ミナミマグロ 1 歳魚の曳縄指数 ―ピストンライン指数の更新とグリッドタイプ曳縄指数の初期的解析

Trolling indices for age-1 southern bluefin tuna: update of the piston line index and preliminary analysis of the grid type trolling index

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要約

オーストラリア南西岸にて、2006 年から 2014 年に行われた曳縄調査および 1996 年から 2006 年に行われた音響調査の曳縄漁獲データから、ミナミマグロ 1 歳魚の 2 種類の資源量指数を求めた。一つは従来から報告しているピストンライン指数（PTI）で、ピストンラインの長さを統一し、いくつかのレコードを修正して、値を更新した。もう一つは、グリッドベースの曳縄指数（GTI）という新たな指数で、両調査の全曳縄操業データを利用し、緯経度 0.1 度、日付、時間、海域別のグリッドにおける曳縄探索距離当たりのミナミマグロ 1 歳魚の群数である。探索合計距離約 49,000km、ミナミマグロ 1 歳魚群数合計 943 群から求めたデータは、ゼロキャッチが多かったことから GLM のデルタログノーマルによる標準化をした。17 年間の GTI は、オペレーティングモデルで推定した加入量および日本延縄 4 歳魚の CPUE から推定した加入量とトレンドがよく一致していた。PTI と GTI は相互に似たトレンドだった。PTI と GTI は CCSBT における資源評価に貢献できるものと考えられる。

Summary

Two recruitment indices of age-1 southern bluefin tuna *Thunnus maccoyii* was developed using trolling catch data in two surveys in the southwestern coast of Australia, the acoustic survey from 1996 to 2006 and the trolling survey from 2006 to 2014. One index is piston-line trolling index (PTI), which have been reported to CCSBT, but correct the searched distance in offshore area and updated. The other

index is grid-type trolling index (GTI) which utilize all of the trolling data that aggregated the trolling effort and the number of southern bluefin tuna schools caught by date, hour, area type and 0.1 degrees square in latitude and longitude. Dataset included about 49,000 km total distance searched with 943 schools. GLM of delta-lognormal method was applied for CPUE standardization because of high percentage of zero catch. Year trend of GTI in 17 years were agreed to those of recruitment estimates from operating model and age-4 standardized CPUE of Japanese longline. Trends of GTI and PTI were similar to each other. GTI and PTI are expected to contribute to the CCBST stock assessment.

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Introduction

Trolling survey for southern bluefin tuna (*Thunnus maccoyii* SBT) aims to provide recruitment index of the stock at age-1. It has provided an index to CCSBT derived from a determined straight line (named piston line) (Itoh and Kurota 2006, Itoh 2007, Itoh and Sakai 2007, 2008, 2009, 2010, Itoh et al. 2011, 2012a, 2013, Itoh and Tokuda 2014). There was a difference in length of the piston line before 2006 and after 2007. There were several data records to be corrected. The corrected piston line index is provided in this paper.

In addition, trolling survey operated trolling in other area of the piston line. Large area was also surveyed with trolling operation in the acoustic survey between 1996 and 2006. These data become available for analysis and development of new trolling index has begun. The preliminary results of the new index is provided in this paper.

Materials and methods

1. Piston-line Trolling Index PTI

Trolling catch data on the piston-line in the acoustic survey in 2005 and 2006 and in the trolling survey between 2006 and 2014 were used for analysis. Details of the survey were described in other papers that submitted every year (e.g. Itoh et al. 2013). It contains data in total of 148 times on the piston-line (Table 1). Data of another ten times were not included because the survey did not complete whole the piston-line due to mainly rough sea conditions. Datasets were separated between the acoustic survey and trolling survey because there were differences in the two surveys for survey design, vessel used especially in size and specification of trolling gears. Trolling operations on the piston-line was repeated from 10 to 20 times per year.

The piston-line was set off Bremer Bay, in the middle of the whole area for acoustic and trolling surveys (Fig. 1). The exact locations have been changed since its first determination in 2005 (Fig. 2). In 2006, the piston-line was moved eastward to avoid the array of hydrophone for acoustic tags (Fujioka et al. 2010). In 2007, the piston-line was cut its offshore portion where few fish had caught in previous years and extended toward coast. The small vessel used for the trolling survey was possible to close to the coastal area, while the large vessel used for the acoustic survey lasted up to 2006 could not. In 2008, the piston-line was moved west in order to avoid the array of hydrophone for acoustic tags and to bring closer to the bay the vessel spent night. The locations of the piston-line have been same since 2008 to 2014.

The piston-line in 2005 and 2006 had a larger part of offshore than after 2007. We made the distance of the piston-line in offshore same as in 2007 and removed some

effort data in 2005 and 2006. There was no SBT catch that removed by this procedure. No correction was made on the coastal portion of the 2005 and 2006 piston-line.

The summary of data after correction was made for location of offshore point of the piston-line, as well as several records on time was shown in Table 2. It reached a total of 366 hours in search time and 4,859 km in search distance. The number of SBT caught was 676 individuals.

Piston line trolling index (PTI) was calculated as catch of age-1 SBT per 100 km search distance. There were five types of catch definition and PTIs were calculated for each of them.

(1) School of age-1 SBT. 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. PTI from this definition is "TRI_2km."

(2) School of age-1 SBT. 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. PTI from this definition is "TRI_20min."

(3) School of age-1 SBT. 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. PTI from this definition is "TRI_30min."

(4) Number of times age-1 SBT caught. All the catches even it was likely to be from the same school were counted as different. PTI from this definition is "TRI_Times."

(5) Number of age-1 SBT individuals. PTI from this definition is "TRI_ind."

Confidence intervals of PTI were calculated from data sampled 1000 times by bootstrap method, and the results were shown by box plots or median, 5% and 95% points.

Usually, piston-line was surveyed two times per day. It was evaluated whether the two datasets of the same day, outward run and inward run, can be assumed to be independent. If two datasets in the same date were strongly correlated, the variance between them was expected to be small. So, limit the data in a year for both outward and inward runs were operated in the same day. Chose data randomly with 1000 times bootstrap in following two cases and compared the variability of estimates. One case was that, for example it was three days, chose three days randomly and used data

in both outward and inward runs of these days to calculate PTI. Another case was that chose six days randomly, and used data either outward or inward run (it also chose randomly) to calculate PTI.

2. Grid-type Trolling Index GTI

Data were from trolling catch in the acoustic survey between 1996 and 2003, 2005 and 2006 and trolling survey between 2006 and 2014. The survey were carried out in the period from December to March, and year was represented in the year at January in this paper.

Searched distance of trolling, catch of age-1 SBT and CPUE (catch/100km searched) were aggregated by survey type (acoustic survey / trolling survey), year, month, day, hour, longitude (0.1 degree), latitude (0.1 degree) and area type (described later). Data west of 117.5E were removed.

Interval of latitude and longitude records was different by year. Up to 2005, latitude and longitude were only recorded when any events occurred, including hourly environmental observation, catch, detection of anything in sonar, arrival of transect reflection point, CTD observation, etc. Locations at every one minute were calculated by interpolating two points available. Since 2006, locations were recorded in short interval such as 10 or 15 seconds by GPS logger devises and mean locations by one minute were used for analysis.

In the acoustic survey, it was planned that trolling was operated in daytime from 6 AM to 6 PM. Start and end time of trolling was not recorded. Some records of catch before 6 AM and after 6 PM were removed. In the trolling survey, all the times of start and end of trolling operations were recorded.

Catch was limited for age-1 SBT (40-63 cmFL) in the analysis. Catch was defined as a fish school and schools were defined as that successive catches more than 30 minutes were from different schools.

In the research area, SBT distribution was different in area types. Area types were categorized as follows (Fig. 1).

Lump: Small seamounts or small islands. Its center position was measured on nautical charts. A range of effect of each of lumps was determined by observing contour of depth and SBT catch locations. Lumps specified for analysis were "BaldIs27", "lumpA40", "lumpB36", "lumpC35", "lumpD48", "lumpE5", "lumpF50", "lumpG35", "lumpH49", , "BBeast50", "BBeast16", "Investigator Island", "West Group(Figure of Eight)". The figures came from depth of its summit.

