ミナミマグロ 1 歳魚の加入指標のためのピストンライン曳縄モニタリング調査 2011/2012 の結果報告

Report of the piston-line trolling monitoring survey for the age-1 southern bluefin tuna recruitment index in 2011/2012

伊藤智幸・境磨・徳田大輔

Tomoyuki ITOH, Osamu SAKAI and Daisuke TOKUDA

（独）水産総合研究センター 国際水産資源研究所

National Research Institute of Far Seas Fisheries, Fisheries Research Agency

要約

ミナミマグロ *Thunnus maccoyii* 1 歳魚の加入指数を低コストで求める曳縄調査を、2012 年 1 月から 2 月に、2006 年以降と一貫した方法で実施した。この調査では、豪州船を用船し、西オーストラリア州南岸の Bremer Bay 沖に設定した単一ライン（ピストンライン）上を曳縄をしながら 1 日に一往復、合計 7 往復（14 ライン）を調査した。ピストンラインの周辺海域及び Esperance -Albany 間の海域のミナミマグロ分布状況も調査した。航海を通じて漁獲したミナミマグロは 212 個体で､その内 91 個体には CCSBT 標識及びアーカイバルタグを、10 個体にはポップアップアーカイバルタグを装着して放流した。探索 100km 当りのミナミマグロ 1 歳魚の群れ数である曳縄指数は 1.6（90%信頼範囲は 0.8-2.4）であり 2011 年よりも低くなった。しかしながら、体長組成が従来と大きく異なっていたことから、2012 年の曳縄指数で加入状況を単純に判断するのは適切ではないだろう。

Summary

In January and February 2012, the trolling research survey that provides the recruitment index of age-1 southern bluefin tuna *Thunnus maccoyii* (SBT) with low cost was carried out in similar manner since 2006. In the survey, a chartered Australian vessel goes and back on the same straight line (piston-line) off Bremer Bay in the southern coast of Western Australia using trolling for a total of 7 times (14 lines). The adjacent area of the piston-line and the area between Esperance and Albany were also surveyed. During the cruise, a total of 212 SBT individuals were caught. Among them, 34 fish were tagged and released with CCSBT conventional tags and archival tag, and other 10 fish were deployed pop-up archival tag. The trolling index, the number of age-1 SBT school per 100 km searched, was 1.6 with a 90% confidence range of 0.8-2.4, which was lower than that of 2011. However, because length frequency distribution was quite different with those in previous years, assess the recruitment level simply from the index in 2012 would not be appropriate.

1. Introduction

Recruitment level is crucial information on stock management of southern bluefin tuna (*Thunnus maccoyii*, SBT). Since 2006, Australia has the largest national allocation of TAC of SBT in CCSBT (Anon. 2006). Most of the Australian catch, used for farming, is mainly age three with a range between two and four, which is the earliest age of SBT fished compared to other nations' fisheries. Given high fishing pressure in their younger life stage, monitoring the recruitment level of SBT in their early life stage becomes much more important than in previous years.

Several research activities have been attempted for the recruitment monitoring of SBT. Since 1989, Japan has been conducted a series of recruitment monitoring surveys within a cooperative research framework with Australian scientists. Japan carried out a trolling and pole-and-line catch monitoring survey from 1989 to 1993, and then carried out an acoustic monitoring survey using sonar and echo sounder from 1995 to 2006, for age-1 SBT distributed off the southern coast of Western Australia (Itoh 2006). These researches had been providing the recruitment indices of age-1 SBT to CCSBT for years. Australia carried out a scientific aerial survey in the Great Australian Bight in South Australia since 1993 and also provided the recruitment indices, as aerial survey index, to CCSBT (Eveson et al. 2006). However, because the aerial survey index is for SBT age three which is the same age of the Australian purse seine catch, it gives little time to consideration to regulate the fishery based on the results of the research survey. Catch information of SBT age-1 off the southern coast of Western Australia had been provided by the CCSBT tagging since 2001, but the areas surveyed by the cruise were limited and the tagging was suspended in 2007.

