

## Observation of Juvenile Southern Bluefin Tuna (*Thunnus maccoyi* C.) School Response to the Approaching Vessel Using Scanning Sonar

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The aim of this study was to obtain the basic data on the fish school behavior change to approaching vessel and fish species identification by means of their swimming speed. The surveys were carried out for the juvenile southern bluefin tuna and other fish schools off Esperance, western Australia from January to March 1999. We observed changes of fish school behavior in response to the approaching vessel using 360-degree scanning sonar. The results showed that, a horizontal direction index used to quantify a change of fish school behavior did not identify dependence of a radial distance and a swimming speed. A Mann-Whitney test conducted using the horizontal swimming speed of both species identified by sonar specialists, did not reveal a significant difference.

Key words: Scanning sonar, Avoidance behavior, Fish species identification,  
Juvenile southern bluefin tuna

### Introduction

In the acoustic resources survey, the avoidance behavior of fish school in response to the vessel may induce a bias in the estimates of fish abundance (Olsen, 1990; Traynor et al., 1990; Fréon et al., 1993b). The fish school avoidance behavior is caused by a noise from the vessel and the change of water mass, which bifurcates by the collision of the moving vessel. By these effects, the avoidance behavior apparently changed the fish school behavior and its swimming direction away from the survey course. These avoidance behavior differed with respect to the swimming depth, maturity stage,

and stimuli due to the vessel size, materials, vessel speed and deck light (Ona and Toresen, 1988; Mitson, 1993).

Observations of avoidance behavior to the approaching vessel were reported earlier for herring, capelin and polar cod (Olsen et al., 1983; Ona and Toresen, 1988; Misund, 1990; 1993; Misund et al., 1993; Hafsteinsson and Misund, 1995). Other reports on the avoidance behavior of haddock to trawling vessel was studied by Ona and Godø (1990) and change of school structure and school density of herring to approaching dinghy were reported by Fréon et al. (1992; 1993a).

Miyashita and Nishida (1999) reported juvenile southern bluefin tuna (SBT) had seldom swum beneath the vessel during recruitment monitoring survey using the echo sounder. Therefore, the sonar

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specialists with the help of a sonar image display did the acoustic estimation of juvenile SBT. However, studies on quantitative bases in relation to the change of school behavior towards an approaching vessel and the species identification were few.

Therefore, we observed changes of fish school behavior in response to the approaching vessel using scanning sonar. The attempt was to obtain the basic data on the fish school behavior change to approaching vessel and fish species identification by means of their swimming speed.

## Materials and Methods

### Acoustic survey and fish sampling

The surveys were carried out for the juvenile SBT (0~2 years old) off Esperance, western Australia during M/V TAIKEI (117 tons) cruise from January to March 1999. A 360-degree scanning sonar (CSH-23, FURUNO), with a frequency of 38 kHz, a transmitting beam width of  $360^\circ \times 14.5^\circ$ , and a receiving beam width of  $13.8^\circ \times 14.5^\circ$  was used.

The survey area is shown in Fig. 1. Juvenile SBT migrated into survey area from January to March (Robins, 1963). Survey track line was established as a randomly zigzag course to cover almost all the survey area of the oblique lines.

Survey conditions were determined with a sonar detection range of 600 m, a tilt angle of 6 degrees, and a survey speed about 8 knots. Sonar specialists identified the species by using a sonar image display.

Sonar display showed 16 colors of plan position indication image in accordance with the echo intensity. Video signals of the sonar were converted to NTSC video signals through a digital scan converter (DSC04m, Digital Arts Co.). These signals were recorded by a videocassette.

Fish sampling was conducted by pole and line to identify the fish species. The fork length and the body weight were measured and stomach contents were analyzed.

