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SRP Proposal:

Identification of spatial distributions of fish by age from otolith microchemistry

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Abstract

A long-standing question in SBT spatial dynamics has been the proportion of the population of juvenile SBT (age 2-5 years) that spend the summer in the Great Australian Bight (GAB) foraging grounds. Otoliths may be able to provide such information about movements and residency because they act as a natural archive of the environmental conditions experienced over the life history of fish.

An initial examination of 21 SBT otoliths collected from 3 locations (the GAB, the spawning grounds and the western coast of Australia; Clear et al., 2014) explored the trace element concentrations from laser ablation transects at the otolith core and outer margin. This study indicated that significant differences can be detected between fish collected at different sites and in different years.

Having seen the potential of this technique, the analysis of a larger number of otoliths, from a more comprehensive spatial and temporal design, will aim to quantify the average fraction of the juvenile population that spends the summer in the GAB and the extent to which this varies systematically over time.

The results of such as study would be relevant for the interpretation of the aerial survey index, as well as the validity of the assumption about the extent of mixing related to the conventional tagging program, and the design of any future tagging programs.

This is a draft proposal for a collaborative project among CCSBT members, for further development at the ESC. There are opportunities for contributions and capacity building in analytical design, otolith preparation and micro-chemical and data analysis.

1 Introduction

A critical question in SBT dynamics has been what proportion of the juvenile population spends summer in the Great Australian Bight (GAB), and whether this proportion is constant over time. This information is central for interpreting the index of relative juvenile abundance in the GAB from the line-transect aerial-survey as an index for the juvenile population of SBT (Eveson et al., 2010). The index is one of two inputs series to the CCSBT management procedure (MP) and is also the only fishery independent relative abundance index in the operating-model (OM). The CCSBT-SC (Anon, 2007) noted “the importance of additional research to determine what proportion of the juvenile SBT population enters the GAB as large variability or trends in the proportion would complicate the interpretation of these recruitment series.” The potential to address this question via otolith microchemistry has been identified as a priority activity in the CCSBT Scientific Research Program 2014-18 (Anon, 2013). Otoliths may be able to provide such information about movements and residency because they act as a natural archive of the environmental conditions experienced over the life history of fish.

SBT otoliths have been collected and archived by CSIRO and others since the 1980s and stored in the CSIRO SBT hardparts archives and are used to monitor the age distribution in the commercial catch (Farley et al., 2010a). SBT otoliths from mature fish have been collected from the spawning grounds since 1994 and used to monitor changes in size and age of the spawning population (Farley et al., 2010b; Farley et al., 2014). The otoliths exist as pairs and only one otolith from each pair has been used for direct ageing in these projects so the remaining otoliths provide us with a valuable opportunity for further analysis. In addition, the CSIRO hard parts archives contain a limited number of otoliths that have been collected from fish that had been tagged with archival tags. We will analyse the otolith chemistry of these individual otoliths and use the archival tag position estimates to establish a known time and position of summer feeding grounds.

Advances in otolith microchemistry have shown that trace element composition can be used to infer tuna movements and as a stock identification tool (Rooker et al., 2003; Wang et al., 2009). Wang et al. (2009) identified a spawning site signal in the otoliths of SBT at the primordium, the earliest-deposited part of an otolith. At the otolith margin, which is formed later, they found significant differences between the otolith elemental composition in the sub-adults caught on the central Indian Ocean feeding grounds and adults on the spawning grounds.

The objectives of the otolith microchemistry study are:

1. Measure trace elements in of 80 SBT otoliths using laser ablation inductively coupled mass spectrometry (LA-ICP-MS).
2. Establish the trace element fingerprints by area, year and age class.
3. Estimate the proportion of juvenile SBT resident in the GAB in summer for each year.
4. Summarise implications of results for (a) the interpretation of the aerial survey as a relative index of abundance of the 2-4 year old proportion of the SBT stock and (b) the spatial structure of SBT population models.

This is a proposal for a collaborative project among members. There are opportunities for contributions and capacity building in design, laboratory and analysis.

2 Methods

Samples

To obtain site-specific otolith chemistry signals we will examine otoliths collected from different locations including the GAB, the west coast of Australia and the spawning grounds, all of which are available in the CSIRO archives. If we are able to establish collaboration between member countries, this could be expanded to samples collected from fishing areas in the central and south-western Indian Ocean and possibly the Tasman Sea.

Preparation for LA-ICP-MS

Otoliths will be sectioned to expose a plane that contains the earliest formed part of the otolith, the primordium, and the most recently-formed portion at the margin. The sections will be polished using several stages of lapping film, decreasing in grit size, to produce a highly-polished finish in preparation for LA-ICP-MS analysis. Analysing the otolith from primordium to margin provides a “life-history” of the trace elements incorporated into the otolith matrix.