The acoustic index derived from the acoustic monitoring survey predicted the low recruitment levels of the 1999-2001 year classes of SBT so that it was likely to be a reliable index. However, the survey was ceased after the final survey in 2006 due to the budget restriction. Alternatively, a type of survey that can be done with lower cost was sought. Since 2006, we have carried out a monitoring survey that a chartered Australian vessel go-and-back on a single straight transect line and find SBT schools by catching with trolling (Itoh and Kurota 2006, Itoh and Sakai 2007, 2008, 2009a, 2010, Itoh et al. 2011). In January 2012, we carried out the 7th trolling monitoring survey and the results of the survey are presented in this paper.

2. Materials and methods

Cruise of the piston line trolling survey

An Australian vessel, St Gerard M with 18 m in total length, was chartered (Fig.1).

The vessel was also used in the surveys for last six years. Three researchers and two Australian crew members were on board.

The research area was off the south coast of Western Australia between Esperance (122E) and Albany (118E), including off Bremer Bay (Fig. 2). The area covers 370 km x 37 km. Within the research area, continental shelf of 70 m in depth extended largely and then dropped sharply to deeper than 500 m in depth at shelf edge within 2 km distance toward offshore. The piston-line laid between the two points same as last year; one was at 34°29.2′S-119°23.1′E and the other was at 34°44.9′S-119°36.9′E so that the piston-line covered a range from continental shelf to offshore through shelf edge. In addition to the piston-line, adjacent areas, east, west or south (offshore) of the piston-line as well as the area west to off Albany, were also surveyed in order to examine whether the piston-line is a representative area in regard to SBT distribution (Fig. 2).

The vessel operated trolling at speed of 7-8 knots. Eight trolling lines at maximum were trolled. The specifications of the trolling gears were consistent with those used in the last year survey.

Because the index derived from the survey is based on the number of SBT schools, not the number of SBT individuals caught, we did not try to maximize the number of fish caught. When catch was succeeded and reach 10 individuals presumably from single school, trolling was suspended and the vessel went forward around 1.0 mile without using trolling lines so that left from the school, in order to minimize mortality by the survey.

Individuals caught of any species were measured its length. SBT in good condition were tagged and released with an archival tag (Lotek Inc., LAT2810) and one CCSBT conventional tag following the CCSBT tagging procedure. Other relatively large SBT individuals in good condition were tagged and released with pop-up archival tag (Wildlife Computers Inc., mini-PAT). Other SBT individuals were weighed and taken biological samples (stomach contents, otoliths and muscle tissue).

Vertical profile of temperature and salinity (conductivity) were measured down to just above sea bottom or 200 m in depth using a CTD (JFE Advantech Co. ltd., CTD RINKO-Profiler). GPS position data were recorded every ten seconds.

Underwater video images were taken sometimes during trolling conducted out of the piston-line. A video camera in waterproof case was towed and placed 20-30 m behind of the vessel and 2-3 m below the sea surface. The camera took image toward below and behind direction. The images taken were observed later in laboratory and SBT presence was checked on PC monitor.

Calculation of Trolling Index

Five types of trolling indices were calculated as follows.

(1) The number of schools of age-1 SBT per 100 km search distance. A catch of age-1 SBT that apart from 2 km in distance from last catch of age-1 SBT is defined as a different school. TRI_2km.

(2) The number of schools of age-1 SBT per 100 km search distance. A catch of age-1 SBT that apart from 20 minutes in time from last catch of age-1 SBT is defined as a different school. TRI_20min.

(3) The number of schools of age-1 SBT per 100 km search distance. A catch of age-1 SBT that apart from 30 minutes in time from last catch of age-1 SBT is defined as a different school. TRI_30min.

(4) The number of times of catch of age-1 SBT per 100 km search distance. All the catches even it was likely to be from the same school were counted. TRI_times.

(5) The number of age-1 SBT individuals per 100 km search distance. TRI_ind.