### Data processing

The sonar images were recorded for 480 hours. About 1 minute up, tracked school was saved to convert into a fixed sonar image at 10-second in-

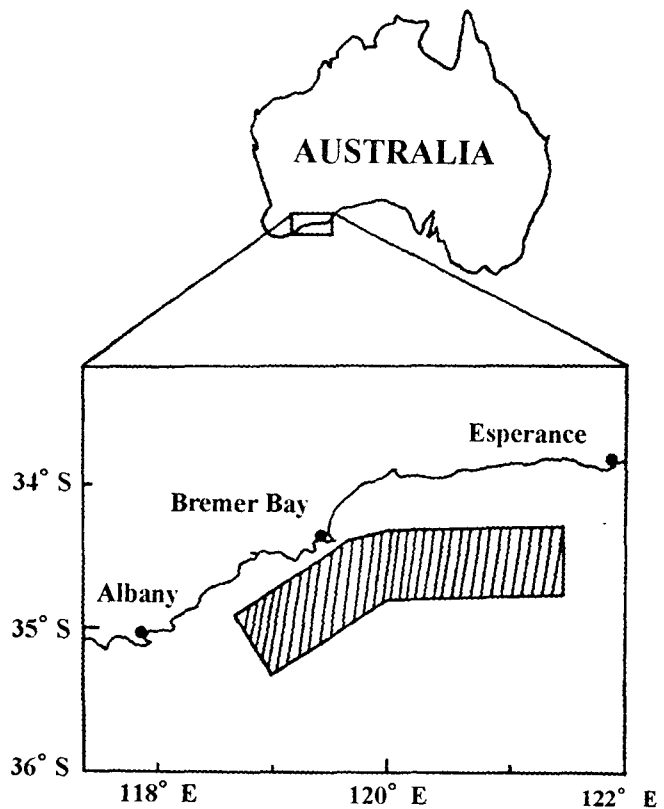


Fig. 1. Geographical position of survey area for monitoring juvenile SBT.

terval by a video capture software (Video shot, Kazuki IWAMOTO). These were read by an image processing software (Scion image, Scion Co.), and the center position of schools was determined from geographical center of fish school on fixed sonar image. The geographical center was the center of fish school length and width. The radial distance from vessel to schools position, tilt angle, and vessel speed obtained relative and absolute co-ordinates of school.

During acoustic surveys, sonar specialists identified fish species by their swimming speed, school size, and echo intensity. We calculated the horizontal swimming speed ( $V_H$ ) from the moving distance of school within 10-second interval. Significant difference of  $V_H$  for both SBT schools and other fish schools was tested utilizing the result of sonar specialists.

The change of school behavior was quantified by the horizontal direction index ( $D_H$ ); closed to 1 if the school moves a straight forward and close to 0 if the school moves in a circular way (Misund, 1990).

$$D_H = \frac{H_{dist}}{\sum_{i=1}^N F_H(i)}$$

Where  $H_{dist}$  is a distance between first and last school position;  $F_H(i)$  is a distance in 10-second interval.

### Results

#### Fish sampling

For species confirmation, fish samples were collected by pole and line. Figure 2 shows the relationship between fork length (cm) and frequency of fish samples. Result showed that SBT, skipjack, and other fish had frequency of 81.7%, 8.0% and 10.3%, respectively. We noticed that SBT with an average fork length of 51.6 cm was 1 year old.

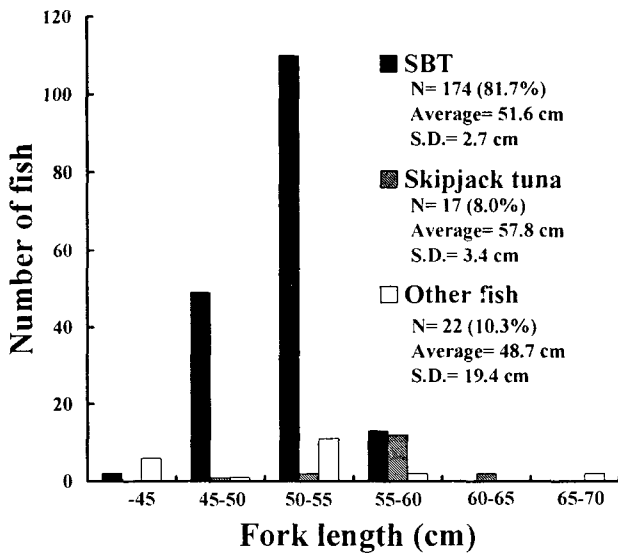


Fig. 2. Frequency distribution of samples fork length caught by pole and line.

