# 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 2012/2013 の結果報告

# Report of the piston-line trolling monitoring survey for the age-1 southern bluefin tuna recruitment index in 2012/2013

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## 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、2013 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 13 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 461 個体で、その内 89 個体にはアーカイバルタグを、6 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 3.48（90%信頼範囲は 3.27-4.69）であり曳縄指数の中間的な値であった。

## Summary

In January and February 2013, 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 13 lines. The adjacent area of the piston-line and the area between Esperance and Albany were also surveyed. During the cruise, a total of 461 SBT individuals were caught. Among them, 89 fish were tagged archival tags, and other 6 fish were deployed pop-up archival tag. The trolling index, the number of age-1 SBT school per 100 km searched, was 3.48 with a 90% confidence range of 3.27-4.69, which was the moderate level in the series.

1. Introduction

Recruitment level is crucial information on stock management of fish, including southern bluefin tuna (*Thunnus maccoyii*, SBT). Since 2006, Australia has had 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 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 two to four which is the same age of the Australian purse seine catch, it gives little time of 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 SRP tagging program 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 which was confirmed by the model based assessment 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, 2012a). In January 2013, we carried out the 8th 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 seven 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 from the coast and then dropped sharply to deeper than 500 m in depth at shelf edge within 2 km distance. 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 distance of 35.9 km. 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.

The vessel operated trolling at speed of 7-8 knots. Eight trolling lines at maximum were trolled. Each line has one hook with a plastic lure. 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 total 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 with an archival tag (Lotek Inc., LAT2810L or LAT2310) and one CCSBT conventional tag following the CCSBT tagging procedure. Some other relatively large SBT individuals in good condition were tagged with pop-up archival tag (Wildlife Computers Inc., mini-PAT). Some other SBT individuals were weighed and taken biological samples (stomach contents, otoliths and muscle tissue). There were some SBT individuals only its length measured and released.

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 18 years between 1996 and 2013; 1) piston-line trolling survey from 2006 to 2013, 2) trolling catch on the piston-line in the acoustic survey from 2005 to 2006, and 3) trolling catch in other area of the piston-line in the acoustic survey from 1996 to 2006 (Itoh, 2007).

## 3. Results

The vessel departed Esperance on 18 January 2013, which was six days earlier than the survey in 2012. The vessel surveyed off Bremer Bay from 19 to 22 January, and then went further west and surveyed an area between Bremer Bay and Albany from 23 to 27 January. The vessel came back and surveyed off Bremer Bay again from 28 to 31 January. The vessel left off Bremer Bay and surveyed west of Esperance, near Investigator Island and West Group, from 1 to 3 February and back to Esperance on 4 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. The piston-line was surveyed off Bremer Bay in seven days for 13 lines.

During the cruise, a total of 738 fish individuals were hooked, including 461 SBT, 4 skipjack *Katsuwonus pelamis*, 203 bonito *Sarda orientaris*, 29 yellowtail kingfish *Seriola lalandi* and 41 unidentified individuals which escaped far from the vessel. Among the 461 SBT individuals, 89 SBT were implemented archival tags in their body cavity with CCSBT conventional tags on their dorsal. Other 6 SBT were attached the pop-up archival tags. 116 SBT were killed for biological sampling. Total weight of SBT sampled was 295.6 kg of 116 individuals.

Many SBT were caught off Bremer Bay not only on the piston-line but also in adjacent areas (Fig. 2). No SBT were caught on shelf edge nor offshore area. Compare to previous years, it was remarkable that most of SBT were caught in the half of continental shelf closer to the coast in 2013.

Length frequency of SBT caught is shown in Figure 3. SBT caught ranged from 32 to 76 cmFL. SBT caught in 2013 is consistent with previous 16 years in terms that fish around 50 cmFL, presumably age-1, was the main component. SBT in 2013 was slightly smaller than those in previous years, even length was adjusted on the same day of year as 1st February by assuming straight growth to the difference of date of catch (Itoh et al. 2012b) (Fig. 4 and Fig. 5).