Mauda Reef: Mauda Reef is a large lump off Albany. It was treated separately

because it was very large in size and surveyed many years.

Shelf edge: A range near 200 meter isobath. The range was determined from SBT catch records that 3.0 km toward inshore and 0.5 km toward offshore. Two People Canyon off Albany, a large sea canyon, was included in shelf edge.

On shelf: northern area of shelf edge.

Offshore: southern area of shelf edge.

Delta model was applied for CPUE standardization because of high percentage of zero observations (Lo et al. 1992, Li and Jiao 2013). The delta model handles zero data and positive catch data in two separate sub-models, i.e. one sub-model to estimate the probability of catching SBT age-1 (probability sub-model) with an assumption of binomial distribution and logit link function, and the other to fit the positive catch data (positive catch sub-model) with an assumption of lognormal distribution. Product of estimates from these two sub-models give the final estimate of the Grid-type Trolling Index (GTI).

Full model of probability sub-model

log(p/(1-p)) ~ year + month + hour + area + survey + offset(log(dist)) + error,

error ~ binomial

where p is the probability of positive catch.

Full model of positive catch sub-model

log(catch) ~ year + month +hour + area +survey +offset(log(dist)) + error,

error ~ gaussian

The explanatory variables were selected through a stepwise approach based on the AIC. Bootstrap method was applied to obtain a range of estimate. 1000 datasets were made through stratified sampling by year.

The trolling indices, GTI and PTI, were compared to various recruitment indices, including the recruitment estimated in the 2011 CCSBT stock assessment through OM in the scenario of "MP3_2035_3000_inc_base", standardized CPUE (W0.8) for age-4 SBT in Japanese longline, and aerial survey index and commercial aerial spotting index (SAPUE) in the 2014 CCSBT data exchange.

R software (version 2.15.1) was used for analysis (R-core team 2012).

Results

1. Piston-line Trolling Index PTI

PTI estimated were shown in Fig. 3 and Table 3 for five types. Fig. 4 shows median of the five indices that adjusted to the mean of the each series. There was small difference among TRI_20min, TRI_30min and TRI_2km in the period from 2006 to 2008. There was a good agreement in the trends in the period from 2009 and 2014.

Fig. 5 shows the comparison between present PTI and previous trolling index that had been submitted to CCSBT. The general trend is similar to each other. The present estimates are higher in 2005 and 2006 because of cutting some offshore area on the piston-line where was no catch. Small changes in other years are due to corrections of records.

Graphs for the independence of data between outward and inward piston-line on the same day are shown in Fig. 6. It was not observed that variance (range between hinges here) of PTI became smaller when pairs of same day piston-line were chosen. It suggests independence of the two datasets of the piston-line on the same day.

2. Grid-type Trolling Index GTI

Summary of data aggregated by grid is shown in Table 4. It consists of 9,851 records in total that reaches about 49,000 km search distance and 943 SBT age-1 schools. One record with anomalously high CPUE (>2000) with a short distance was removed for analysis. Quite a large part of data was zero catch (90.8%).

Distributions of effort, catch and CPUE are shown Fig. 7 by year. It is noted that substantial efforts were made in other area than the piston-line except 2007. It is also noted that few catch was observed in offshore area in spite of substantial amount of efforts had been made (Table 5).

Relationships between probability of catch and various variables (Fig. 8) and between CPUE and various variables (Fig. 9) were surveyed. Any relationships to be considered in GLM were found in year, month, hour and area type.

Nominal CPUE is shown in Fig. 10. Note that a substantial part of effort were made ub offshore where few SBT caught from 1996 to 2005. It must be underestimated in this period compare to later half period.

In the GLM standardization, step function of R chose a model for the probability sub-model that removed the survey factor based on AIC. The estimated values are shown in Table 6.

log(p/(1-p)) ~ year + month + hour + area + offset(log(dist)) + error
error ~ binomial

For the positive catch sub-model, a model that includes year, hour and area was chosen. QQ plot is shown in Fig. 11 and the estimated values are shown in Table 7.
log(catch) ~ year + hour + area + offset(log(dist)) + error
error ~ gaussian

LS-means for year trend in each sub-model are shown in Table 8, Table 9 and Fig. 12. Year trend of the probability sub-model was transformed with logistic function and that of the positive catch sub-model was transformed with exponential function. Product (GTI) of both sub-models is shown in Table 10 and Fig. 12.

Table 11 and Fig. 13 show GTI with confidence interval calculated through 1000 times bootstrap. Comparing to nominal CPUE in Fig. 10, GTI is higher in 1996-1999 and similar trend after that except GTI is higher in 2008.

3. Comparison to other indices

Fig. 14 shows comparison between recruitment estimated in OM and trolling indices. OM recruitments after 2007 year class (2007YC) would be inappropriate for comparison because these were estimated without Japanese longline CPUE or just predicted from spawning stock biomass. Among 2004YC to 2006YC, PTI showed same large increase from 2004YC to 2005YC. In GTI, the trends were similar from 1995YC to 2005YC. A high correlation was observed between OM recruit and GTI ($r=0.59$、$p<1\%$) (Table 12). Note that trolling indices were not included in OM and independent information from it.

Fig. 15 shows comparison between age-4 CPUE in Japanese longline and trolling indices. PTI showed similar trend from 2004YC to 2009YC. GTI also showed similar trend from 1995YC to 2005YC. A high correlation was observed between age-4 CPUE in Japanese longline and GTI ($r=0.77$、$p<1\%$). The two indices were less similar after 2006YC but common in the point that both indices were higher than that in the period of low recruitments around 2000YC.

Fig. 16 shows comparison between aerial survey index and trolling indices. Aerial survey index is a mix of age-2, age-3 and age-4. In the figure, age-3 was assumed to assign a year class. Aerial survey index was not similar to the trolling indices. Note that aerial survey index was not obtained around 2000YC when extremely low recruitment observed.

Furthermore, three year running average of GTI was compared to the aerial survey

index considering that aerial survey index was the mix of three year classes (Fig. 17). The trends of them were not similar to each other in the year between 2008 and 2014 when both series were available.

Fig. 18 shows comparison between commercial aerial spotting index (SAPUE) and trolling indices. SAPUE was not similar to the trolling indices, but agreed in the point that 2000YC or 2001YC were the lowest. Comparison to three years running average of GTI is shown in Fig. 19.

Discussions

The present paper provided PTI and GTI. PTI is the trolling index on the piston-line that made the distance in offshore area from shelf edge same. GTI is new index.

PTI was not standardized like as using GLM. It does not need standardization because the survey itself was standardized that the vessel used, specification of trolling gears and survey methods have been identical for nine years and survey was carried out in almost same area and season. There is a possibility that standardization including environmental conditions such as strength of Leeuwin Current improve the index.

PTI was separated so far that from the acoustic survey and that from the trolling survey. In the GLM of GTI, the difference of the survey type was not significant. It may be appropriate to combine the two PTIs into one.

Both Trolling indices, PTI and GTI, are based on catch that is the number of school. When we encountered SBT school, the numbers of fish individuals caught and catch times were able to increase if we handle the trolling line well and/or the vessel moved well to catch up or attract the school. The numbers of fish individuals caught and catch times was decreased when several trolling lines were tangled at one catch and we needed some time to solve the tangling before resume trolling operation. The numbers of fish individuals or catch time were affected such skills of trolling. The number of school was selected as catch in order to avoid the influence of the skill. However, definition of catch as school for index means to set an assumption that the probability distribution of the size of school (the number of individuals per school) is same every year.

There were various types of school definition. Three definitions have been used; two subsequent catches are from different schools if 20 minute apart, 30 minutes apart, and 2 km apart. Definition by time would be inappropriate because it is affected by trolling gear skill and definition by distance seems more appropriate. Detail location data in every 10 seconds have been available since 2006 by using GPS data logger. However,

because detail location records were not available in the period from 1996 to 2005, the 30 minutes definition was chosen to keep the consistency. Fortunately, no large difference was observed among trends of index in different catch definition.

