Preliminary report on west-to-south movement rate of juvenile southern bluefin tuna determined by acoustic tagging in Western Australia 2009-10

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2009/10 年の音響タグを用いたミナミマグロ幼魚の西オーストラリア州西岸から南岸への移動率調査の予備報告

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Abstract

Southern bluefin tuna (SBT) movements from the west coast of Australia to the south coast were studied with acoustic tags and listening stations for the years 2006/07, 2007/08. In both years of the experiments, it is clear that during the summer (December onwards), few tagged fish from the west coast move around to the south coast (only 1 of 73 detected over the two years). Thus, age-1 SBT present in the vicinity of the listening stations on the south coast of western Australia must arrive earlier in the season (before December). The fraction of fish that move to the south coast is unknown, and has implications for our understanding of stock structure. Several alternate migration paths are possible, and need further consideration. Beginning in 20010/11 a cooperative two-year project between Japan and Australia will examine in more detail whether age-1 SBT population from west-coast in Western Australia move to the south coast in the austral summer or remain on the west coast. Determining the fraction of fish that utilize particular migration pathways during the migration season will also provide insight for survey approaches and improved abundance estimation. In the first year of this experiment, we acoustically tagged 146 age-1 SBT in December (n=62, December 9-16th 2009) and January (n=84, January 8-14th 2010) on the west (n=82) and south coast (n=64) of Western Australia. Movements of these tagged fish are being monitored at three cross-shelf lines of listening stations: Rottnest Island on the west coast, Chatham Island on the south-west coast, and Pt Henry on the south coast. To date (July 2010) we have recovered 15 of 43 stations from the Chatham Island and Point Henry Lines and 16 tagged fish have been detected by these recovered stations. All these fish were tagged on the south coast. An additional 12 fish tagged on the west coast have been detected at the Rottnest Island line of stations.

要約
2006/07 年および 2007/08 年に、ミナミマグロの豪州西岸から南岸への移動を音響タグと受信機を用いて調査した。両年の夏季（12 月以降）において、西岸から南岸へと移動した標識個体はほとんどいないことが明らかとなった（73 回の受信のうち唯一 1 回は 2 年にわたり記録があった）。このように、1 歳魚は西豪州南岸の受信機付近に存在していたことから、この年の来遊は 12 月よりも早期であると考えられる。南岸へ移動する個体の割合は明らかではないが、親魚構造が影響しているものと考えられる。他にいくつかの移動経路が存在する可能性があるため、今後さらに検討する必要がある。2010/11 年から開始される日豪共同の 2 年間のプロジェクトでは、1 歳魚個体群が夏季の間に西岸から南岸へと移動するのか、それとも西岸に留まり続けるのかどうかをより詳細に調査する。移動期において詳細な移動経路の利用割合を明らかにすることは調査アプローチや加入量推定の改良において貴重な知見となるものと考えられる。本研究の 1 年目では、12 月と 1 月に西岸から 82 個体および南岸から 64 個体の合計 146 個体の 1 歳魚に音響タグを装着して標識放流した。これら標識個体の移動は沿岸から陸棚斜面に向けて大陸棚を縦断して係留した 3 ラインの受信機によって記録した。受信機の係留位置は西岸の Rottnest Island、南岸西端の Chatham Island と南岸の Pt Henry である。これまでに（2010 年 7 月）、Chatham Island と Pt Henry に係留した 43 台の受信機のうち 15 台を回収し、16 個体の受信記録が得られている。これらの個体はすべて南岸で標識放流した個体であった。加えて、西岸で標識放流した 12 個体は Rottnest Island に係留した受信機で受信記録があった。

Introduction

Juvenile SBT move down the west coast of Australia from the spawning grounds, and are subsequently found as age-1 fish in southern Australia during the austral summer (**Figure 1)**. The fraction of age-1 fish that move around to the south coast is unknown, and has implications for stock structure, mixing rates, and population estimates, particularly if there is inter-annual variation in the fraction moving to southern Australia. The acoustic monitoring approach has shown patterns of habitat use along the south coast (Hobday et al., 2009; Fujioka et al., 2010), however, the fraction of fish that arrived in the southern region, and ultimately move to the Great Australia Bight (GAB) as 2-4 year olds is unknown.

