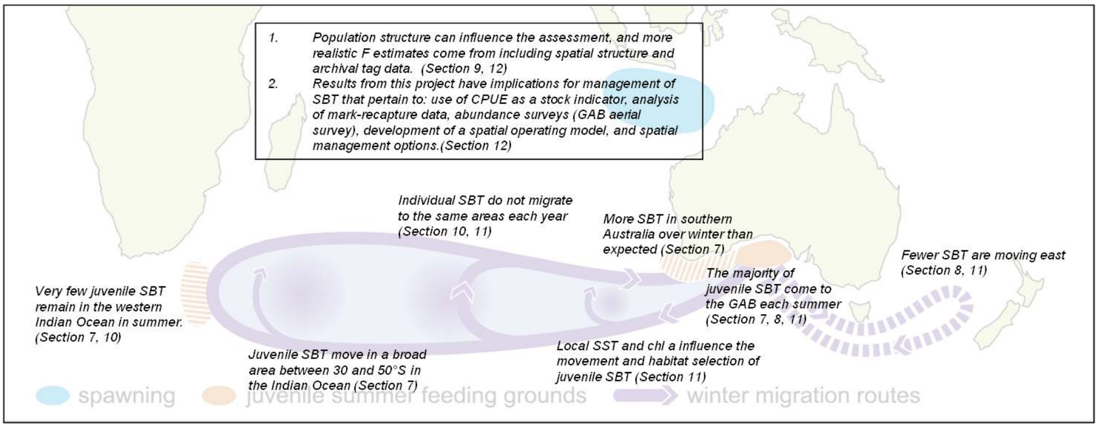
Results have increased our confidence in the recruitment index based on the aerial survey in the Great Australian Bight (GAB) by confirming that the timing and duration are ideal, that the majority of juvenile SBT are likely to return to the GAB each summer, and that based on current evidence it is unlikely that a large proportion of juvenile SBT remaining off South Africa over summer. This is of benefit to all stakeholders and management bodies, including the CCSBT. The extension of a tag-based assessment model for SBT to include a spatial component, and the incorporation of archival tag data into the model, is a significant achievement and of major interest to the international community. Methods developed to study migration patterns and habitat preferences of SBT suggest that habitat-based CPUE standardization is unlikely to be as useful for SBT as first anticipated, but these methods may be useful for dealing with unfished areas when standardising CPUE.

By using information in this report, the fishery can now also address requirements within the guidelines under the strategic assessment provisions of the Environmental Protection and Biodiversity Conservation Act 1999 that "the distribution and spatial structure of the stock(s) has been established and factored into the management response".

Spatial structure of fish populations has long been recognised as a potentially critical factor in a population's overall dynamics, and hence of importance to stock assessments and management. Neither the population model used for southern bluefin tuna (SBT; *Thunnus maccoyii*) assessment and evaluation of management procedures, nor the management of SBT by a global total allowable catch (TAC) take spatial structure into account. In this ambitious project we used archival tags to provide the necessary data to start integrating the spatial dimension into the population ecology and assessment of SBT.

International collaboration between several SBT fishing nations was critical to the deployment and recovery of archival tags for this project. Tags were successfully released in all five desired areas (n = 568) on juvenile SBT ('juveniles' refers to ages 1-4, but our dataset has few age 1 individuals). The recoveries to date (n = 74) represent 13% of releases, and include tags deployed by collaborators. Combined with earlier tag programs, a total of up to 122 tags were available for this project. To date there are no returns from tags released off South Africa, so questions about the movement dynamics of juveniles off South Africa remain. Tags recorded up to 5 years of data (n=2), 75% of tags covered at least 6 months, and

41% covered at least one year – a marked improvement on the performance of early archival tags. The following schematic illustrates some of the findings discussed in the report.



The first step in analysis was the difficult task of estimating the daily position of each SBT (latitude and longitude) from the light and depth data recorded by the archival tags. Two different approaches gave broadly consistent results, thus increasing confidence in subsequent use of these location estimates. Clear signals of cyclic seasonal movement are apparent from the estimated tracks. All SBT in our dataset spent each summer (or part thereof) in waters south of Australia (i.e., the GAB and waters south of WA), except one SBT tagged in the Indian Ocean in winter that visited the GAB in the summer following tagging, but spent two subsequent summers in waters off South Africa. Given the relatively low selection of age 2-4 fish in longling catches, and the absence of a surface fishery off South Africa for those ages, our dataset has mostly returns from the surface fishery in the GAB. This means that juvenile SBT that cease to visit the GAB, or that never visit the GAB, may be under-represented in our dataset. The majority of SBT in our dataset migrated from southern Australia to the Indian Ocean for winter, a much lesser percentage to the Tasman Sea and, somewhat surprisingly, a number of individuals overwintered in southern Australia. Juvenile SBT move in a broad area between 30-50^{o}S in the Indian Ocean; there does not appear to be specific, or narrowly defined, migration routes.