PTI has an upper limit because the piston-line has a determined distance. At present, the trolling survey operates the piston-line with about 35 km in 2 hour 40 minutes in average. When school definition is 30 minutes, six schools and PTI=17.1 becomes upper limit. If catches are repeated less than 30 minutes interval, it results in the number of school caught as 1 and PTI=2.9, in spite of there were many catch. PTI has such a potential problem. However, up to now, PTI trends were similar among various types of catches, including 30 minutes, catch times and number of individuals, and suggests such an extreme situation did not occurred.

GTI is a comprehensive index that includes not only the piston-line but also all the area surveyed. PTI is derived for 10 years since 2005. GTI could extend the years to 17 years, by adding the period from 1996 to 2003.

The acoustic survey and the trolling survey were not originally designed to obtain GTI. However, because the acoustic survey was well designed to cruise randomly in the research area for sonar detection, the trolling catch operated simultaneously in daytime is expected to be a random sampling in the area. While the survey area was concentrated on the piston-line in 2006 and 2007, the trolling survey was also operated in larger area since 2008 intending development of GTI. When trolling was operated on a lump, we tried to operate trolling in the area out of the lump so that collect data to evaluate the SBT distribution difference in area types.

In GLM standardization, the delta method which frequently used for data with high percentage of zero observation was used. Area type was highly significant in the probability sub-model. It is well known the effect of sea bottom topography, such as lumps, on SBT distribution (Hobday and Campbell 2009). It should fully consider the effect of lumps and islands on SBT distribution for survey design and for data analysis.

Year trend of GTI was similar to those in OM recruitment and age-4 CPUE in Japanese longline. The impression given and high correlation were depends on broader scale agreement that medium level in year classes in the mid-1990s, low level in the 2000YC-2002YC and high level since 2005YC. In detail trend, some were agreed but others were not.

Recruitment from OM will be estimated in the coming ESC for more recent several years. Age-4 CPUE will be also updated in future. Those new points of recruitment allow further evaluation of GTI accuracy and precision.

GTI and PTI were similar to each other except 2008 and 2009 (2007YC and 2008YC).

Agreement to aerial survey index was not good. It may be attributed that aerial survey did not included around 2000 when extremely low recruitment occurred. SAPUE agreed to GTI in the point that showed low indices in those years.

Trolling indices and trolling survey design has several problems in terms of SBT ecology. Distribution dynamics of age-1 SBT, which could be different by year, effect on the trolling indices. Study using electronic tagging is desirable. Structure of age-1 fish that consists of two sub-cohorts which spawned in different season may effect on the indices (CCSBT-ESC/1409/33). However, how a targeted local population in a survey represents whole the SBT stock is quite a big proposition, being common to age-4 Japanese longline CPUE and aerial survey index.

Recruitment of OM, based on the widest data including Japanese longline CPUE, seems to be the most reliable estimate. Trolling indices, GTI and PTI, could provide year trends that not inconsistent with OM recruitment. GTI and PTI are expected to contribute to the CCSBT stock assessment.

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Table 1. Number of times piston-line surveyed

Year	Total	Used for index	Incomplete and not used for index
Acoustic Survey			
2005	21	20	1
2006	22	18	4
Trolling Survey			
2006	16	12	4
2007	14	14	
2008	10	10	
2009	11	10	1
2010	11	11	
2011	12	12	
2012	14	14	
2013	13	13	
2014	14	14	
Total	158	148	10

Table 2. Summary data on piston-line survey

Acoustic survey

Year	Value	Search hours	Search distance (km)	Date	Start time	End time	sch20min	sch30min	sch2km	hit.times	number SBT	Index sch20min	Index sch30min	Index sch2km	Index hit.times	Index numberSBT
2005	min	1:57	30.3	2005/1/15	5:45	8:10	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
	max	2:26	30.3	2005/2/15	12:23	14:23	2	2	3	5	11	6.61	6.61	9.92	16.53	36.36
	mean	2:09	30.3	2005/1/30	8:38	10:47	0.70	0.60	0.80	1.00	2.00	2.31	1.98	2.64	3.31	6.61
	total	1.804	605.0				14	12	16	20	40					
2006	min	1:52	29.7	2006/1/15	6:11	8:14	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
	max	2:50	29.7	2006/2/13	14:54	16:50	3	2	6	12	27	10.11	6.74	20.22	40.43	90.97
	mean	2:07	29.7	2006/1/27	10:13	12:21	1.61	1.39	2.50	4.33	7.89	5.43	4.68	8.42	14.60	26.58
	total	1.595	534.2				29	25	45	78	142					

Trolling survey

Year	Value	Search hours	Search distance (km)	Date	Start time	End time	sch20min	sch30min	sch2km	hit.times	number SBT	Index sch20min	Index sch30min	Index sch2km	Index hit.times	Index numberSBT
2006	min	2:08	26.8	2006/1/23	5:15	7:30	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
	max	2:47	29.8	2006/1/30	11:07	17:45	4	3	4	7	16	13.77	11.52	13.77	23.58	61.42
	mean	2:21	28.6	2006/1/26	8:26	11:59	1.42	1.25	1.58	2.75	6.08	4.98	4.41	5.59	9.66	21.54
	total	1.193	349.2				15	13	17	26	62					
2007	min	2:14	28.7	2007/1/22	6:46	9:46	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
	max	3:15	36.1	2007/1/28	11:31	18:18	5	5	6	7	21	16.63	16.63	18.11	23.49	69.83
	mean	2:44	32.5	2007/1/25	8:53	13:41	1.93	1.43	2.36	3.07	7.00	6.13	4.55	7.51	9.84	22.53
	total	1.600	455.0				27	20	33	43	98					
2008	min	2:32	31.6	2008/1/21	6:55	9:53	1	1	1	1	1	2.81	2.81	2.81	2.81	2.89
	max	3:14	35.9	2008/1/31	14:26	18:05	3	3	3	3	7	8.61	8.61	8.61	8.89	19.72
	mean	2:47	34.6	2008/1/25	9:22	13:37	1.70	1.70	1.90	2.10	4.70	4.92	4.92	5.49	6.07	13.52
	total	1.160	346.4				17	17	19	21	47					
2009	min	2:16	30.7	2009/1/18	6:23	8:46	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
	max	3:55	35.9	2009/1/28	12:06	17:04	3	3	3	5	11	9.76	9.76	9.76	14.59	32.11
	mean	2:41	34.3	2009/1/21	8:19	12:28	1.30	1.20	1.30	1.70	3.70	3.87	3.58	3.87	5.02	10.86
	total	1.120	343.2				13	12	13	17	37					
2010	min	2:27	33.7	2010/1/20	5:22	8:02	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
	max	3:04	36.3	2010/1/31	13:32	16:06	2	2	3	8	11	5.93	5.93	8.69	23.72	31.85
	mean	2:40	34.7	2010/1/26	8:17	11:57	1.00	0.91	1.18	2.09	3.36	2.88	2.62	3.41	6.10	9.77
	total	1.224	381.5				11	10	13	23	37					
2011	min	2:20	27.6	2011/1/26	5:28	8:28	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
	max	3:20	35.3	2011/2/8	10:32	17:46	4	4	6	10	18	14.47	14.47	18.00	30.01	65.12
	mean	2:46	33.6	2011/1/31	7:41	12:22	2.08	1.67	2.25	3.08	5.92	6.33	5.11	6.77	9.37	18.52
	total	1.387	402.8				25	20	27	37	71					
2012	min	2:31	33.8	2012/1/25	5:21	8:06	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
	max	3:27	36.2	2012/2/7	13:27	16:02	2	2	2	2	5	5.77	5.77	5.77	5.77	14.42
	mean	2:52	35.3	2012/1/31	7:50	11:36	0.57	0.57	0.64	0.64	0.93	1.63	1.63	1.83	1.83	2.66
	total	1.672	493.6				8	8	9	9	13					
2013	min	2:38	33.8	2013/1/19	5:56	9:21	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
	max	3:21	36.0	2013/1/31	12:21	15:04	2	2	3	13	18	5.69	5.69	8.42	37.72	52.23
	mean	2:49	35.2	2013/1/24	8:34	12:25	1.54	1.31	1.69	3.62	7.38	4.34	3.70	4.78	10.26	20.95
	total	1.530	458.0				20	17	22	47	96					
2014	min	2:30	34.3	2014/1/26	6:04	8:55	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
	max	3:04	35.7	2014/2/7	11:54	14:29	3	2	4	7	7	8.41	5.83	11.21	19.62	20.23
	mean	2:46	35.0	2014/1/31	1:53	5:23	1.14	1.00	1.36	1.71	2.36	3.26	2.86	3.88	4.88	6.74
	total	1.615	490.0				16	14	19	24	33					

Exclude the data not used for PTI. Unit of total search hours is day.