Confidence intervals of the trolling indices were calculated from data sampled 1000 times by bootstrap methods, and the results were shown by box plots or median, 5% and 95% points. The indices were calculated for the following three data series and compared over 17 years between 1996 and 2012; 1) piston-line trolling survey from 2006 to 2012, 2) trolling catch on the piston-line in the acoustic (sonar) survey from 2005 to 2006, and 3) trolling catch in other area of the piston-line in the acoustic (sonar) survey from 1996 to 2006 (Itoh, 2007).

3. Results

The vessel departed Esperance on 24 January 2012, which was one day before than the survey in 2011. The vessel surveyed off Bremer Bay from 25 to 28 January, and then went further west and surveyed an area between Bremer Bay and Albany from 30 January to 4 February. The vessel came back and surveyed off Bremer Bay again from 5 to 7 February. The vessel left off Bremer Bay and surveyed west of Esperance, near Investigator Island and West Group, from 8 to 9 February and back to Esperance on 10 February in which the research survey was finished.

Usually, the vessels engaged in the research survey from 6:00 to 18:00 and anchored in calm bay at night. While there were a few days in rough sea, we could carry out the surveys all the 18 days except one day (29 January). The piston-line was surveyed off Bremer Bay in seven days for 14 lines.

During the cruise, a total of 341 fish individuals were hooked, including 212 SBT, 49 skipjack *Katsuwonus pelamis*, 4 bonito *Sarda orientaris*, 4 blue mackerel *Scomber australasicus*, 26 yellowtail kingfish *Seriola lalandi*, 2 barracouta *Thyrsites atun* and 44 unidentified individuals which escaped far from the vessel. Among the 212 SBT individuals, 91 SBT were implemented archival tags in their body cavity with CCSBT conventional tags on their dorsal. Other 10 SBT were attached the pop-up archival tags. 98 SBT were killed for biological sampling. Total weight of SBT sampled was 324.9 kg of 98 individuals.

Many SBT were caught off Bremer Bay not only on the piston-line but also in adjacent areas (Fig. 2). Few SBT were caught offshore area from self edge on the piston-line. Compare to previous years, fewer SBT were caught near shelf edge this year.

Length frequency of SBT caught is shown in Figure 3. SBT caught ranged from 30 to 84 cmFL. The size was concentrated around 50 cmFL in previous years, however, the size varied largely between 43 and more than 80 cmFL this year. The variable size was observed not only in Bremer Bay but also whole the surveyed area. Different to previous years, it was difficult to determine size range of age-1 fish based on length frequency. Previous size range between 40 and 63 cmFL was used for age assignment for the calculation of the trolling index for the present.

Underwater video images were taken 20 times, reaching 55 hours in total. Those footages were under observation.

On the 14 piston lines, the total number of age-1 SBT school was 8 and 9 when the successive SBT catches more than 30 minutes and 2 km are defined from different schools, respectively. The total distance searched on the piston line was 494 km. The mean trolling indices are calculated as 1.6 school/100 km (30 minutes school definition) or 1.8 school/100 km (2 km school definition).

If fish size included was extended as between 40 and 80 cmFL, the numbers of school were 11 (30 minutes school definition) and 13 (2km school definition) and mean trolling indices were 2.2 (30 minutes school definition) and 2.6 (2km school definition), respectively.

Figure 4 shows the five different trolling indices produced by 1000 times bootstrap sampling to the number of lines. The indices were standardized to mean of the 1000 values produced. Along the number of lines increased, median values become more stable larger than four lines and the confidence interval between 5% and 95% points were decreased largely to five lines and then decreased gradually. The number of lines actually carried out this year, 14, was appeared to be sufficient.

Figure 5 shows three series of trolling indices. Because there were no sequential detail location records (GPS time series data) in the acoustic survey and TRI_2km was not available, TRI_30min was used for comparison. Although each index was derived from different methods (vessel or area) and we need to be careful, it allows interpretation of the recent index within the longer time series of 17 years between 1996 and 2012. Indices in 2005 and 2006 provide calibration among the three indices. Generally, indices of the three series were in similar values to each other in each of the two years and all the three indices increased in 2006. Median of indices of the acoustic survey on the piston-line were 1.2 (2005) and 1.5 (2006) times higher than that in the whole area, respectively. Median of index of the acoustic survey on the piston-line was 1.3 times higher than that of the trolling survey in 2006. It appears that the indices from the acoustic survey in the whole area during 1996-2006 were as 1.2-1.5 times high that shown in the figure, when compare to the indices from the trolling survey since 2006.