#### Swimming trace

Six hundred thirty-six fish schools were recognized on sonar images for about 480 hours. One hundred ninety-three fish schools were traced among these schools. Figure 3 shows specific horizontal swimming tracks that were used for school positions. Figure 3(A) shows the relative plotting of horizontal school direction in relation to the vessel. Arrows show change of direction. Figure 3(B) is the true plotting, which shows a school real movement, to avoid the effect of a vessel speed.

In Fig. 3(B), fish schools A and H far from the

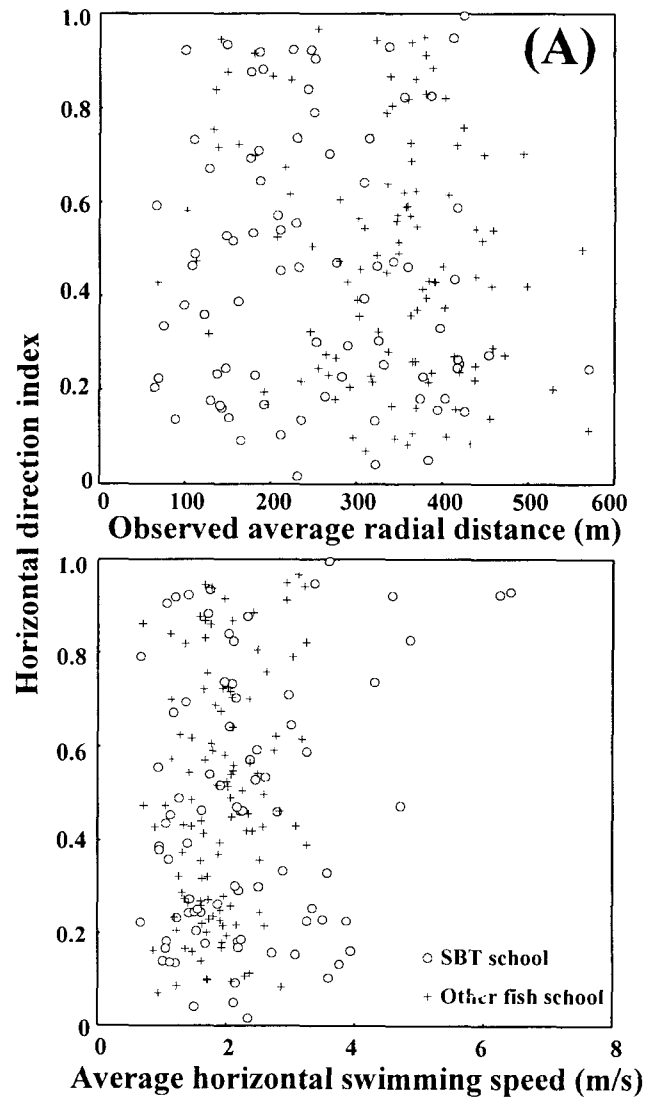


Fig. 3. Traces of swimming behavior of fish schools observed with the scanning sonar. (A), relative plotting; (B), true plotting.

survey course did not show apparent change of their direction. Also an acoustic track line of about 240 m in front of the vessel, fish school I also did not change. However, fish schools B, C, D, E, F, G changed their swimming directions at closer distance away from the survey course.