SBT movements from the west coast of Australia to the south coast were studied with acoustic tags and listening stations for the years 2006/07, 2007/08. In both years of the experiments, it is clear that during the summer (December onwards), few tagged fish from the west coast move around to the south coast (only 1 of 73 detected over the two years). Age-1 SBT present on the south coast of Western Australia must arrive earlier in the season (before December). The fraction of fish that move to the south coast, and when they do so, is unknown, and has implications for understanding stock structure. Several alternate migration paths are possible, and need further consideration.

In the new project, running from 2009/10 and 2010/11, our principal objectives are the acoustic tracking each year of over 100 juvenile SBT in coastal waters of Western Australia in order to:

1. Determine the west-to-south movement rate of age-1 SBT into the southern coast of Western Australia (WA), where a Recruitment Monitoring Survey has been conducted since 1995 to estimate the relative abundance of age-1 SBT.

2. Determine the oceanographic factors regarding the influence on interannual fluctuation of movement rate from the west coast to the southwest coast and then would be needed to be relevant and necessary for the estimation of the proportion of the juvenile stock that is in southern Australia during the austral summer.

These data are relevant and necessary for the estimation of the proportion of the juvenile stock that is in southern Australia during the austral summer, when other fishery-independent surveys are completed (Hobday et al., 2009).

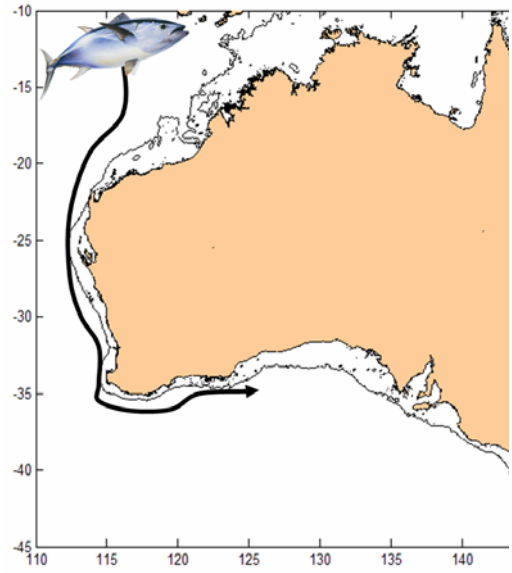

Figure 1. The possible migration path for age-1 southern bluefin tuna from the spawning ground into southern Australia.

Summary of achievement to date

At this stage, we have achieved progress against objective 1 above, and we summarize progress below.

Deployment of listening stations and tagging of bluefin tuna

A total of 4 cruises have occurred in this first field season, as summarized:

• December 2009 − deployment of listening stations and fish tagging (Albany to Fremantle)

• January 2010 – fish tagging (Fremantle to Albany)

• May 2010 – recovery of listening stations (planned)

• June 2010 – recovery of listening stations (unplanned cruise).

The successful deployment of listening stations took place between December 7-16th 2009 aboard the FV Quadrant, under the direction of Alistair Hobday (Australia) and Ryo Kawabe (Japan). The 19m fishing vessel with 3 crew and the 2 scientists left

from Albany and docked in Fremantle. Listening stations were assembled and deployed and tuna were tagged.

Each listening station consists of a Vemco VR2 acoustic receiver, floats, and release equipment (**Figure 2**). Each package is deployed below the surface, and then after a pre-specified period of time (say 6 months), releases and a set of floats draw the equipment to the surface. Each is collected using a chartered fishing vessel, and the data from the instrument downloaded. By deploying the listening stations in a line across the continental shelf, a "curtain" is created, which can detected fish passing across the line of stations.