Length frequency seems to be comprised of three or four different size groups, around 32 cm, 47 cm, 55 cm and > 60 cm. It was decomposed by normal distributions (Itoh et al. 2012b). It was reported that there are two peaks of longline catch rate for adult SBT in the spawning area in October and February within the spawning period which ranged from September to April (Mimura and Warashina 1962, Shingu 1970, Farley and Davis 1998). It suggests two sub-cohort for recruitment SBT stock and lengths for the sub-cohorts at 1st February were assumed as in Table 2.

Figures 6 and 7 show that mixed-distribution from four normal distributions fit well to the length frequency in whole the survey area and off Bremer Bay, respectively. It is well corresponded that 1st mode of 32.5 cmFL with age-0.3, 2nd mode of 46 cmFL with age-1.0 and 3rd mode with 55 cmFL with age-1.3 (Table 3). Proportion of age-1.0 fish was the largest (57% in the whole area and 46% off Bremer Bay) followed by age-1.3 fish more than 30%.

SBT in 4th mode which has mean of 63.7 cmFL in the whole area or 62.1 cmFL off Bremer Bay was too small to be assigned to be age-2.0 (79.4 cmFL). This group of fish could be fast grown age-1 or slow grown age-2. Irrespective of the age of the 4th mode

belonged, proportion of 4th mode fish was not so large ant it was further suggested that age-1 (age-1.0 and age-1.3) fish was the main component as more than 80% of fish caught.

Underwater video images were taken 28 times, reaching 36 hours in total. Those footages were under observation in laboratory.

On the 13 piston lines, the total number of age-1 SBT school found was 17 and 22 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 458 km. The mean trolling indices are calculated as 3.7 school/100 km (30 minutes school definition) or 4.8 school/100 km (2 km school definition).

Figure 8 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, 13, was appeared to be sufficient.

Figure 9 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), it allows interpretation of the recent index within the longer time series of 18 years between 1996 and 2013. 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 to the highest value of 5.7 schools/100 km in 2011 followed by sharp decrease to the value of 1.6 schools/100 km in 2012. In 2013, the index increased again to the value of 3.5 schools/100 km (3.3-4.7 in the 90% confidence interval) which is the moderate 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 asess 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 from as many as possible to decide stock status appropriately. Trolling survey provide an important information of age-1 SBT.

SBT of age three 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 longliners in Taiwan and Japan. 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 is complementary with other methods. Species identification and size of SBT are definite 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 eight 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 and 2012 year classes are high, though the 2011 year class is low as the 2002 and 2004 year classes. The trolling index 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, the trolling index is consistent with Japanese normalized longline CPUE in age 4 and 5 that the 2004-2007 year classes are higher than previous years (Takahashi and Itoh 2012). New Zealand longline nominal CPUE both

chartered and domestic that has been higher since 2008 than previous years suggests higher recruitment after the 2005 classes than the 1999-2001 year classes. Comparison to scientific aerial survey index and SAPUE is difficult because the indices are mix of ages between two and four and the age composition of farming catch is suspected to be biased (Itoh et al. 2012 c). In addition, the indices were high in 2011 and then dropped in 2012 which is "somewhat of a puzzle if we assume that it was again a combination of ages 2, 3, and 4" (Farley and Basson 2012). Because the youngest age obtained from other sources is age three, the trolling survey is the only one source that provides cohort strength of the 2011 and 2012 year classes.

Trolling index is not the only one result we can draw from the survey. The survey can provide information for assessment whether extremely low level of recruitment such as the 1999-2001 year classes occurred. In the 2013 survey, the trolling index was not low and SBT age-1 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 2012 year class was extremely low as the 1999-2001 year classes.

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.

Two sub-cohorts in age-1 were observed in the 2013 data. Such two sub-cohorts and age-2 fish were also observed in 2011 and 2012 (Itoh et al. 2012b). These three years between 2011 and 2013 has another common feature that sea-surface temperature off the west coast of Western Australia was higher than other years and suggested stronger Leeuwin Current which go down to south off western Western Australia subsequently passes through off southern Western Australia. At present, it is unclear the mechanism of sub-cohort distribution in the trolling survey area and its relation to the oceanographic dynamics.

