Tracing the migratory environmental history of southern bluefin tuna (*Thunnus maccoyii*) by otolith elemental fingerprints

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Introduction

Fish otoliths are mainly composed with calcium carbonate ($CaCO_3$) and grow simultaneously with fish grow. Therefore, it has been commonly used for age determination of fish, reconstructing the histories of their ontogenetic change event and calculating their daily / annual growth rates (Campana, 1999; Secor *et al.*, 1995). The trace element composition on the otolith also records the environment history that fish have been experienced. In recent year, the state-of –the-art otolith trace element analyzing technique has been established and the information of otolith microchemistry trends are useful tool for tracing the migratory environmental history of the fish. Therefore, present study applied the technique on the otolith of southern bluefin tuna (*Thunnus maccoyii*), and expect to understand their migratory pattern.

Southern bluefin tuna (SBT) is a long-lived, slow-grow temporal fish, and it is also one of the most valuable tuna species. It was discovered that SBT has a single spawning ground near tropical Java in the Indian Ocean (7-20^{o}S) and its main spawning season is around January-February. The feeding ground of SBT is in between 30-50^{o}S (Caton, 1999). The differences of the water mass chemistry between its tropical spawning ground and temporal feeding ground should be able to be detected from otolith trace element composition.

Materials and Methods

Sample collections

Eleven SBT otoliths collected in spawning ground (south of Java, Indonesia) were used for analyses. Five of them were sampled on January and 6 were sampled on February 2004. SBT otoliths collected from feeding ground (central Indian Ocean) were also analyzed for comparing. Four SBT sampled in July 2003 and 12 sampled in July 2004 were analyzed for present study.

Trace element analysis

The LA ICP-MS system consists of a Merchantek LUV266 laser microprobe connected to a Finnigan MAT ELEMENT 2 high resolution inductively coupled plasma mass spectrometry were used for analyzing SBT otolith chemical composition. Each otolith was embedded in resin to make a transverse section cutting and was pre-ablated to remove surface contamination. The laser was pulsed at 20 Hz across the transverse section moving from the core to the terminal edge at a speed of 15 μm per second (Fig. 1). Each data point takes about 2.46 second that represent the chemical composition of each 37 μm. The distance from the edge to the core and each annual position on the otolith section were measured for understanding the corresponding elemental data point of specific duration of the life history. Another analysis was carried out along the terminal edge of each otolith and the data were used for represent the chemical fingerprints of the sampling location. We intent to compare SBT individuals collected in different area (south of Java, spawning ground; central Indian Ocean, feeding ground) to see if the chemical mark of the sea water mass could be left on SBT otolith.

Results

Six elements were detected on SBT otolith, and they are Na, Mg, Mn, Sr, Ba and Ca. Data were presented as element to Ca ratios in all further statistic analysis. Mg/Ca and Mn/Ca ratios were high before 1 year age, but decreased dramatically after 1 year. Na/Ca ratio trends were also high before 1 year, and decreased slightly after 1 year. Sr/Ca ratios were increasing along the fish grow and were lower in annulus and gradually increase toward the edge. The Ba/Ca ratios were changed different in each individual.

Canonical discriminant analyses showed that the chemical composition of the edge of SBT otolith from the four groups of samples (Spawning group Jan 2004, Feb 2004, Feeding group: July 2003 and 2004) could be separated (Fig. 2a). However, the spawning groups collected at different month show similar composition at the edge of the otoliths. Moreover, by comparing the composition of the SBT otolith core (about 100 μm around the core) and juvenile stage (150 μm outside the core area), it was found that fish collected in different area showed similar chemical composition at the core and it indicated the these SBT might be from the same spawning ground (Fig. 2b).