Considering these, the indices were similar level between 1996 and 1999, decreased to quite low level between 2000 and 2002, increased again in 2003 and 2006 (research was not carried out in 2004) to the same level during 1996-1999, and further increased between 2007 and 2008. After decreasing in two years of 2009 and 2010 to the same level during 1996-1999, the index increased in 2011 to the highest value (5.7 schools/100 km). In 2012, the index decreased to the value with median of 1.6 schools/100 km (0.8-2.4 in the 90% confidence interval) which is the lowest level among the trolling survey series. Note that cohort (year class) is one year before mentioned above.

4. Discussion

Fishery data are basic information to estimate current stock status of SBT in CCSBT. Especially, CPUE of Japanese longline, which covers wide area and season and wide age range and based on detailed information reported from fishermen, is a long time series index more than 40 years for SBT stock status. Aerial survey is also a valuable research. It covers wide area in a short duration in the Great Australian Bight by using airplane and data of school biomass is derived as an estimation of spotter. However, there is no index that directly reflects the status of SBT stock in whole ranges in both age and geographical distribution. Therefore, we need to collect information as many as possible to decide stock status appropriately. Trolling survey provide an important information of age-1 SBT as one of pieces of information.

SBT of age 3 and more are distributed so widely in the area between off New Zealand and off Cape that means a fraction of the whole stock is the subject of the aerial survey in the Great Australian Bight and Taiwanese and Japanese longliners. SBT of age-1 is thought to be distributed in the coastal area of Western Australia (Itoh and Sakai 2009b).

A recruitment index derived from SBT age-1 in Western Australia by any measure (not restricting trolling catch) has a potential that represents whole the stock at an age.

There are advantages of the trolling survey compared to the acoustic survey and the aerial survey, which could be complementary with other methods. Species identification and size of SBT are certain data which were actually measured in the trolling survey. The trolling survey is a robust research against wind, wave and swell. There were few days that suspended the research during the cruise due to rough sea condition in seven years. We did not find a tendency that SBT were less caught in rough sea condition.

The results obtained from the piston-line trolling survey and trolling data in the acoustic survey show that the SBT recruitment level of the 1999-2001 year classes are low, those of the 2002 and 2004 year classes are as the similar level of the 1995-1998 year classes, and those of the 2005-2010 year classes are high. It is consistent with the assessment of SBT stock status in CCSBT that the 1999-2001 year classes are low level derived from various fishery data and scientific researches (Anon., 2006). For the subsequent year classes, aerial survey index and fishery data from longline in Japan and New Zealand suggests that the 2002 and 2009 year classes are in relatively high level, which also consistent with trend of the trolling index. Information of the year classes after 2010 has not been obtained from other sources.

Two points should be noted. One point is difference of size distribution among years. Almost all of SBT in southern Western Australia we caught in the surveys had been age 1.0 born in February (Itoh CCSBT-ESC/1208/39). However, composition of sub-cohort in 2012 survey (2011 cohort) was quite different that age-1.3 born in October 2010 was 45% and age-1.0, we caught usually, born in February 2011 was 33%. In the 2011 survey, age-1.0 fish were majority as 97% off Bremer Bay where the piston-line exist, though different sub-cohort composition was observed in the whole survey area in southern Western Australia as 42% of age-1.3 and 58% of age-1.0. The reason of such difference in sub-cohort composition is unknown. May abundant age-1.3 fish extend their distribution and age-1.0 become relatively small in abundance, or small abundance of age-1.0 induce extend of distribution of age-1.3? May dynamics of oceanic structure including Leeuwin Current system alter distribution and migration of SBT sub-cohorts? Is such a change temporary and buck again or permanent?