Table 3. Piston-line Trolling Index values

TRI_20min

Survey	Year	Minimum	5%	Median	95%	Maximum
Acoustic	2005	0.496	1.322	2.314	3.471	4.297
Acoustic	2006	3.369	4.493	5.429	6.364	7.113
Trolling	2006	1.994	3.380	4.841	6.562	8.552
Trolling	2007	2.783	4.320	6.139	8.052	10.486
Trolling	2008	2.860	3.980	4.918	5.898	6.893
Trolling	2009	1.407	2.422	3.851	5.530	7.301
Trolling	2010	1.044	1.858	2.881	3.923	4.713
Trolling	2011	2.661	4.400	6.334	8.467	10.226
Trolling	2012	0.202	0.816	1.625	2.448	3.298
Trolling	2013	2.405	3.480	4.344	5.010	5.633
Trolling	2014	1.226	2.242	3.257	4.260	5.452

TRI_30min

Survey	Year	Minimum	5%	Median	95%	Maximum
Acoustic	2005	0.331	1.157	1.983	2.975	3.801
Acoustic	2006	3.182	3.931	4.680	5.429	5.990
Trolling	2006	2.007	3.111	4.278	5.422	6.388
Trolling	2007	1.299	2.859	4.434	6.624	9.066
Trolling	2008	3.130	4.013	4.917	5.900	6.665
Trolling	2009	1.408	2.271	3.559	5.125	6.240
Trolling	2010	0.787	1.587	2.612	3.466	4.409
Trolling	2011	2.668	3.444	5.088	7.019	8.749
Trolling	2012	0.397	0.815	1.622	2.429	2.872
Trolling	2013	2.364	2.835	3.703	4.370	5.007
Trolling	2014	1.220	2.051	2.863	3.683	4.493

TRI_2km

Survey	Year	Minimum	5%	Median	95%	Maximum
Acoustic	2005	0.331	1.322	2.644	3.967	5.289
Acoustic	2006	5.054	6.364	8.236	10.670	13.478
Trolling	2006	2.258	3.418	5.130	6.977	8.554
Trolling	2007	3.252	5.151	7.438	10.010	12.207
Trolling	2008	3.205	4.533	5.499	6.464	7.416
Trolling	2009	1.136	2.333	3.848	5.486	7.415
Trolling	2010	1.068	2.111	3.415	4.770	6.299
Trolling	2011	3.107	4.578	6.761	9.146	12.101
Trolling	2012	0.397	0.998	1.822	2.820	3.682
Trolling	2013	2.392	3.696	4.773	5.845	6.704
Trolling	2014	1.627	2.467	3.840	5.274	6.689

TRI_Times

Survey	Year	Minimum	5%	Median	95%	Maximum
Acoustic	2005	0.331	1.653	3.306	5.124	7.107
Acoustic	2006	7.488	9.921	14.414	19.468	25.083
Trolling	2006	3.108	5.921	9.881	13.977	19.143
Trolling	2007	3.063	6.389	9.570	13.416	17.369
Trolling	2008	3.694	4.834	6.072	7.303	8.129
Trolling	2009	1.165	2.806	4.923	7.525	10.268
Trolling	2010	1.285	2.913	5.887	9.644	16.670
Trolling	2011	3.852	5.663	9.361	13.445	20.655
Trolling	2012	0.202	1.012	1.826	2.838	3.673
Trolling	2013	4.324	6.302	9.944	15.108	20.039
Trolling	2014	1.427	2.876	4.701	7.269	9.705

TRI_ind

Survey	Year	Minimum	5%	Median	95%	Maximum
Acoustic	2005	0.661	3.140	6.446	10.578	15.371
Acoustic	2006	12.355	18.157	26.394	35.753	52.039
Trolling	2006	5.244	11.229	19.130	27.656	36.582
Trolling	2007	9.262	14.724	22.597	31.452	45.399
Trolling	2008	6.847	10.212	13.633	16.266	17.869
Trolling	2009	1.451	5.693	10.562	16.280	22.297
Trolling	2010	2.082	5.442	9.658	14.759	18.829
Trolling	2011	5.046	9.043	18.174	28.688	38.160
Trolling	2012	0.402	1.201	2.661	4.563	6.987
Trolling	2013	8.219	14.533	20.929	27.232	35.221
Trolling	2014	2.052	4.088	6.600	9.602	12.823

Table 4 Summary of data for Grid-type Trolling Index (GTI)

Survey	Year	N_Record	Time_Min	Time_Max	Range			
					South	North	West	East
Acoustic	1996	401	1996/Jan/21 06:00	1996/Feb/13 18:00	−35.2	−34.4	118.2	121.7
	1997	522	1997/Jan/26 09:00	1997/Feb/26 12:00	−35.3	−34.0	117.5	121.8
	1998	535	1998/Jan/19 06:00	1998/Feb/24 17:00	−35.4	−34.4	117.7	121.8
	1999	676	1999/Jan/21 06:00	1999/Mar/14 17:00	−35.4	−34.0	118.0	121.8
	2000	685	2000/Jan/19 06:00	2000/Mar/14 14:00	−35.4	−34.0	117.5	122.5
	2001	760	2001/Jan/22 06:00	2001/Mar/14 16:00	−35.4	−33.9	117.5	121.9
	2002	712	2001/Dec/25 08:00	2002/Mar/14 15:00	−35.4	−33.9	117.5	121.9
	2003	439	2003/Jan/02 13:00	2003/Jan/28 15:00	−35.3	−33.9	117.9	121.9
	2005	888	2005/Jan/14 06:00	2005/Mar/04 16:00	−35.3	−33.9	117.5	121.9
	2006	907	2006/Jan/12 06:00	2006/Feb/18 13:00	−35.4	−34.0	117.5	121.9
Trolling	2006	204	2006/Jan/22 08:00	2006/Jan/31 15:00	−34.8	−34.1	119.3	121.3
	2007	216	2007/Jan/21 10:00	2007/Jan/29 07:00	−34.8	−34.1	119.3	121.3
	2008	395	2007/Dec/03 10:00	2008/Feb/01 08:00	−35.5	−34.1	117.5	121.3
	2009	348	2009/Jan/17 09:00	2009/Jan/29 07:00	−35.5	−34.1	117.7	121.3
	2010	425	2010/Jan/19 08:00	2010/Feb/04 17:00	−35.5	−34.1	117.7	123.4
	2011	438	2011/Jan/25 08:00	2011/Feb/11 10:00	−35.5	−34.1	117.8	121.8
	2012	415	2012/Jan/24 08:00	2012/Feb/10 11:00	−35.5	−34.0	117.9	121.9
	2013	443	2013/Jan/19 05:00	2013/Feb/04 12:00	−35.5	−33.9	117.9	122.1
	2014	442	2014/Jan/25 08:00	2014/Feb/11 10:00	−35.4	−34.0	117.6	123.2

		Distance searched						SBT Catch
Survey	Year	Total	Offshore	Shelfedge	On Shore	Lump	Mauda Reef	
Acoustic	1996	2,786	1,339	463	985			25
	1997	3,206	1,399	406	1,395		6	48
	1998	3,255	1,479	326	1,450			40
	1999	3,979	1,843	354	1,781	1		66
	2000	4,048	1,762	293	1,861	128	4	21
	2001	4,388	1,614	400	2,145	230		27
	2002	4,287	1,542	458	2,022	263	2	21
	2003	2,363	582	304	1,405	64	8	19
	2005	5,052	1,177	422	3,234	220		68
	2006	3,882	1,210	378	2,253	41		106
Trolling	2006	927	130	182	586	29		38
	2007	915	59	215	635	6		48
	2008	1,393	137	143	1,033	25	55	53
	2009	1,171	112	191	798	25	44	44
	2010	1,549	159	198	1,051	35	106	67
	2011	1,469	141	190	1,043	58	38	76
	2012	1,443	132	163	929	119	100	46
	2013	1,592	138	160	1,164	29	101	74
	2014	1,646	91	153	1,266	80	56	56
Total		49,351	15,045	5,398	27,034	1,354	520	943

SBT Catch is the number of school with definition of 30 minutes is necessary for different school.