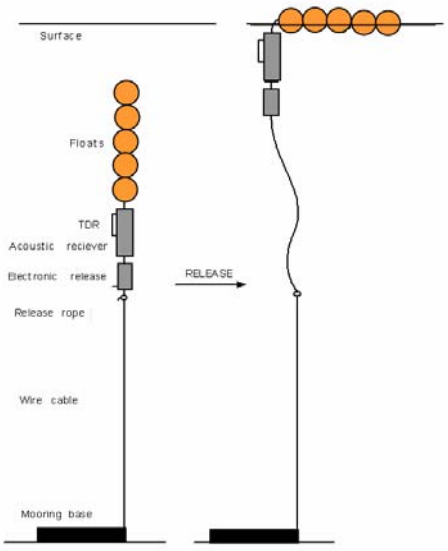

Figure 2. Configuration of the listening station moorings during the sub-surface deployment period (left) and ready for recovery (right).

In December, the 43 listening stations were deployed in two lines of 20 stations each, Line 2 off Bremer Bay, and Line 4, off Chatham island (**Figure 3**). An additional 3 stations were deployed at hotspots between the two lines. Additional listening stations are located in a line off Rottnest island (managed by the Australian Acoustic Telemetry Network), and together the three lines span the region where juvenile (age 1 and 2) SBT move along the Australian coastline during the summer months. Thus, a

total of 96 listening stations are in the study region to detect tagged fish. Tags transmit an acoustic pulse every 30-60s for approximately 9 months.

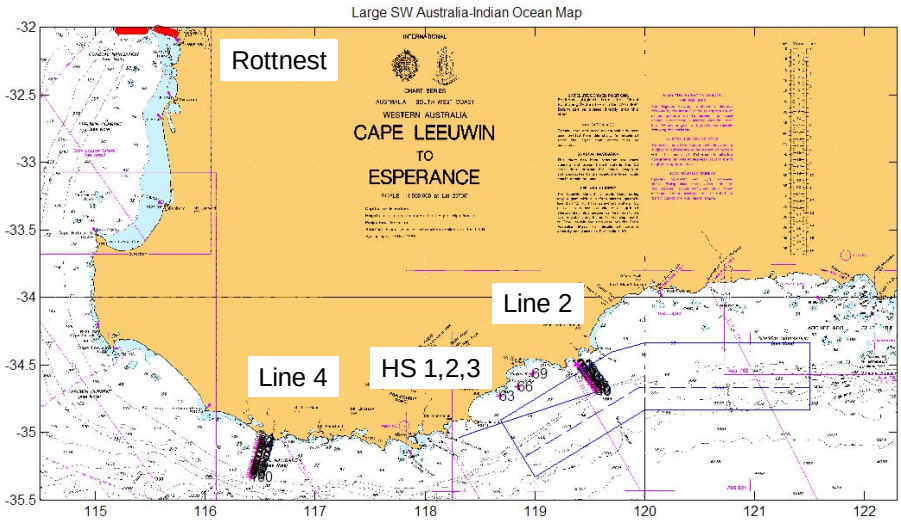

Figure 3. Location of acoustic listening stations in 2009/10. Line 1 (not shown) was located between Line 4 and 2 and was not used in 2009/10.

The same protocol used for the capture and selection of SBT for conventional tagging was followed for the acoustic tagging (Hobday et al., 2001). In brief, fish were caught by poling or trolling at the stern of the vessel and then carried to a tagging cradle and length to caudal fork (LCF) measured. An acoustic tag was surgically implanted in the belly of each fish (see West and Stevens (2001) for an explanation of this procedure), which was also double tagged with conventional orange tags on each side just posterior to the second dorsal fin. The time from capture to release was approximately two minutes. All fish were tagged by a single experienced operator. Acoustic tags (V9, VEMCO) were activated and tested prior to deployment. These tags transmitted a coded pulse at a frequency of 69 kHz at random intervals every 20-60 seconds with a predicted lifetime of 365 days.