Influence of change in sub-cohort composition on trolling index is also unclear. If relative abundances among sub-cohorts varied largely inter-annually, and if proportion of sub-cohorts distributed in southern Western Australia varied largely inter-annually, the trolling survey over the present area and time could not provide recruitment index in consistent reliability over years. Appropriate treatment we can do at present is that do not assess the recruitment level simply from the derived 2012 trolling index value.

Trolling index is not the only one result we can draw from the survey. It can provide information for assessment whether extremely low level of recruitment such as the 1999-2001 year classes occurred. In the 2012 survey, the trolling index was not so extremely low and SBT age-1.0 was caught in many locations. This is different from the 1999-2001 year classes when the trolling indices in the acoustic survey were quite low and SBT were caught in limited number of lumps. It is not likely that the 2011 year class was extremely low as the 1999-2001 year classes.

The other point is exactness of the index to the stock. Since its start, the objective of trolling survey has been to provide a rough recruitment index with low cost. Index on the piston-line which become stable around 4-7 lines in seven years suggests that four days or more is sufficient for the piston-line survey. Indices between on the piston-line and on adjacent areas, as well as those between off Bremer Bay and off Albany were not different very much (Itoh, 2007, Itoh and Sakai 2008, 2009a). However, unfortunately, these differences were not small. We should recognize that the trolling index, which based only on the number of school and ignore the biomass of the SBT school, is a rough recruitment index, though we are trying to evaluate the number of individuals of a school from video footages taken. Even if the number of days for survey or the number of vessels were increased, the resolution of the index is not likely to be increased largely.

The recruitment monitoring is needed to be continued further at least in similar scale in the consistent procedure. In addition, to determine the robustness of the index obtained, more data of the dynamics of distribution of SBT age 0-1 in Western Australia should be collected (Itoh and Sakai 2009b).

Acknowledgement

We thank Mr. Tonkin of St Gerard, Mr. Riggs and Mr. Totterdell in MIRG for their help of cruise. We thank AFMA given us a scientific research permission in the Australian coastal waters.

References

Anon (2006) Report of the thirteenth annual meeting of the Commission. October 2006, Miyazaki Japan.

Eveson, P., Bravington, M., and Farley, J. (2006) The aerial survey index of abundance: updated analysis methods and results. CCSBT-ESC/0609/16.

Itoh, T. (2006) Acoustic index of age one southern bluefin tuna abundance by the acoustic survey in 2005/2006. CCSBT-ESC/0609/37.

Itoh, T. and O. Sakai, and D. Tokuda (2012) Sub-cohort structure of southern bluefin tuna in the recruitment monitoring trolling survey in 2012. CCSBT-ESC/1208/39.

Itoh, T. and Kurota, H. (2006) Report on the piston-line trolling survey in 2005/2006. CCSBT-ESC/0609/38.

Itoh, T. (2007) Some examination on the recruitment index derived from the trolling survey. CCSBT-ESC/0709/35.

Itoh, T. and Sakai, O. (2007) Report on the piston-line trolling survey in 2006/2007. CCSBT-ESC/0709/34.

Itoh, T. and Sakai, O. (2008) Report on the piston-line trolling survey in 2007/2008. CCSBT-ESC/0809/41.

Itoh, T. and Sakai, O. (2009a) Report on the piston-line trolling survey in 2008/2009. CCSBT-ESC/0909/32.

Itoh, T. and Sakai, O. (2009b) Distribution of age 0-1 southern bluefin tuna in Western Australia. CCSBT-ESC/0909/35.

Itoh, T. and Sakai, O. (2010) Report of the piston-line trolling survey in 2009/2010. CCSBT-ESC/1009/25.

Itoh, T. Fujioka, K. and Sakai, O. (2011) Report of the piston-line trolling survey in 2010/2011. CCSBT-ESC/1107/29.

Table 1. Statistics of trolling index.