Discussion

The chemical composition of southern bluefin tuna changed with age might cause by either ontogenetic or environmental effect. Fish at different developmental stage might have different deposition rate on otolith of each element. From the chemical composition of otolith edge, it was found that fish collected at different area showed different pattern in elemental composition, and this might be caused by different water mass in central Indian Ocean and the tropical ocean in the south of Java. SBT spawns in the ocean south of Java, and the juvenile would migrate in the same route arriving at southern Australia until 1 year than move southward to Australia. Past study also indicated the fact of single spawning ground of SBT (Proctor *et al.*, 1995; Grewe *et al.*, 1997). Current study, we analyzed the otolith elemental composition by ICPMS and the composition in the core and juvenile of all SBT were similar, but the edge of those otolith could be separated into groups. In the study of Atlantic bluefin tuna (*Thunnus thynnus*), multiple nurseries were discovered (Rooker et al., 2003), and the same fact was found in Pacific bluefin tuna, *Thunnus orientalis* (Rooker *et al.*, 2001). Those studies used otolith fingerprints of fish at the same ontogenetic stage for the investigating of their nursery ground, and also for stock discrimination analysis (Rooker *et al.*, 2001, 2003). The results recommend that the otolith composition could be used for understanding the past migratory history of SBT.

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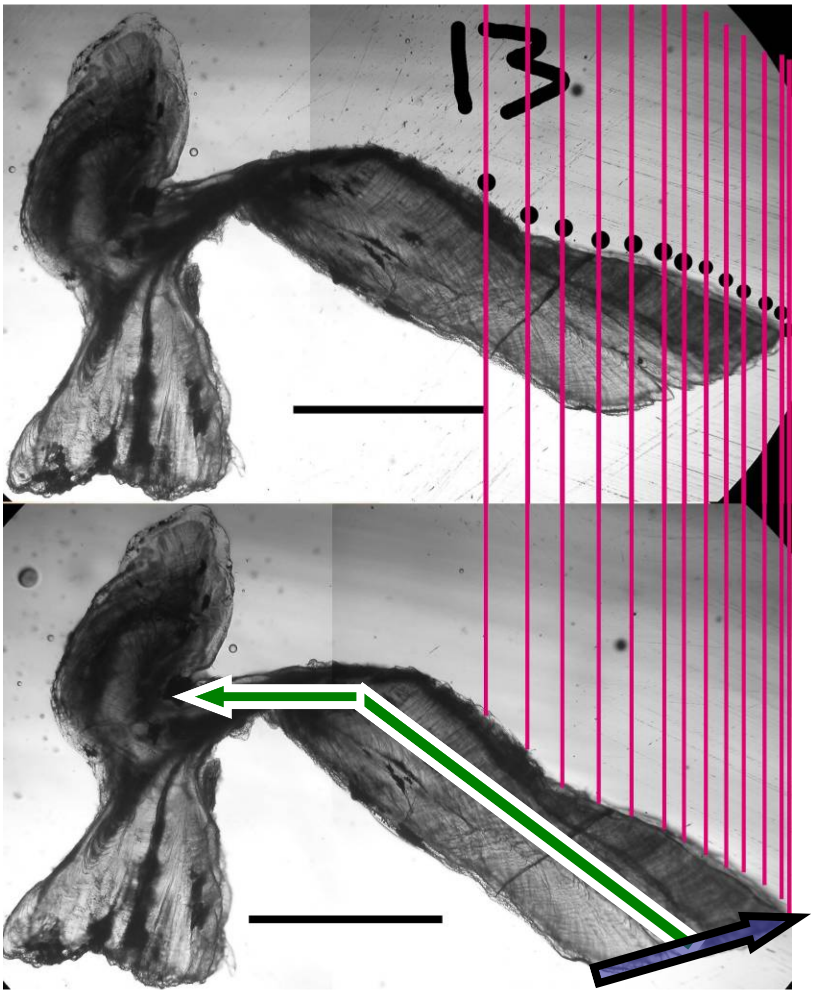
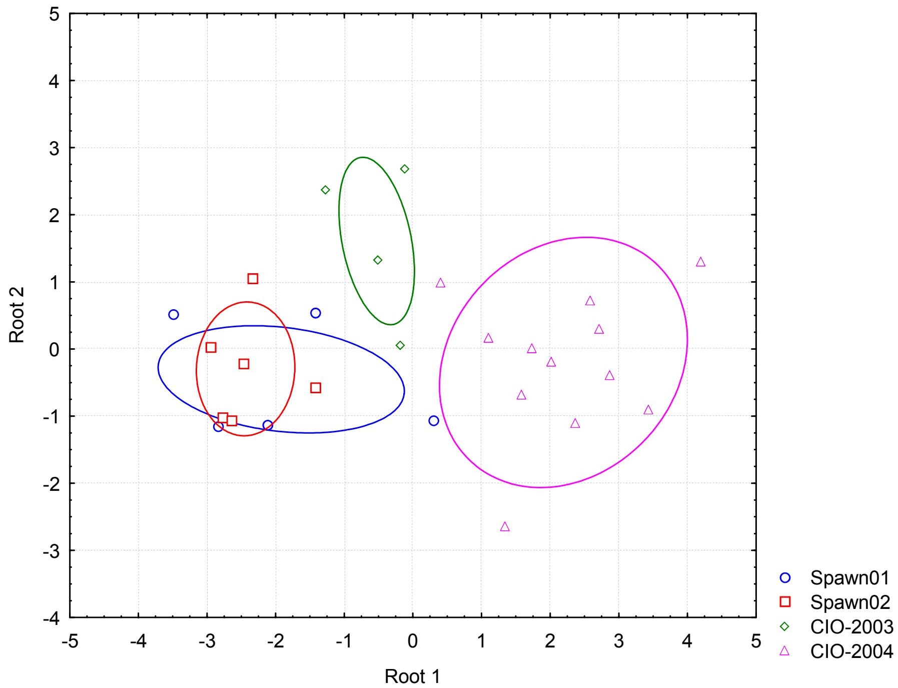