The recruitment monitoring is needed to be continued further at least in similar scale in the consistent procedure (Itoh and Sakai 2013). 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).

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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 | 14 | Piston line only | 0.202 | 0.816 | 1.616 | 2.424 | 3.037 |
| Trolling | 2013 | 13 | Piston line only | 3.262 | 3.267 | 3.480 | 4.689 | 4.777 |

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.

Table 2 Age and expected fork length at 1st February for four length modes

| | 1st mode | 2nd mode | 3rd mode | 4th mode |
|---|---|---|---|---|
| Assumed season of occurrence | Oct. 2012 | Feb. 2012 | Oct 2011 | Feb. 2011 |
| Age corresponded | Age 0.3 | Age 1.0 | Age 1.3 | Age 2.0 |
| Expected length at 1st February | 33.4 cmFL | 49.4 cmFL | 58.8 cmFL | 79.4 cmFL |

Table 3 Estimated parameter values of mixed normal distributions which applied for length frequency in 2013 in whole the survey area and off Bremer Bay

| | 1st mode | 2nd mode | 3rd mode | 4th mode |
|---|---|---|---|---|
| SBT in whole the survey area | | | | |
| Mean length | 32.5±0.71 cm | 46.7±0.16 cm | 54.9±0.34 cm | 63.7±1.40 cm |
| Standard Deviation | 1.1±0.70 cm | 2.5±0.15 cm | 2.8±0.50 cm | 3.0±1.29 cm |
| Proportion | 2.1±1.15 % | 56.5±3.12 % | 31.9±5.42 % | 9.5±6.36 %*) |
| | | | | |
| SBT off Bremer Bay | | | | |
| Mean length | 32.5±0.38 cm | 45.5±0.12 cm | 54.8±0.47 cm | 62.1±1.80 cm |
| Standard Deviation | 1.1±0.37 cm | 2.0±0.12 cm | 2.5±0.39 cm | 3.1±1.42 cm |
| Proportion | 4.9±1.42 % | 43.1±2.05 % | 37.1±7.62 % | 14.8±8.02 %*) |

Values following ± is standard error of mean. *) denotes the standard error was calculated with delta method.