A total of 146 SBT were acoustically tagged 62 in December (December 9-16th 2009) and 84 in January (January 8-14th 2010). The acoustic tags can be detected when fish swim within 400 meters of any of the listening stations. Tagged tuna were mostly between 42 and 52 cm in length, corresponding to small age-1 fish (**Figure 4**). Slightly larger age-1 fish were also tagged (52-66cm) and several small age-2 fish

(>66 cm). This spread of sizes allows the question of size specific movement in relation to the environment around the coast of Western Australia to be considered.

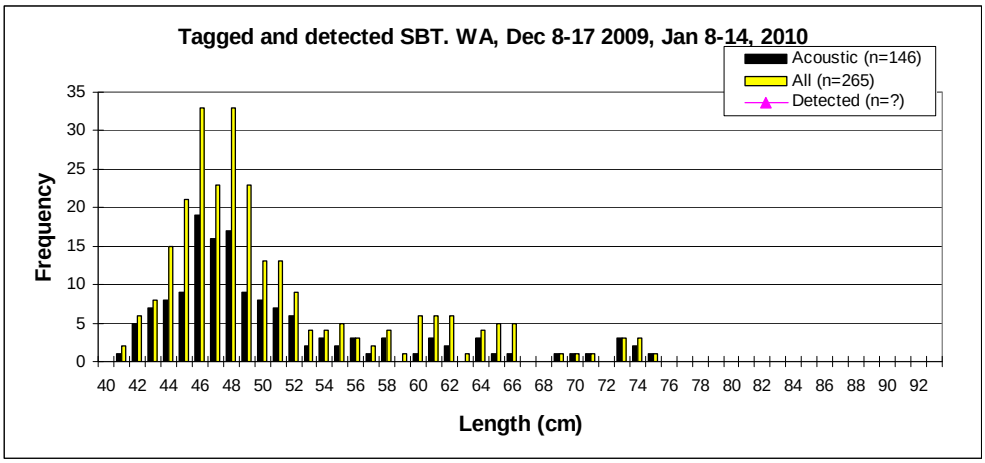

Figure 4. Size distribution of all SBT tagged and captured (some SBT were released without tags, as fish from a wide size range were sought).

Only a small number of fish are tagged from each school to spread the tags among as many fish and locations as possible (**Figure 5**). This was successfully achieved this year, as the spread of tagged fish indicates.

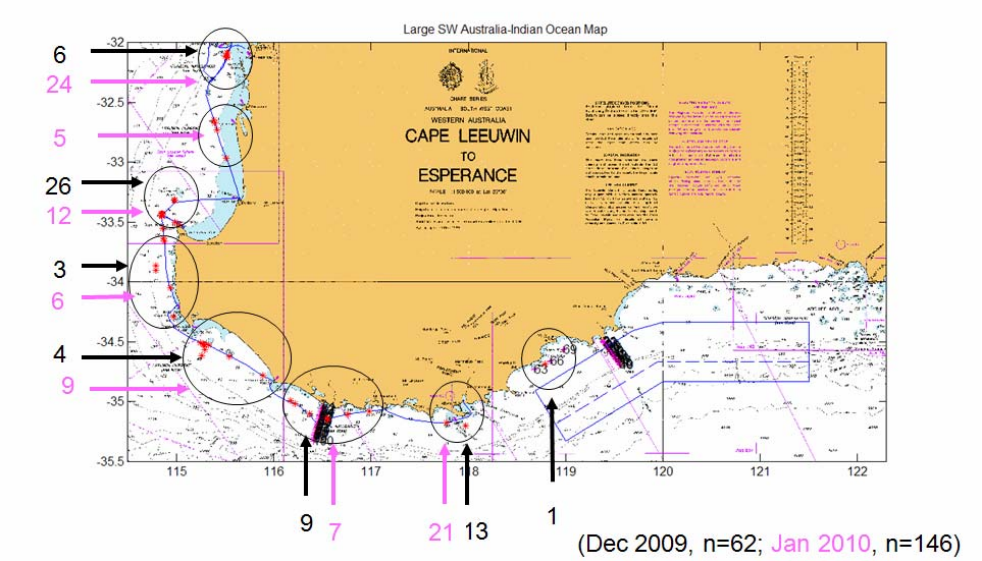

Figure 5. Number of tagged age-1 and age-2 SBT released at several locations in 2009/10. Colors indicate the release period. Black: December, Magenta: January.