Table 5 Summary of data by area type

Area	N_records			CPUE	
	All	positive catch	% positive	Mean	SD
Offshore	2,673	29	1.1%	43.6	81.2
Shelfedge	1,485	114	7.7%	46.0	67.9
OnShore	5,217	640	12.3%	24.2	23.2
Lump	324	78	24.1%	35.1	32.9
MaudaReef	151	47	31.1%	41.2	83.3
Total	9,850	908	9.2%		

CPUE is the positive catch only.

Table 6 Estimated values by GLM for probability sub-model

Item	Estimate	Std. Error	z value	Pr(>|z|)	Significance
(Intercept)	−1.54121	0.36495	−4.22303	2.41E−05	***
year 1997	0.38137	0.27213	1.40141	1.61E−01	
year 1998	0.24165	0.27790	0.86956	3.85E−01	
year 1999	0.83173	0.26201	3.17442	1.50E−03	**
year 2000	−0.81832	0.31950	−2.56125	1.04E−02	*
year 2001	−0.68228	0.30503	−2.23677	2.53E−02	*
year 2002	−1.71112	0.40948	−4.17881	2.93E−05	***
year 2003	−0.38621	0.30568	−1.26344	2.06E−01	
year 2004	−0.09815	0.25566	−0.38390	7.01E−01	
year 2005	0.96312	0.23903	4.02931	5.59E−05	***
year 2006	1.42890	0.28960	4.93411	8.05E−07	***
year 2007	1.05549	0.28310	3.72838	1.93E−04	***
year 2008	0.71456	0.28465	2.51027	1.21E−02	*
year 2009	0.89549	0.26869	3.33276	8.60E−04	***
year 2010	1.06957	0.26021	4.11048	3.95E−05	***
year 2011	0.34949	0.28006	1.24790	2.12E−01	
year 2012	0.98791	0.26476	3.73142	1.90E−04	***
year 2013	0.59258	0.26683	2.22080	2.64E−02	*
month 2	0.04719	0.09255	0.50991	6.10E−01	
month 3	−0.95322	0.25626	−3.71980	1.99E−04	***
month 12	0.09666	0.31691	0.30502	7.60E−01	
hour 6	−0.48766	0.27298	−1.78647	7.40E−02	
hour 7	−0.60451	0.26775	−2.25773	2.40E−02	*
hour 8	−0.64381	0.26997	−2.38470	1.71E−02	*
hour 9	−0.75210	0.27150	−2.77011	5.60E−03	**
hour 10	−0.76013	0.27182	−2.79643	5.17E−03	**
hour 11	−1.01122	0.27661	−3.65573	2.56E−04	***
hour 12	−1.00353	0.27574	−3.63940	2.73E−04	***
hour 13	−1.06165	0.27771	−3.82282	1.32E−04	***
hour 14	−0.65238	0.27116	−2.40592	1.61E−02	*
hour 15	−0.84054	0.28124	−2.98868	2.80E−03	**
hour 16	−0.82697	0.28879	−2.86356	4.19E−03	**
hour 17	−1.22173	0.32075	−3.80901	1.40E−04	***
hour 18	−1.60267	0.64359	−2.49022	1.28E−02	*
hour 19	1.22716	0.98638	1.24411	2.13E−01	

area MaudaReef	−0.39248	0.24555	−1.59839	1.10E−01	
area Offshore	−4.06856	0.24492	−16.61181	5.72E−62	***
area OnShore	−1.60205	0.15729	−10.18561	2.30E−24	***
area Shelfedge	−1.75911	0.18316	−9.60408	7.68E−22	***

Significances are *** < 0.1%, ** < 1% and * < 5%.

Table 7　Estimated values by GLM for positive catch sub-model

Item	Estimate	Std.Error	z value	Pr(>|z|)	Sig.
(Intercept)	0.30421	0.21892	1.38956	0.16502	*
year 1997	0.08185	0.18210	0.44947	0.65320	
year 1998	0.06492	0.18517	0.35061	0.72597	
year 1999	0.14301	0.17172	0.83280	0.40518	
year 2000	0.31013	0.22486	1.37921	0.16818	
year 2001	−0.27612	0.20987	−1.31570	0.18862	
year 2002	0.10246	0.28486	0.35969	0.71917	
year 2003	0.35929	0.19746	1.81956	0.06917	
year 2004	0.08958	0.17164	0.52192	0.60186	
year 2005	0.17339	0.15868	1.09272	0.27482	
year 2006	0.13610	0.18182	0.74858	0.45431	
year 2007	0.57885	0.18192	3.18185	0.00152	**
year 2008	0.06472	0.18026	0.35904	0.71965	
year 2009	0.11179	0.17326	0.64521	0.51896	
year 2010	0.35574	0.16990	2.09389	0.03656	*
year 2011	0.02557	0.18503	0.13817	0.89014	
year 2012	0.20813	0.17131	1.21490	0.22473	
year 2013	−0.04893	0.17650	−0.27721	0.78168	
hour 6	−0.77012	0.16429	−4.68760	0.00000	***
hour 7	−0.75019	0.16176	−4.63769	0.00000	***
hour 8	−0.77766	0.16246	−4.78685	0.00000	***
hour 9	−0.76973	0.16459	−4.67662	0.00000	***
hour 10	−0.67339	0.16528	−4.07430	0.00005	***
hour 11	−0.90348	0.16846	−5.36315	0.00000	***
hour 12	−0.80308	0.16789	−4.78348	0.00000	***
hour 13	−0.61600	0.17021	−3.61909	0.00031	***
hour 14	−0.68629	0.16339	−4.20033	0.00003	***
hour 15	−0.78217	0.17152	−4.56012	0.00001	***
hour 16	−0.84159	0.17662	−4.76507	0.00000	***
hour 17	−0.82709	0.20163	−4.10210	0.00004	***
hour 18	−0.54897	0.44359	−1.23755	0.21622	
hour 19	−0.69483	0.44578	−1.55867	0.11944	
area MaudaReef	−0.04669	0.14409	−0.32403	0.74599	
area Offshore	−0.07587	0.16533	−0.45892	0.64641	
area OnShore	−0.42098	0.09598	−4.38601	0.00001	***
area Shelfedge	0.21017	0.11817	1.77859	0.07565	

Significances are *** < 0.1%, ** < 1% and * < 5%.

Table 8 Year trends of provability sub-model

	Original		Converted		
Year	Mean	SD	Mean	Mean−SD	Mean+SD
1996	−1.6882	0.4205	0.1560	0.1083	0.2197
1997	−1.3068	0.3945	0.2130	0.1543	0.2865
1998	−1.4465	0.3985	0.1905	0.1365	0.2596
1999	−0.8565	0.3773	0.2981	0.2255	0.3824
2000	−2.5065	0.4279	0.0754	0.0505	0.1112
2001	−2.3705	0.4114	0.0855	0.0583	0.1236
2002	−3.3993	0.5013	0.0323	0.0198	0.0523
2003	−2.0744	0.4042	0.1116	0.0774	0.1584
2005	−1.7863	0.3781	0.1435	0.1030	0.1965
2006	−0.7251	0.3660	0.3263	0.2514	0.4112
2007	−0.2593	0.4053	0.4355	0.3397	0.5364
2008	−0.6327	0.3988	0.3469	0.2628	0.4418
2009	−0.9736	0.3891	0.2742	0.2038	0.3579
2010	−0.7927	0.3857	0.3116	0.2353	0.3996
2011	−0.6186	0.3823	0.3501	0.2688	0.4412
2012	−1.3387	0.3964	0.2077	0.1499	0.2804
2013	−0.7003	0.3835	0.3318	0.2528	0.4215
2014	−1.0956	0.3885	0.2506	0.1848	0.3302