Figure 1 St Gerard M, used for the research

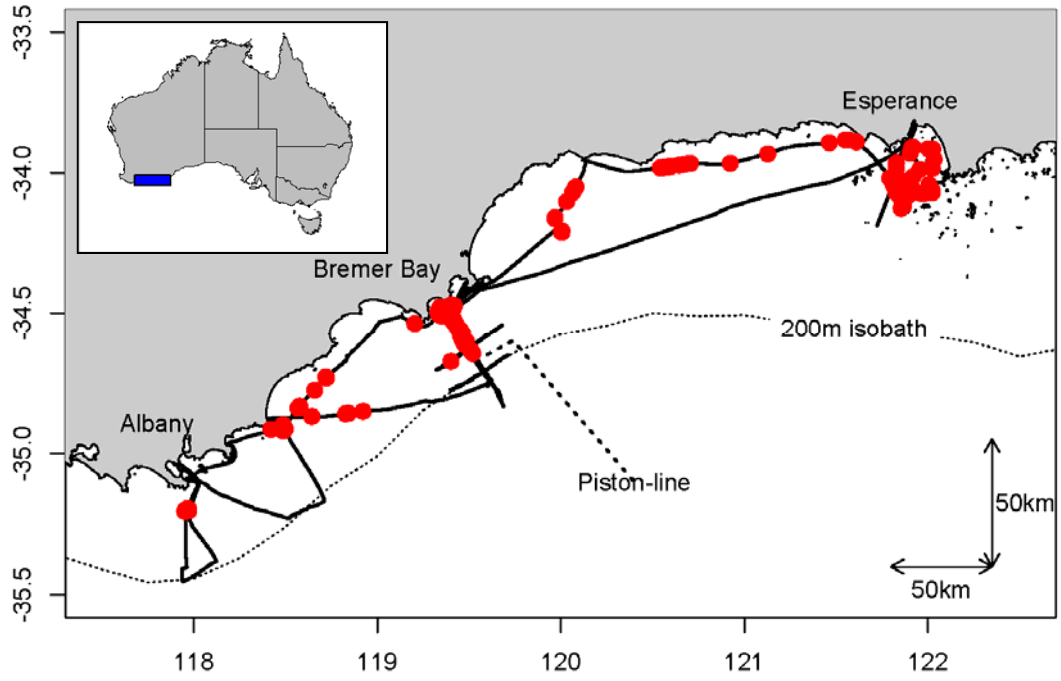



Figure 2 Trajectory of the vessel and location of SBT caught (circles) in the 2013 trolling survey.

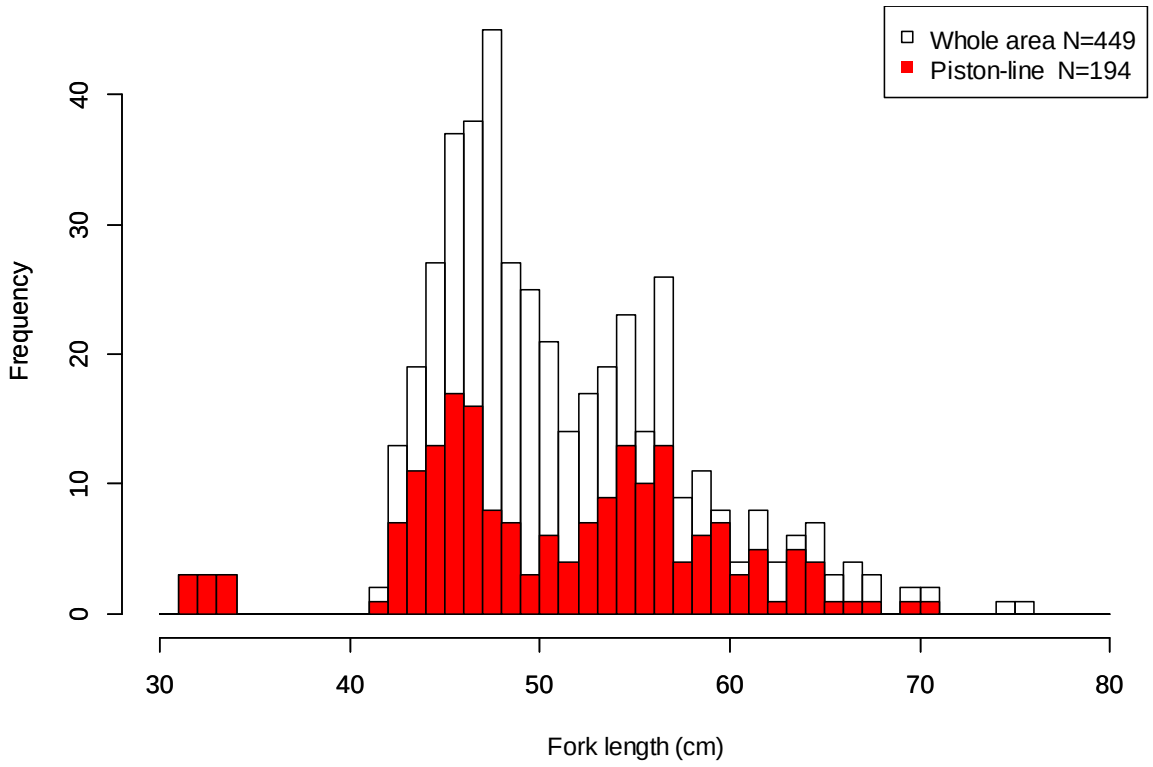



Figure 3 Fork length frequency distributions of southern bluefin tuna caught in the 2013 cruise. That of fish caught off Bremer Bay (119E-120E) is also show as Piston-line.