Fig. 1. The path of the laser beam used for ICPMS analysis on SBT otolith. Scale bar = 1 mm.

(a)



(b)

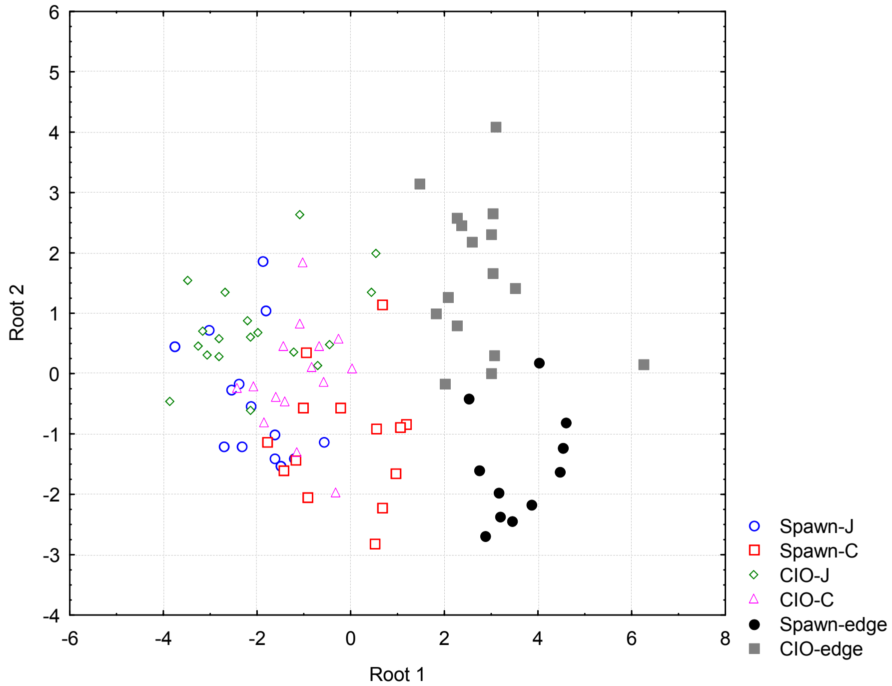


Fig. 2. Canonical discriminant function plot (functions 1 & 2) of the 6 elements: Ca concentration ratios from (a) edges of SBT otoliths, and (b) core, juvenile and edge of SBT otoliths from individuals collected from spawning (spawn, south of Java) and feeding grounds (CIO, central Indian Ocean) .