An electrical fault with the release mechanism for the listening stations has impacted on the recovery of the stations in May 2010. The cause of this fault is being investigated at CSIRO, and appears to be related to a bad batch of batteries that were intended to power the release mechanism. In June we again chartered the tagging

vessel for 5 days and a small remote operated vehicle (ROV – see picture below) and have successfully recovered 8/11 stations on Line 2 (Bremer Line). A picture of the ROV is shown in **Figure 6**, and we were able to find the underwater moorings with the listening station attached in June, and recovered them with the data. A second recovery cruise for stations on the Chatham Island line is planned for August 13-18.

Figure 6. Pictures of operating of ROV to detect the listening stations.

To date (July 2010) we have recovered 15 of 43 stations from the Chatham Island and Point Henry Lines and 16 tagged fish have been detected by these recovered stations. An additional 12 fish tagged on the west coast have been detected at the Rottnest Island line of stations. Preliminary analysis from the listening stations that have been recovered shows that tuna from the west coast have remained on the west coast (detected at Rottnest Island line – data not shown), while fish tagged on the south coast have been detected at Line 2. This indicates local residence, and thus counts of tuna on the south coast would underestimate the fish stocks, as fish are also resident on the west coast. This is new information, and will change the interpretation of the fish abundance estimates in southern Australia.

An example of the detections for a subset of tuna detected on the south coast is shown in **Figure 7**. Red lines show the movement between the tagging location (open circles) and a listening station. Circles with no lines indicate fish that have not been detected on the stations that have been recovered at this stage (NB: most of Line 4 – Chatham Island has not been recovered). Detection of fish on the west coast at Rottnest Island Line are also not shown on this figure, but note that 15 fish tagged on the west coast have been detected on the west coast.

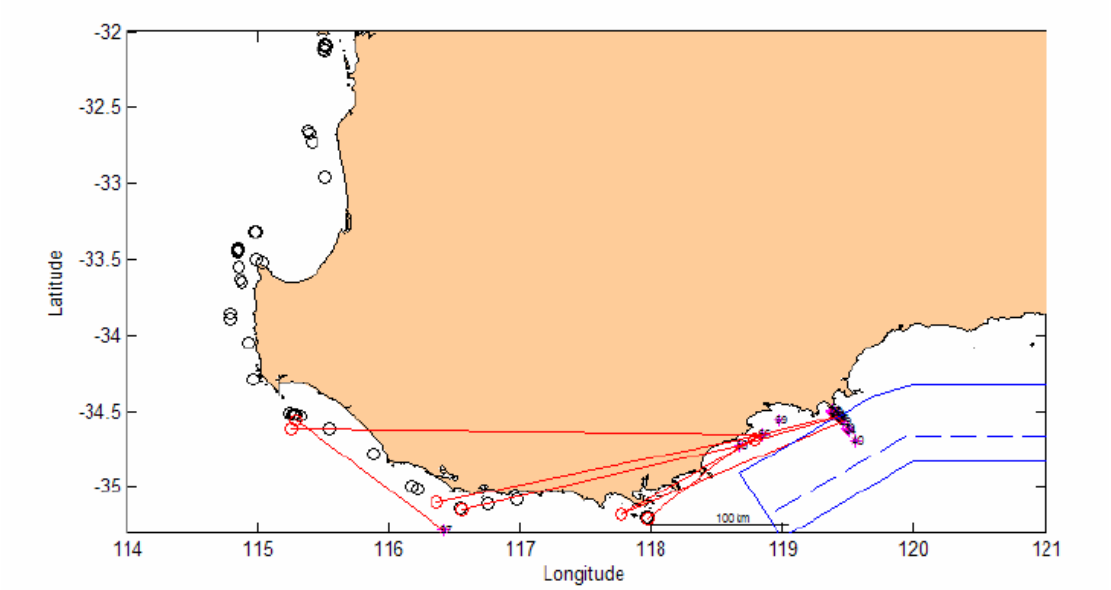

Figure 7. Tracks of tagged SBT from release locations (circles) to receivers for 2009/10. Data from 15 receivers is contained in this figure.