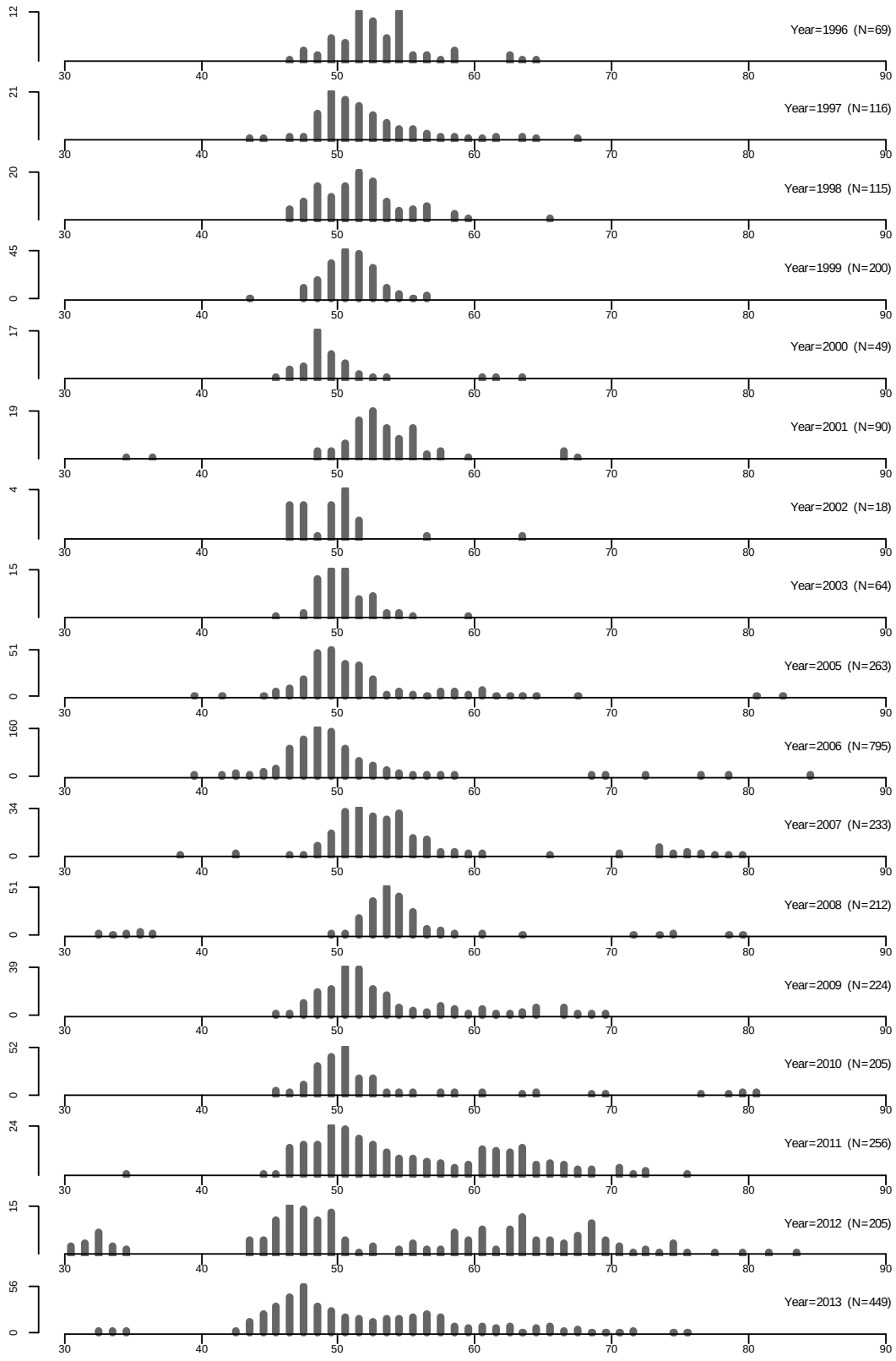