Survey	Year	N_line	Area	Minimum	5%	Median	95%	Maximum
Acoustic	1996		Not including piston line	0.365	0.711	1.260	1.912	2.955
Acoustic	1997		Not including piston line	0.317	0.644	1.075	1.604	2.361
Acoustic	1998		Not including piston line	0.423	0.958	1.576	2.215	2.949
Acoustic	1999		Not including piston line	0.819	1.373	1.932	2.528	3.127
Acoustic	2000		Not including piston line	0.000	0.092	0.367	0.658	1.068
Acoustic	2001		Not including piston line	0.000	0.000	0.101	0.301	0.716
Acoustic	2002		Not including piston line	0.000	0.000	0.000	0.000	0.000
Acoustic	2003		Not including piston line	0.161	0.570	1.046	1.554	2.270
Acoustic	2005		Not including piston line	0.128	0.483	1.196	2.120	3.390
Acoustic	2006		Not including piston line	1.309	1.859	2.420	3.052	3.738
Acoustic	2005	18	Piston line only	0.142	0.718	1.442	2.284	3.158
Acoustic	2006	18	Piston line only	2.500	2.951	3.682	4.422	5.015
Trolling	2006	12	Piston line only	1.335	2.167	2.854	3.732	4.223
Trolling	2007	14	Piston line only	1.542	3.049	4.883	6.935	8.934
Trolling	2008	10	Piston line only	3.675	4.469	5.469	6.586	7.712
Trolling	2009	9	Piston line only	1.256	2.252	3.646	5.341	7.090
Trolling	2010	11	Piston line only	1.163	1.765	2.918	3.812	4.954
Trolling	2011	12	Piston line only	3.340	4.184	5.736	7.430	8.790
Trolling	2012		Piston line only	0.202	0.816	1.616	2.424	3.037

Unit of index was N_school/100 km. School definition was >30 minutes between two catches.

Minimum, 5%, median, 95%, and maximum points were calculated from 1000 times bootstrap samplings.

Figure 1 St Gerard M, used for the research

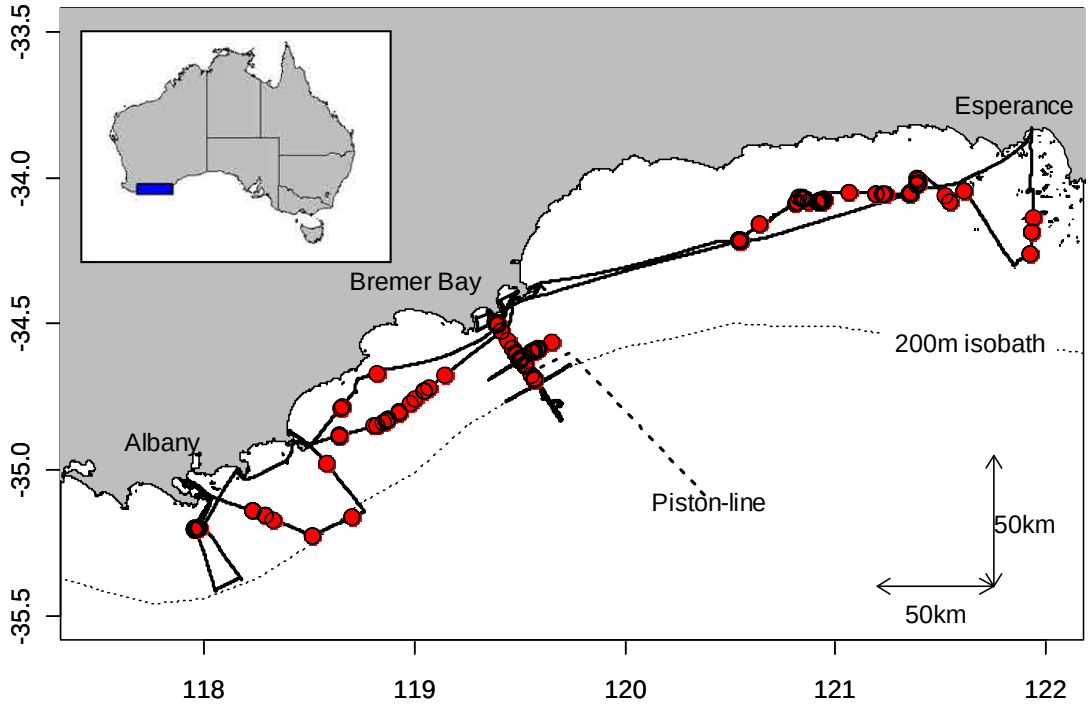

Figure 2 Trajectory of the vessel and location of SBT caught (circles) in the 2012 trolling survey.