The position estimates were used in: 1) a spatial model for analysing mark-recapture data, (2) development of a seasonal migration model, and (3) estimating habitat preference. Two large conventional tagging programs were conducted by the CCSBT in the 1990s and the 2000s to reduce uncertainty in the assessments by providing estimates of mortality rates and abundance. For logistic reasons, juvenile SBT can only cost-effectively be tagged off southern Australia in summer. In such a situation, an analysis that ignores spatial structure can lead to biased estimates of mortality rates and abundance. We developed methods for incorporating archival tag data into a spatial mark-recapture model and applied these methods to simulated data, as well as to SBT conventional and archival tag data from the 1990s and 2000s. The simulations showed that including data from even a modest number of archival tags can substantially improve the precision of movement and fishing mortality estimates, particularly when fish are only tagged in some areas. In the application of the model to SBT data from the 1990s and 2000s, estimates of movement probabilities were unrealistic without archival tag data (e.g. for the 1990s almost no fish were estimated to return to the GAB for summer); realistic estimates were only obtained when archival tag data were included. For the 2000s data, cohort size estimates were consistently higher and natural and fishing mortality estimates were consistently lower with the spatial model compared to estimates obtained from a non-spatial model. Thus, using a spatial model to analyse the 2000s tagging data had an important effect on results. A spatial model is considered important for planning and analyses of future mark-recapture programs.

A seasonal model of migration (directed, fast movement) and residency (undirected, slow movement) was developed. Although there is variability in movement dynamics amongst individuals, we quantify the periods of time spent in the resident state in summer and in winter, and the time spent migrating, either out of the GAB or back into the GAB. We have quantified the main departure times from, and arrival times to, areas of high residency, as well as the variability in those times. These results have confirmed that the aerial survey timing and duration are well matched with the arrival and departure of SBT. In addition, we did not find evidence to suggest that there is a large proportion of juvenile SBT resident in waters off South Africa in summer. This substantially increases our confidence in the aerial survey as an index of juvenile SBT abundance. However, the archival tag data to date does not answer the question of whether there are juveniles (age 4 and younger) that never visit the GAB in any summer; the answer could still be “yes”. A returned tag released off South Africa (of which we have had none to date) may help answer the question, but an answer is more likely, and more cost effectively, obtained by otolith microchemistry.

The migration model results confirm that the high variability in migration paths and timing among individuals and years mean that low spatial (and temporal) coverage of effort remains a serious problem for getting a reliable index of abundance from catch and effort data. A spatial model and spatially explicit CPUE indices are likely to provide a more reliable interpretation of trends in CPUE series.

Habitat preference was determined by considering the combination of (i.e. interaction between) sea surface temperature and chlorophyll *a*. Preference maps show that in most years the GAB is highest preference summer location in the southern oceans. In some years the area off NSW, where a surface fishery used to operate until the early 1980s, and areas off South Africa also show up as areas of high preference. Maps for the late 1990s show a linking band of high preference around Tasmania and into the Tasman Sea in April to June, which is almost absent in recent years. This could be one reason why fewer juvenile SBT have been migrating to the Tasman Sea in winter since 2001.

Habitat preference analyses could potentially help deal with unfished areas (i.e. no fishing effort) when standardizing CPUE. However, habitat preference for the predominant age classes in the longline catches (i.e. older than the age classes involved in this study) will first have to be developed, and variability in preferences and environmental conditions over time will have to be considered. Other approaches to CPUE standardisation, such as models for estimating catchability by depth, will require substantial additional data collection (e.g. on sub-adult SBT behaviour) and analyses. We doubt the value of embarking on such an exercise for this purpose, given that it would not resolve the major concerns of (1) operational changes in longline fleet behaviour and (2) lack of spatial and temporal coverage. We do not doubt the value of collecting more data on sub-adult behaviour, which is lacking for SBT, just that we discourage doing so solely for the purpose of CPUE standardisation.

Spatial structure of a population can influence stock status assessments, and results from this project suggest that a spatial operating model for SBT would be preferable to a non-spatial model, both from the point of view of mark-recapture data analyses and the interpretation of CPUE indices. Developing a spatial operating model should be possible, but will not be a straightforward or quick task. Decisions about a range of modelling issues would need to be made within the relevant CCSBT forums. A program for ongoing data collection to inform a spatial model would need to be designed. However, the operating model framework is ideal for dealing with uncertainty and gaps in knowledge, and ideal as a tool for guiding the development of a cost-effective future data collection program. Given the challenges with CPUE interpretation, we also suggest a return to mark-recapture approaches, both for use in the (ideally, spatially explicit) operating model and for potential use in a future management procedure.

Regarding spatially explicit management, there is a strong case for a separate TAC on age 2-4 juveniles in the GAB during summer because of their segregation by age and the strong summer site fidelity suggested by the dataset considered in this project. By accident – rather than design – this is the case since the Australian 'member country' allocation is currently almost entirely taken by the juvenile surface fishery in the GAB. We have not found any evidence to suggest that there is a large proportion of juvenile SBT off South Africa in summer, but the question remains unanswered. If this situation changes and if a sizeable fishery did develop off South Africa, then spatial management of the juvenile component would need to be considered. This is because there is a strong possibility that juveniles off South Africa would show similar high levels of summer site fidelity as juveniles in the GAB do. The need for spatial management of the winter longline component, i.e. 'Tasman SBT' and 'Indian Ocean SBT', to avoid localised depletion is less clear because winter site-fidelity of age 5 and older SBT is unknown. Another advantage of a spatial operating model would be the ability to evaluate the need for spatially explicit management.

Overall, we have assembled the most comprehensive picture yet of the cyclical seasonal migration and global movements of juvenile SBT, which will support future spatial assessment (and management where appropriate), as well as process understanding for this species.

Keywords: Southern bluefin tuna, *Thunnus maccoyii*, archival tagging, spatial dynamics, habitat use, spatial mark-recapture model

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