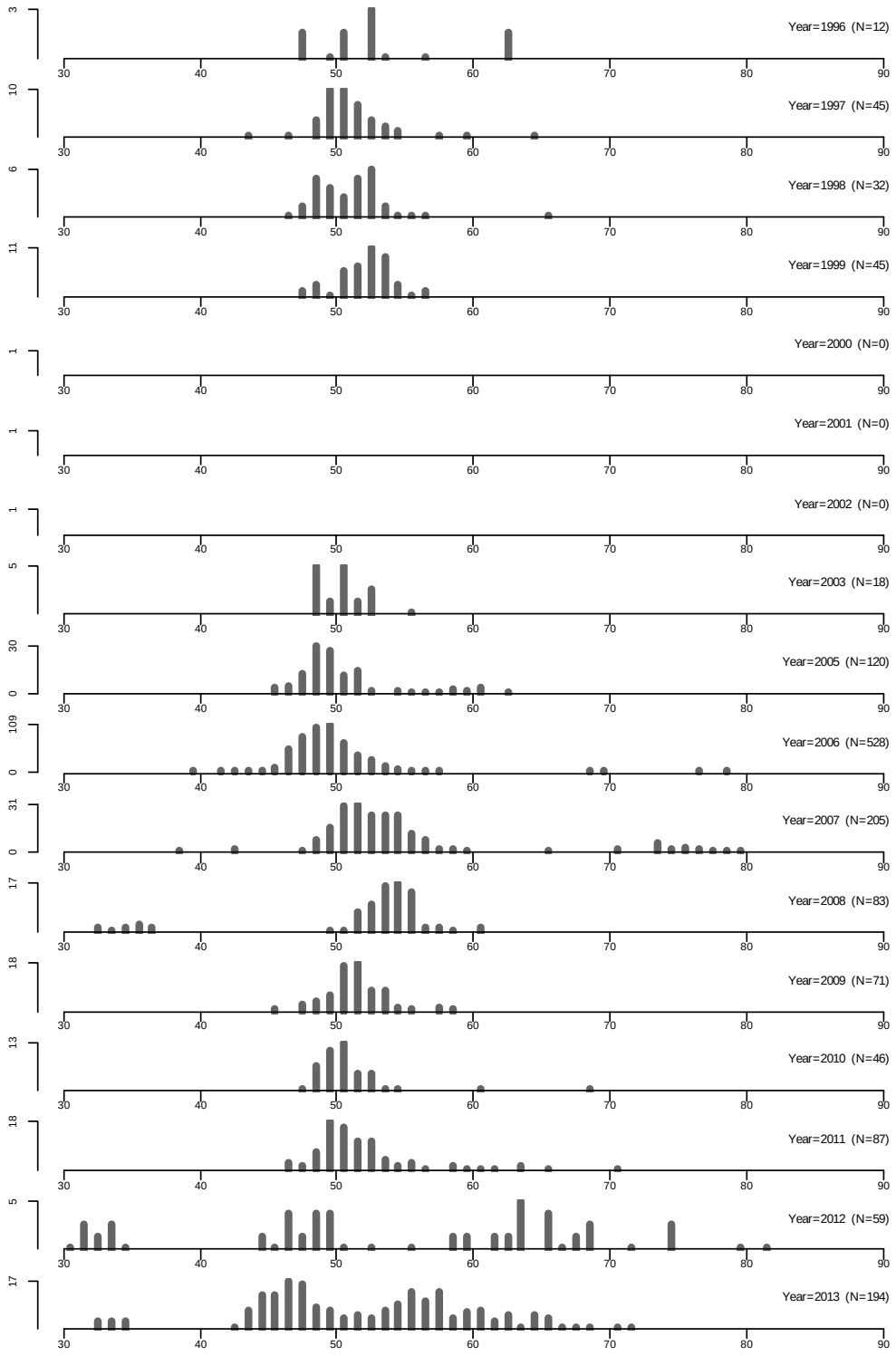