Table 9 Year trends of positive catch sub-model

	Original		Converted		
Year	Mean	SD	Mean	Mean−SD	Mean+SD
1996	1.8438	0.2282	6.3206	5.0309	7.9409
1997	1.9257	0.2057	6.8597	5.5846	8.4259
1998	1.9087	0.2094	6.7445	5.4705	8.3152
1999	1.9868	0.1942	7.2923	6.0051	8.8555
2000	2.1539	0.2441	8.6187	6.7522	11.0012
2001	1.5677	0.2294	4.7956	3.8125	6.0322
2002	1.9463	0.3043	7.0025	5.1651	9.4935
2003	2.2031	0.2188	9.0530	7.2737	11.2676
2005	1.9334	0.1939	6.9129	5.6947	8.3918
2006	2.0172	0.1812	7.5173	6.2712	9.0109
2007	1.9799	0.2055	7.2421	5.8971	8.8940
2008	2.4227	0.2039	11.2758	9.1955	13.8267
2009	1.9085	0.2033	6.7432	5.5028	8.2631
2010	1.9556	0.1945	7.0682	5.8190	8.5856
2011	2.1996	0.1933	9.0210	7.4357	10.9443
2012	1.8694	0.2053	6.4843	5.2808	7.9620
2013	2.0519	0.1934	7.7830	6.4146	9.4433
2014	1.7949	0.1982	6.0188	4.9367	7.3380

Table 10 Point estimates of Grid-type Trolling Index

Year	Prob*Pos	Standardized
1996	0.9861	0.5660
1997	1.4612	0.8387
1998	1.2851	0.7376
1999	2.1737	1.2477
2000	0.6499	0.3730
2001	0.4098	0.2352
2002	0.2263	0.1299
2003	1.0104	0.5800
2005	0.9922	0.5695
2006	2.4527	1.4078
2007	3.1542	1.8105
2008	3.9116	2.2452
2009	1.8487	1.0611
2010	2.2024	1.2641
2011	3.1582	1.8128
2012	1.3469	0.7731
2013	2.5820	1.4820
2014	1.5081	0.8656

Table 11 Grid-type Trolling Index with confidence intervals calculated by 1000 times bootstrap

Year	5 percentile	25 percentile	Median	75 percentile	95 percentile
1996	0.346	0.468	0.563	0.671	0.855
1997	0.581	0.722	0.826	0.931	1.110
1998	0.512	0.626	0.723	0.831	0.987
1999	0.955	1.121	1.235	1.369	1.586
2000	0.218	0.305	0.368	0.447	0.576
2001	0.151	0.200	0.232	0.274	0.342
2002	0.053	0.091	0.127	0.170	0.248
2003	0.373	0.478	0.567	0.667	0.810
2004					
2005	0.427	0.508	0.570	0.637	0.740
2006	1.184	1.297	1.394	1.500	1.655
2007	1.385	1.605	1.781	1.965	2.327
2008	1.683	1.996	2.230	2.467	2.856
2009	0.799	0.942	1.046	1.165	1.354
2010	0.989	1.138	1.259	1.371	1.560
2011	1.445	1.646	1.798	1.954	2.212
2012	0.560	0.684	0.769	0.872	1.018
2013	1.176	1.354	1.462	1.603	1.809
2014	0.681	0.785	0.869	0.947	1.074

Table 12 Correlation between trolling indices and other indices

Var1	Var2	N	df	cor	t	p.val	sign.
OM	TR	9	7	0.184	0.494	0.6364	
OM	GTI	18	16	0.590	2.926	0.0099	**
JP_age4	TR	5	3	0.398	0.751	0.5073	
JP_age4	GTI	14	12	0.773	4.217	0.0012	**
ASI	TR	7	5	−0.607	−1.707	0.1486	
ASI	GTI	12	10	−0.055	−0.175	0.8648	
ASI	GTI_3yr	9	7	0.204	0.550	0.5993	
SAPUE	TR	7	5	−0.141	−0.318	0.7634	
SAPUE	GTI	11	9	0.366	1.179	0.2686	
SAPUE	GTI_3yr	9	7	0.639	2.199	0.0638	

cor: Pearson's correlation

sign.: significance; *** < 0.001, ** < 0.01 and + < 0.05.

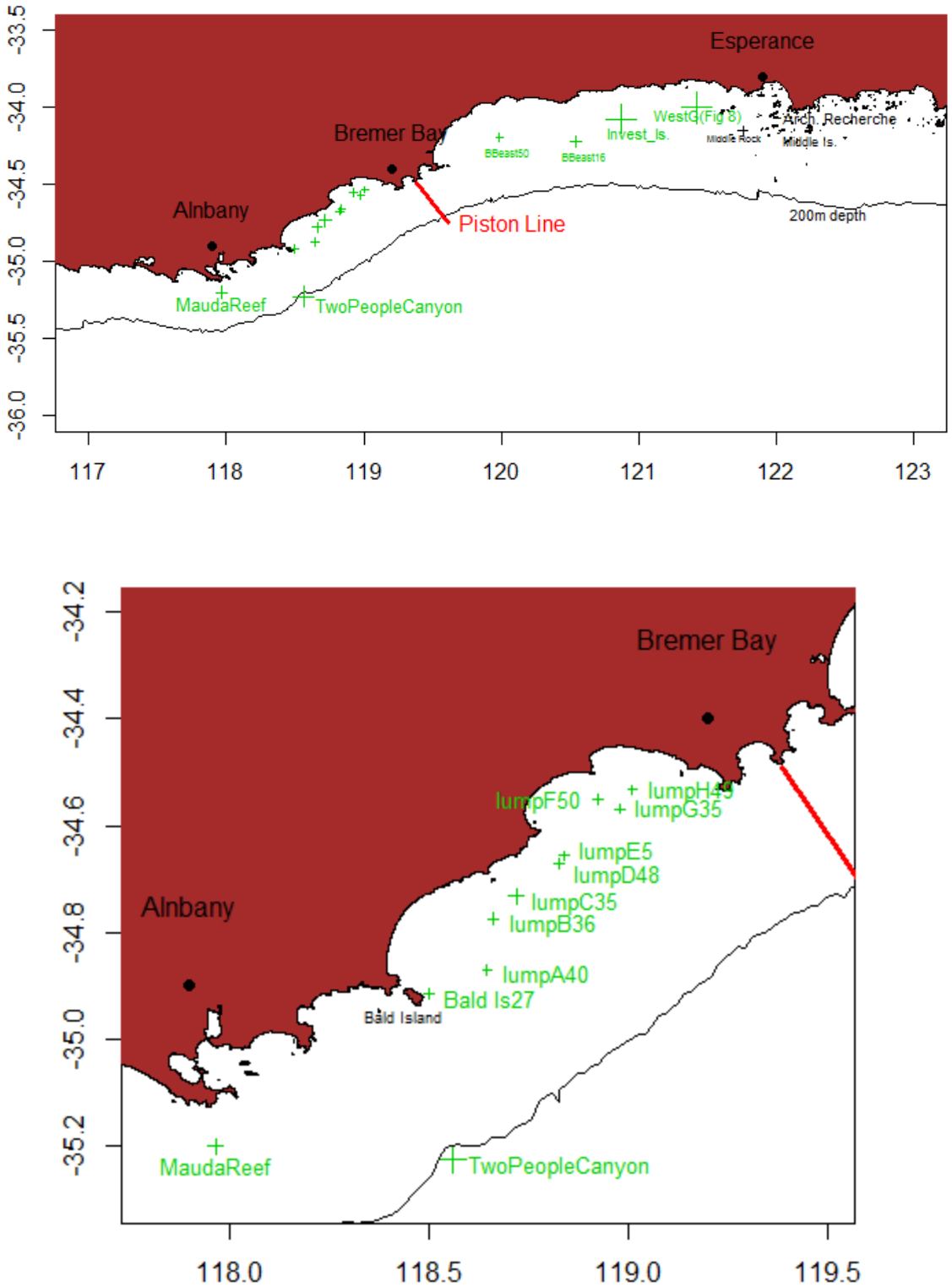

Fig. 1 Map and relating places

Lower panel is an enlargement of a part of upper panel. Size in cross mark reflects determined range of effect of the lump.