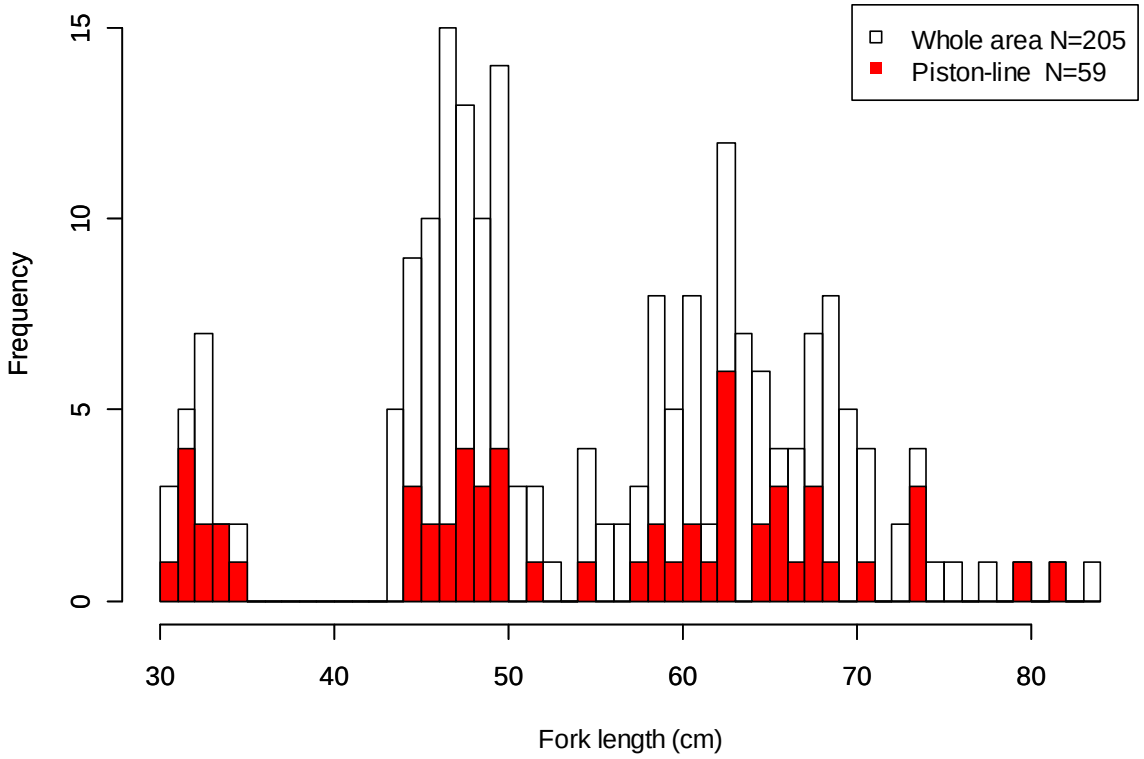

Figure 3 Fork length frequency distributions of southern bluefin tuna caught in the 2012 cruise. That of fish caught off Bremer Bay (119E-120E) is also show as Piston-line.