Figure 4 SBT length frequency of recruitment surveys by year adjusted to be caught on 1st February off southern Western Australia. X axis shows fork length in centimeter. Data came from the acoustic survey in 1996-2006 and the trolling survey in 2006-2013.




Length frequency of SBT at Feb.1 off Bremer Bay (119E-120E) in southern WA from the acoustic monitoring survey (1996-2006) and the trolling survey (2006-2013)

Figure 5 SBT length frequency of recruitment surveys by year adjusted to be caught on 1st February off Bremer Bay in southern Western Australia (119E-120E). X axis shows fork length in centimeter. Data came from the acoustic survey in 1996-2006 and the trolling survey in 2006-2013.

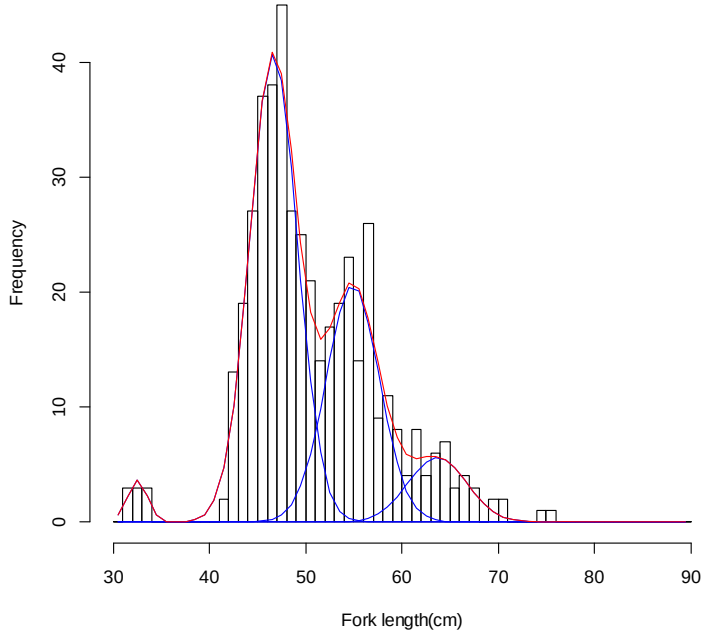



Figure 6 SBT length frequency caught in the whole range of the trolling survey 2013 and applied mixed normal distribution.

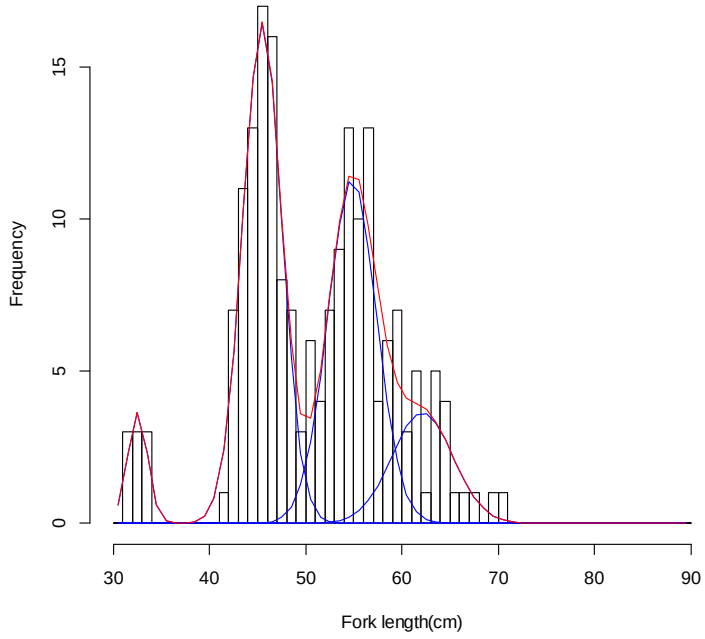



Figure 7 SBT length frequency caught off Bremer Bay (119E-120E) in the trolling survey 2013 and applied mixed normal distribution.