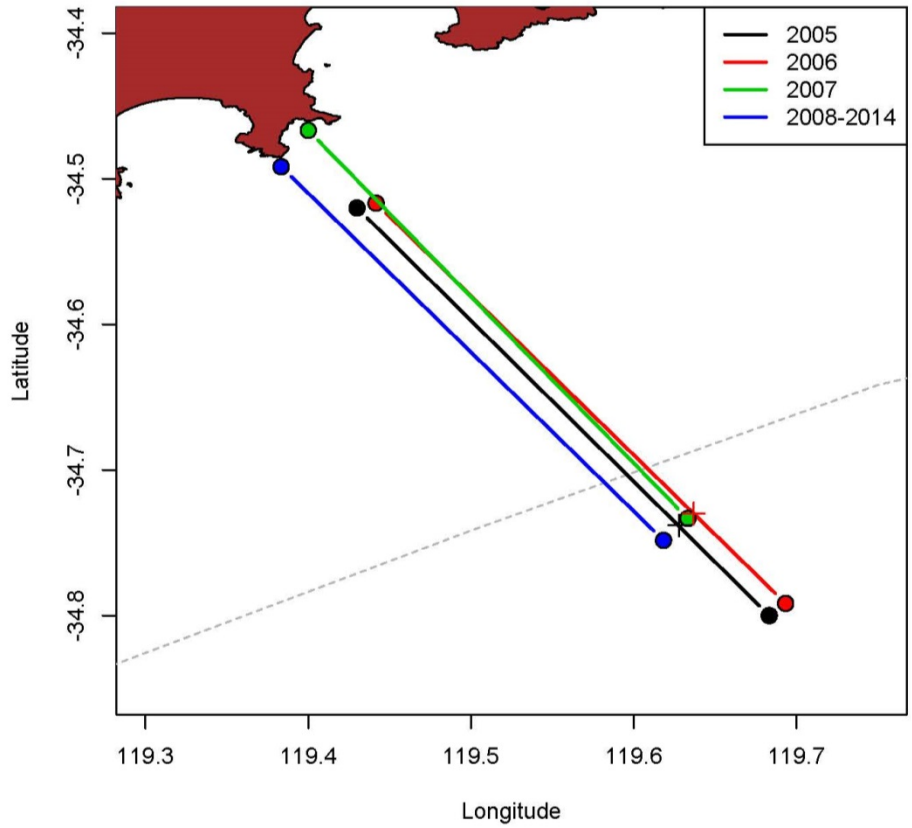

Fig. 2. Locations of piston-line

Circles denote each ends of piston-line surveyed. Cross marks are the offshore points of the 2005 and 2006 piston-lines that adjusted to the 2007 piston-line.

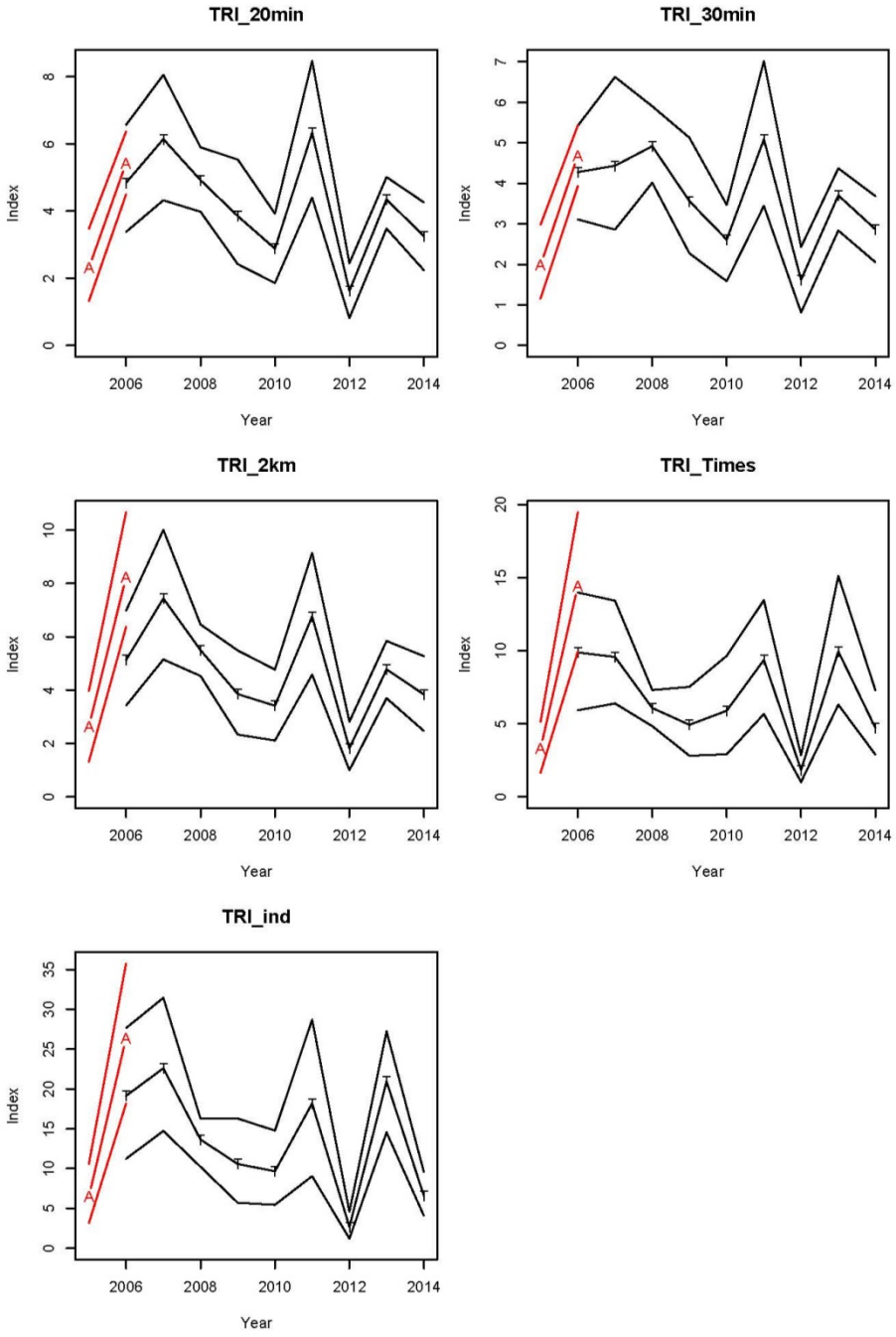

Fig. 3. Five types of piston-line trolling index

Showing median, 5 percentile and 95 percentile. A in red was from the acoustic survey and T in black was from the trolling survey.

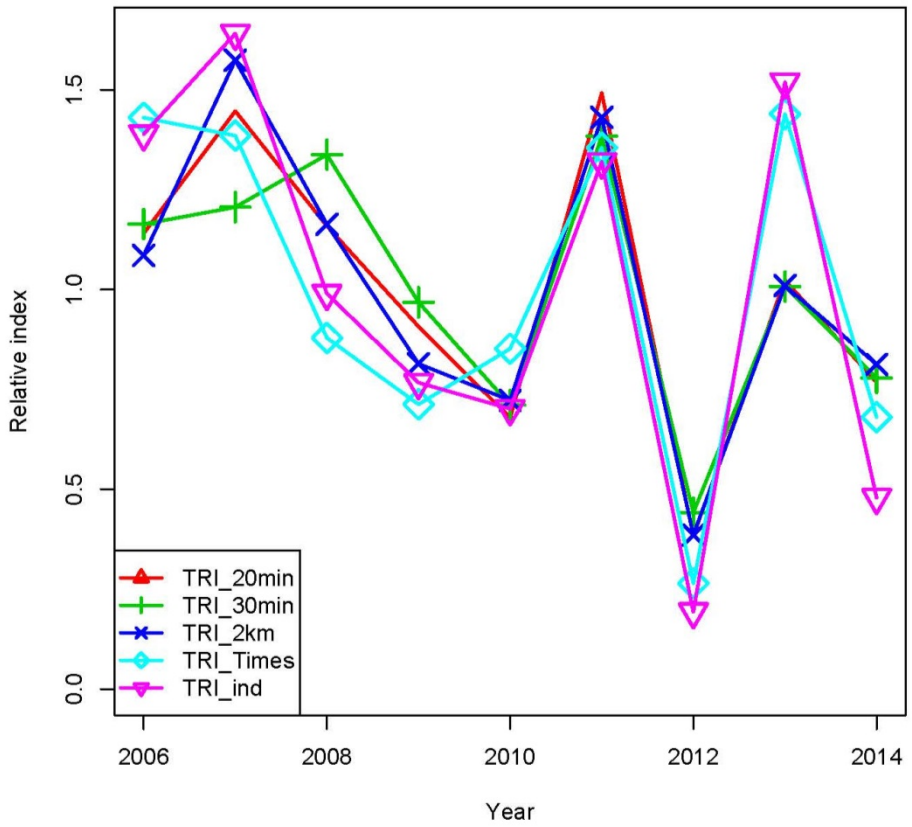

Fig. 4. Comparison of median from five types of piston-line trolling index

Standardized with the mean of each index. Only shows that from the trolling survey.