#### Swimming speeds

Frequency distribution of maximum, average, and minimum swimming speed of 193 traced fish schools is shown in Fig. 4. Figure 4(A) shows identified SBT schools, and Fig. 4(B) represents identified other fish schools. Among other fish schools,

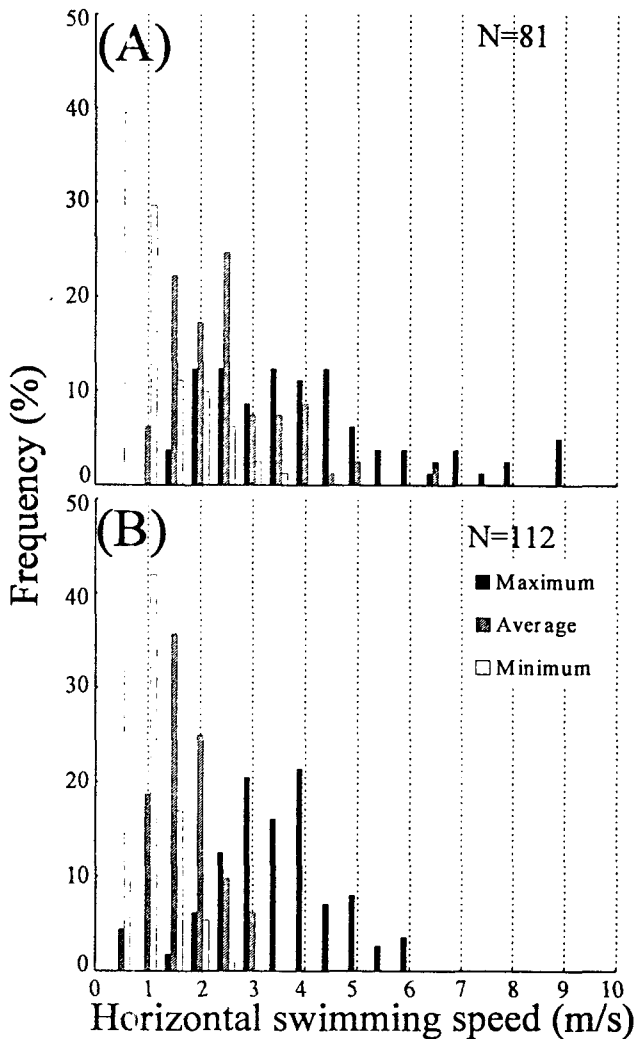


Fig. 4. Frequency distribution of swimming speed of identified fish schools by sonar specialists. (A), SBT schools; (B), other fish schools.

the highest maximum horizontal swimming speed was 6.0 m/s, and the highest minimum speed was 2.5 m/s, and the highest average speed was 3.5 m/s. A comparison between the nearest horizontal maximum swimming speed between these two schools showed 3.6% for other fish schools and 17.3% for SBT schools at 6 m/s. The average horizontal swimming speed at 3.5 m/s was 6.3% for other fish schools and 22.2% for SBT schools. The minimum horizontal swimming speed at 2.5 m/s was 0.9% for other fish schools and 9.9% for SBT schools.

A Mann-Whitney test conducted using the horizontal swimming speed of both species identified by sonar specialists, did not reveal a significant difference (Table 1).

Table 1. Average and standard deviation of swimming speed of identified fish schools by sonar specialists

	SBT schools		Other fish schools		Mann-Whitney test (p)
	Avg.	S.D.	Avg.	S.D.	
$V_H$ MAX	3.85	1.91	3.33	1.03	0.24
$V_H$ MEAN	2.25	1.16	1.92	0.57	0.17
$V_H$ MIN.	0.88	0.70	0.74	0.46	0.57
N	81		112		

$V_H$ , Horizontal swimming speed.  
N, Number of fish school.

#### Horizontal direction index

Figure 5 shows the horizontal direction index ( $D_H$ ) of both species. In spite of increase or decrease of the average radial distance,  $D_H$  did not identify the dependence of average radial distance in both the species (Fig. 5(A)). Similarly, in spite of increase or decrease of the average swimming speed,  $D_H$  did not identify the dependence of average horizontal swimming speed (Fig. 5(B)).

#### Discussion

The SBT were about 1 year old during the field collections from the study area. SBT spawns in the northwestern Australia area (Yabe et al., 1966). Robins (1963) reported that hatched larvae grow to juvenile fish and then move toward south of Australian western coast and migrate to eastern coast. In June and July from east coast they start moving north and in October and November they migrate to southern coast.