When the remainder of the listening stations are recovered from the additional cruise (July 2010?), analyses will continue. In particular, the movements in relation to environmental conditions will be considered. Deployment of listening stations and tagging of fish for year 2 is planned for November 2010.

With regard to the migration pathways, there are several possibilities. Two alternatives to direct migration to the GAB (**Figure 8**, pathway A) are that fish move along pathway C, and ultimately migrate to the GAB in subsequent years, or that fish move to the west, and do not appear in the GAB in subsequent years (pathway B).

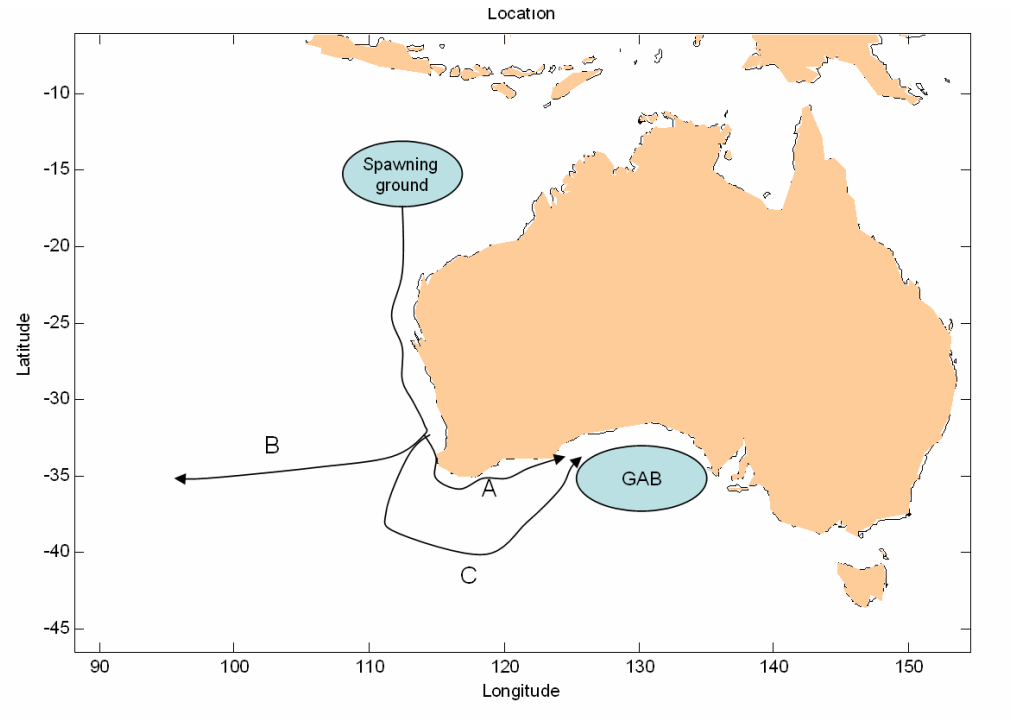

Figure 8. Hypothetical SBT migration pathways for juvenile SBT from the spawning ground to the GAB.

Electronic tagging with two technologies, acoustic tags for fine scale location in combination with acoustic listening stations, and archival tags for basin-scale movements could used to estimate fractions for migration pathways A, B and C (**Figure 8**). Pathways A and C can be distinguished with acoustic tags, while B can be distinguished from A+C with archival tags, and not with archival tags. These tagging techniques have been applied independently and successfully in the past. Deployment of an acoustic array in southern Western Australia could be used to detected acoustic tags released on the west coast. Support is needed to resolve this uncertainty regarding the interannual fraction of the juvenile stock that is ultimately present in the GAB.

Acknowledgements

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