Age estimates

The otolith sections will be examined under transmitted light microscope to estimate the age of each fish and to identify the position of annual increments.

Analysis by LA-ICP-MS

Elements in the otolith will be measured along the growth axis from the primordium to margin using a laser ablation system coupled with an ICP-MS. Samples will be analysed at two points: near the primordium, which will provide a chemical fingerprint for the spawning ground, and at the otolith edge, which will provide a site signal from the area and time in which the fish were caught. A subset of otoliths will be analysed by following a continuous path along the whole growth axis from primordium to the otolith edge to provide seasonal information.

Data Analysis

To differentiate the otolith chemical fingerprints of SBT caught in different areas, we will use statistical analyses similar to those used to analyse data from the initial pilot study in CCSBT-ESC/1409/22 (Clear et al. 2014). Specifically, univariate statistical analyses (e.g. ANOVAs using individual elements) and multivariate analyses (e.g., MANOVAs and discriminant function analysis using multiple elements) will be used to test for significant differences between areas in element concentrations at the otolith margin (which corresponds to the time and location where the fish was caught). We will also examine the data for temporal variation in site signals by comparing element concentrations at the margin of fish caught at the same location but in different years. Moreover, we will examine the data for ontogenetic effects that produce changes in the fingerprint over the life of the fish by comparing element concentrations at the margin of fish caught at the same location in the same year but at different ages.

Similar analyses can be done using data from the otolith core, corresponding to when fish are in their larval stage on the spawning ground. We would test whether fish caught in the same year have the same trace element patterns at the core and, if so, whether there are significant differences in element concentrations between different years. We would also investigate whether the composition of the otolith already formed is altered over time, by comparing data at the core from fish spawned in the same year but caught at different ages.

Ideally, the size for each sample group from different areas, ages and years would be a minimum of 5 fish. We would aim to analyse otoliths from 50-80 SBT to cover the sample groups. The results from the pilot study (Clear et al. 2014) will be included in any future data set, taking the total number of samples to around 100.

In addition to looking at data from the margin and core, where the location of fish is known, we would investigate the use of hidden Markov models (HMM) to reconstruct individual life histories from their otolith signatures, using individual or multiple elements (see Fablet et al. 2007). In our case, the hidden states are different habitat types and/or locations. Each measure of an elemental concentration along the otolith transect is associated with a specific hidden state, and the HMM attempts to reconstruct the temporal sequence of hidden states based on the observed sequence of element concentrations.

Validation using archival tag data and oceanographic data

The CSIRO hard parts archives contain a limited number of otoliths that have been collected from fish that had been tagged with archival tags. We will analyse the otolith chemistry of these individual otoliths and use the archival tag position estimates to establish a known time and position of summer feeding grounds. From this we will validate the chemical fingerprints we establish from non-tagged fish. Independent sources of oceanographic data that describe conditions in areas where SBT are caught will provide additional validation.

3 Collaboration

Collaboration and member contributions are welcome in this project. In particular we welcome member assistance in the design and analysis phases. CSIRO is willing to co-invest funding to meet the cost of this project.

4 Approximate Costs

STAGE	COMPONENTS	TIMING (BASED ON CCSBT CALENDAR YEAR FUNDING)	COSTS
1	Design of study Determine which available samples will best fulfil objectives	Year 1	$0
2	Otolith preparation	Year 1	~$40,000
3	LA-ICP-MS analysis	Year 1	~$25,000
4	Data analysis Application of results to the interpretation of the aerial survey index and spatial structure of SBT	Year 2	~$30,000
Total			~$95,000

5 Benefits

The analysis of the otolith chemistry data could contribute to assessing the validity of the current assumptions of consistent and complete mixing of juvenile SBT and that a constant proportion of the juvenile population spend their summer in the GAB and are available to the scientific aerial survey. Similarly, this would apply to the assumptions relating to tag mixing.

Completion of the study in 2016 would mean the results would be available for consideration by the ESC and Commission in time for the review of the MP scheduled for 2017 and consideration of the relative cost-effectiveness of gene-tagging of juvenile SBT as an alternative means to a recruitment index. Given the potential for the otolith chemistry results to provide information for the design of a large gene-tagging project, it is a relatively small investment for the benefit it could provide. The overall cost of the project could be reduced if collaborators provided access to LA-ICP-MS facilities, hence reducing the call on CCSBT member funding.

The application of techniques developed in the project would have the potential to establish a periodic monitoring series to examine whether spatial dynamics change as population recovers. The routine collection and archiving of otoliths from the Indonesian longline fishery and the Australian surface fishery,(funded by the Australian Fisheries Management Authority and CSIRO) has provided a valuable source from which to choose samples, and has allowed us to examine the temporal signal in the otolith fingerprint from those areas. A collaborative otolith chemistry project that included CCSBT member countries would provide an opportunity to expand the samples analysed to all SBT areas.

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