The change of various factors of the school to the approaching vessel as observed in this study has been reported earlier. Misund et al. (1993) reported that when vessel run in track line during acoustic survey, about 20% of herring population avoids the vessel while capelin did not avoid to the vessel. Traynor et al. (1990) suggested the fish response probably to the approaching vessel was at about 100 m depths and 150 m distances from the vessel.

The horizontal direction index did not identify the dependence of radial distance. In spite of distance from vessel, analyzed schools showed the same track i.e. the school did not avoid from a close distance of the vessel. From analysis of the horizontal direction index, the vessel showed a

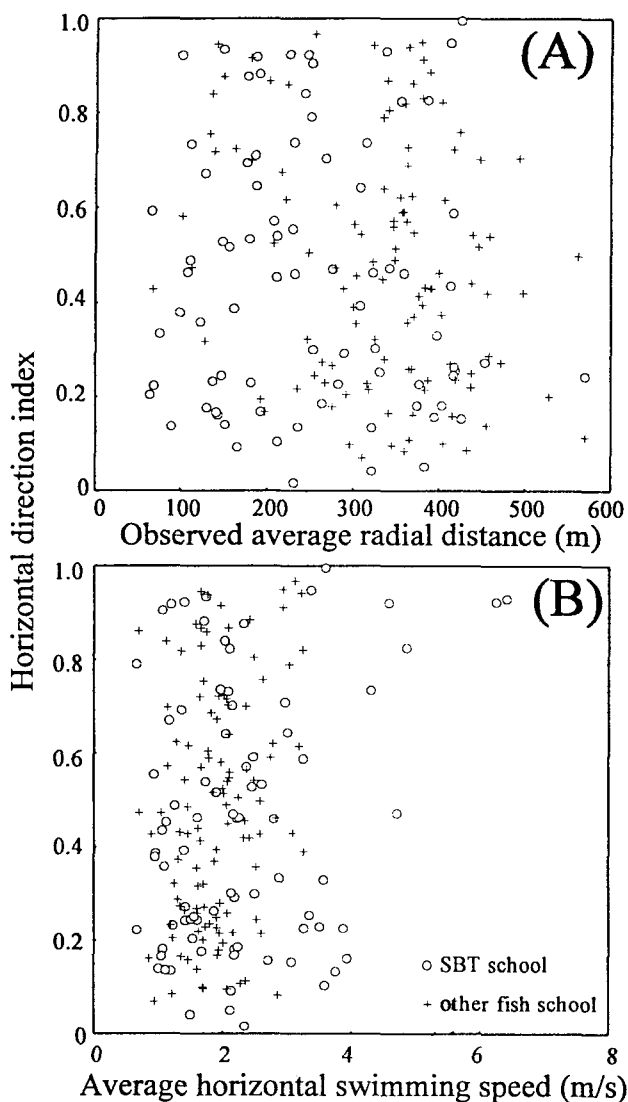


Fig. 5. Horizontal direction index of traced fish schools related to observed average radial distance (A); average swimming speed (B).

straightforward direction. However, if bow direction changes during approach, the accuracy of a horizontal direction index of fish school at long distance from vessel falls down at close distance from vessel.

In relation to the tuna swimming speed, maximum speed of 1 m yellowfin tuna was about 20 m/s (Walters and Fierstine, 1966). A relationship between maximum swimming speed and body length was reported to be 20 times (He, 1993).

The maximum horizontal swimming speed of 8.9 m/s was observed in this study with a 15.81-fork length/sec. We identified other fish school as mac-

kerel and sardine etc. The maximum swimming speed of mackerel was reported to be 10~15 times of length/sec (He, 1993). Which could be due to the difference of swimming capacity between SBT and other fish school because of their difference in body length. Therefore, between SBT and other fish school, the swimming speed was a useful parameter. However, a sufficient accuracy cannot expect for fish school identification by using one parameter. To get good result of fish school identification, we have to consider other parameters related to fish school size, shape and echo intensity.

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