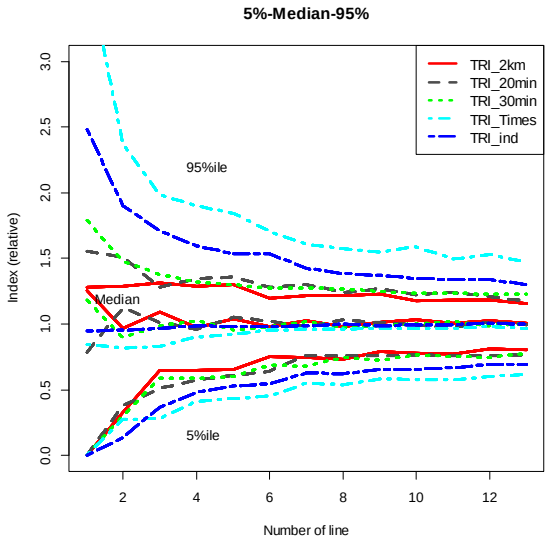



Figure 8 Bootstrap simulation for the five types of trolling indices to the number of line surveyed in 2013. Relative values of median and 5 percentile and 95 percentile points to the mean of each trolling indices are shown.

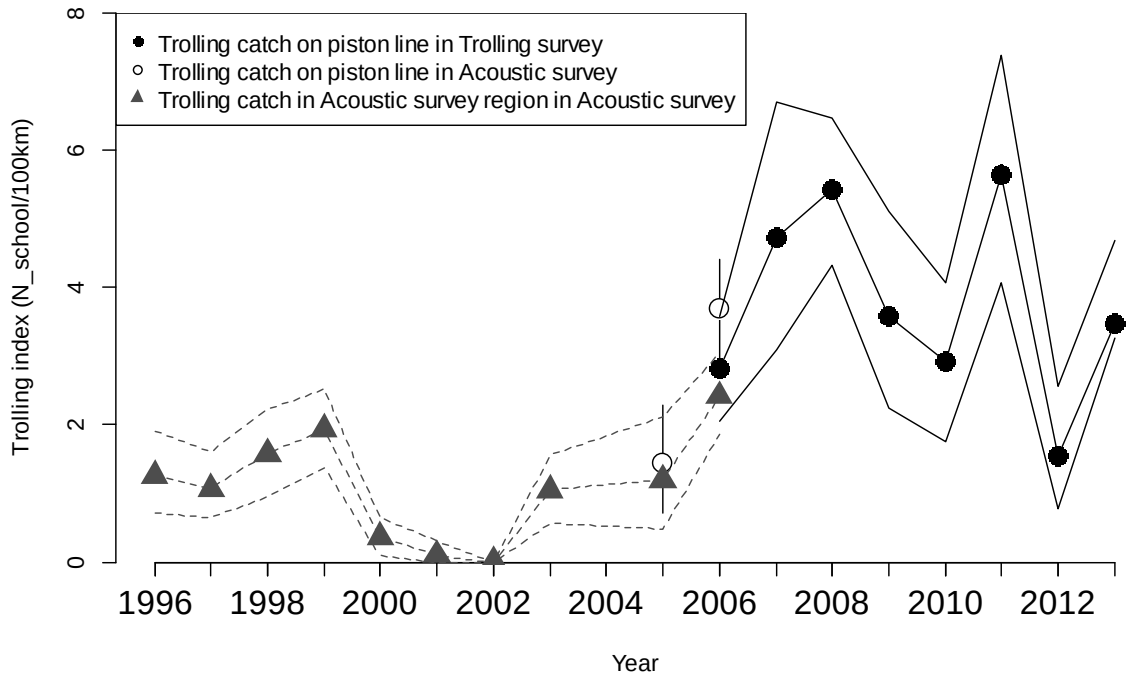



Figure 9 Trolling indices (TRI_30min) from the trolling survey on the piston line (2006-2013), from the acoustic survey on the piston line (2005-2006) and from the acoustic survey in whole the rectangle research area except the piston line (1996-2006). Marks and upper and lower lines (or bar in 2005 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.