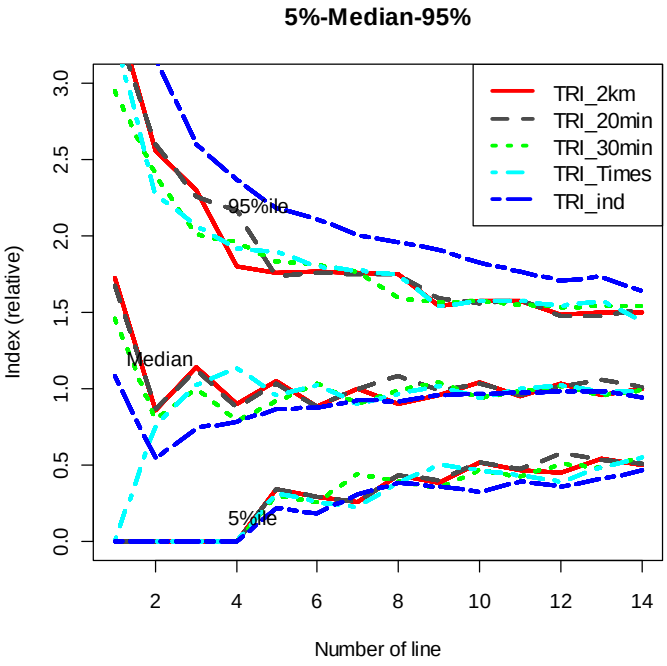

Figure 4 Bootstrap simulation for the five types of trolling indices to the number of line surveyed in 2012. Relative values of median and 5 percentile and 95 percentile points to the mean of each trolling indices are shown.

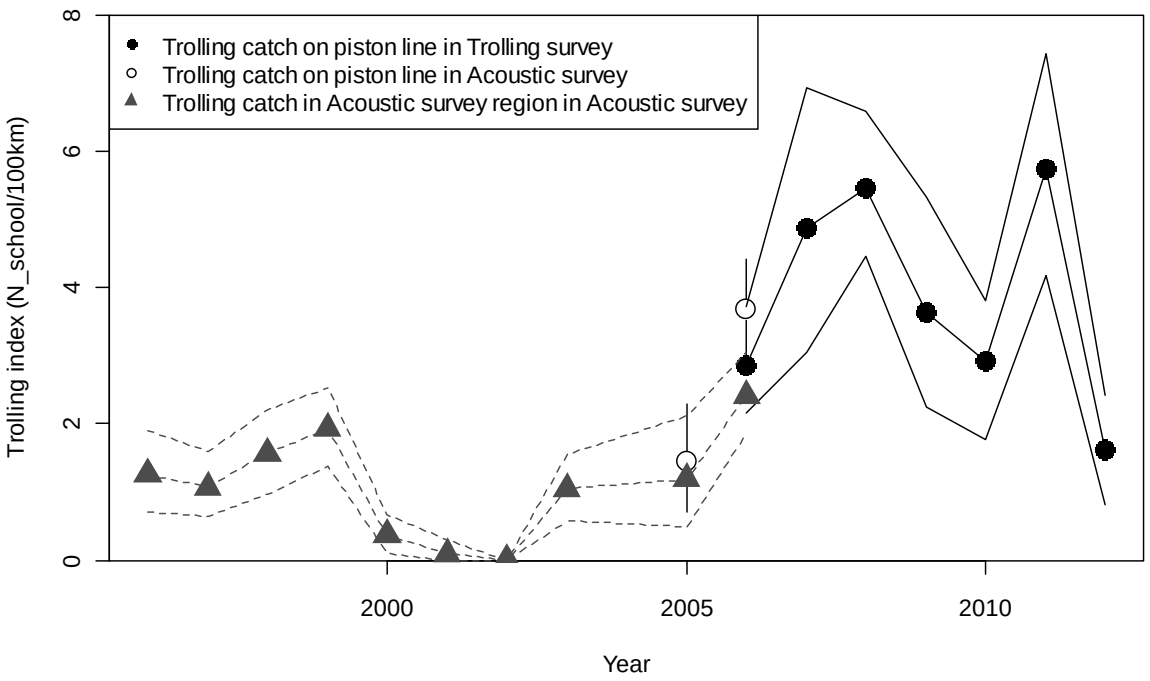

Figure 5 Trolling indices (TRI_30min) from the trolling survey on the piston line (2006-2012), from the acoustic survey on the piston line (2005-2006) and from the acoustic survey in whole the rectangle research area except the piston line (1996-2006). Marks and upper and lower lines (or bar in 2005 and 2006 for trolling catch on the piston line in the acoustic survey) denote median, 5% and 95% points from 1000 times bootstrap samplings, respectively.