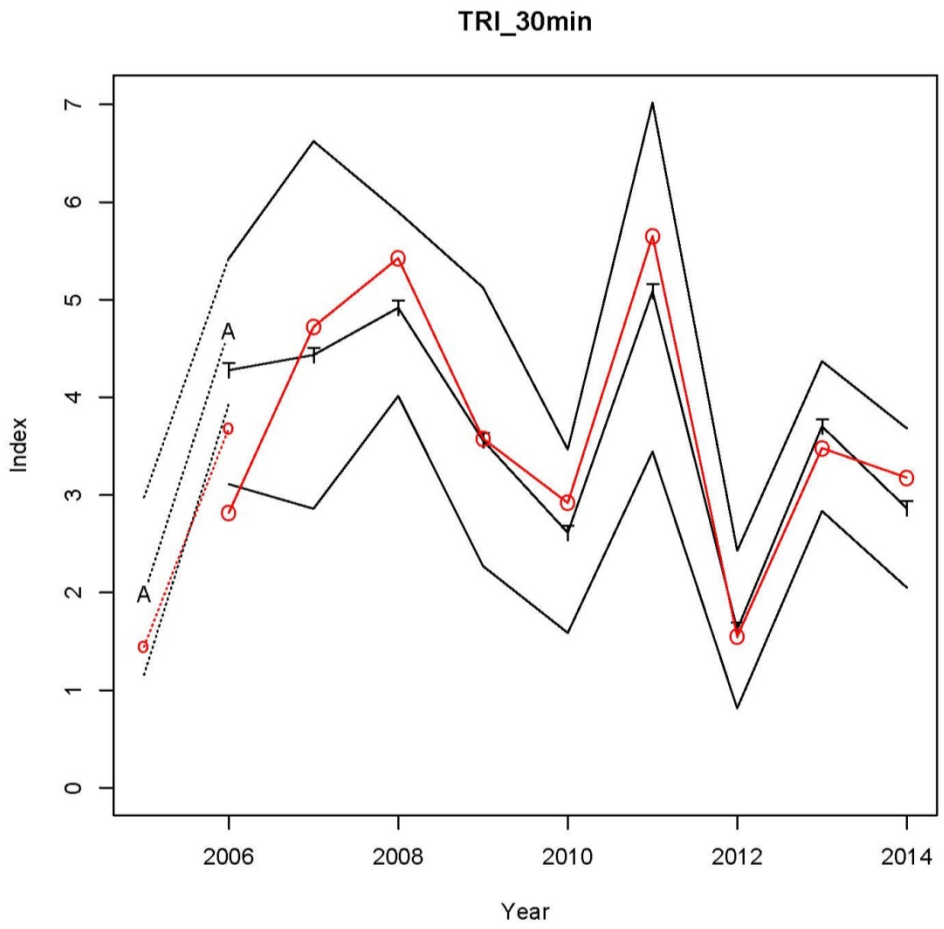

Fig. 5. Comparison of the piston-line index between present and previous one

Comparison of the index has been submitted to CCSBT data exchange (o/O) and updated index (A/T). "A "and "o" came from the acoustic survey and "T" and "O" came from the trolling survey. Catch was defined as school with definition of 30 minutes is necessary for different school.

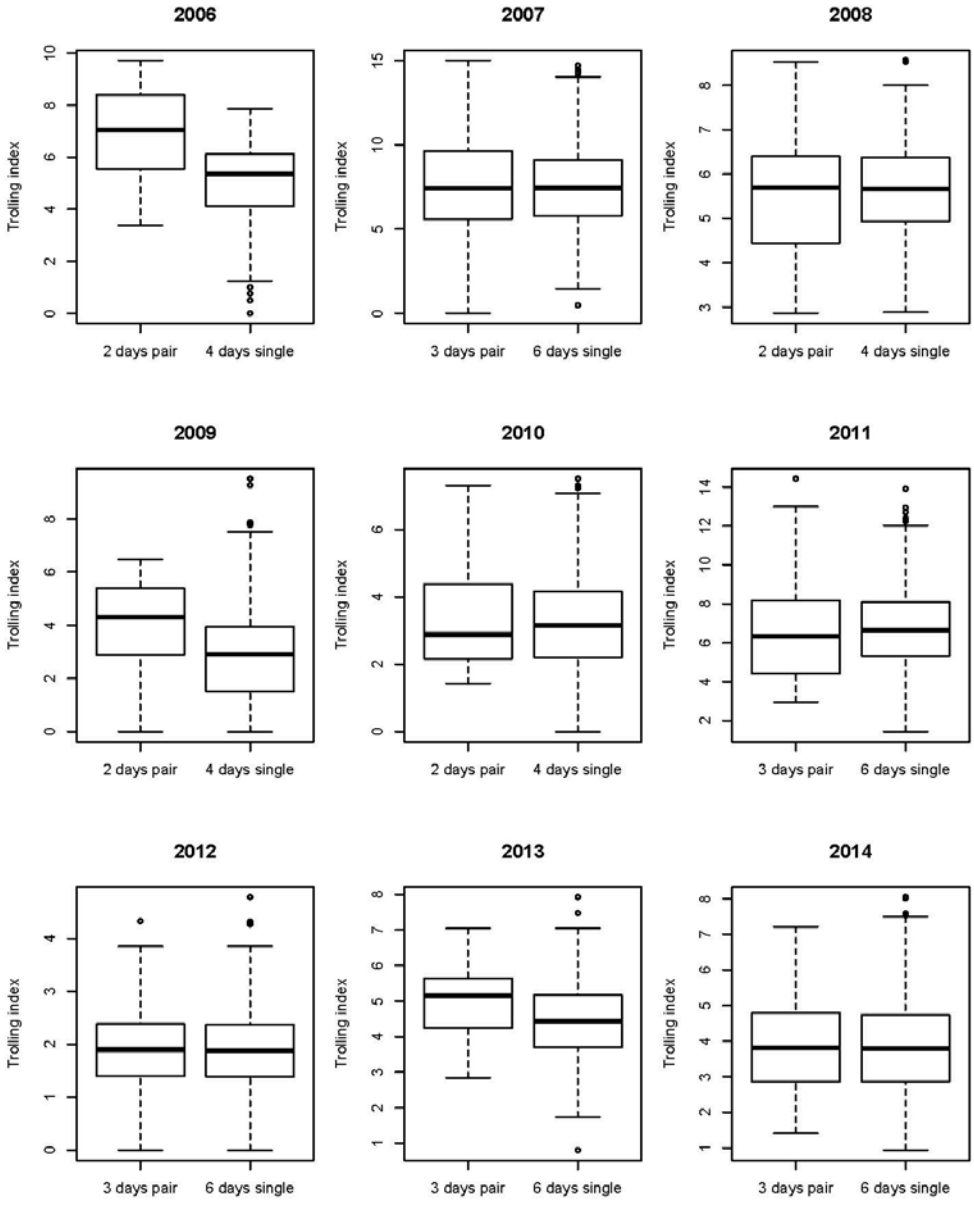

Fig. 6. Examination of independence of data between outward and inward piston-line on the same day by the piston-line trolling index

On each panel, left hand side is the index based on data in both outward and inward surveys of a day. Right hand side is the index based only on either of them. Catch is school with definition of 2 km is necessary for different school. Data in the trolling survey were used. Estimates were simulated by 1000 times bootstrapping.

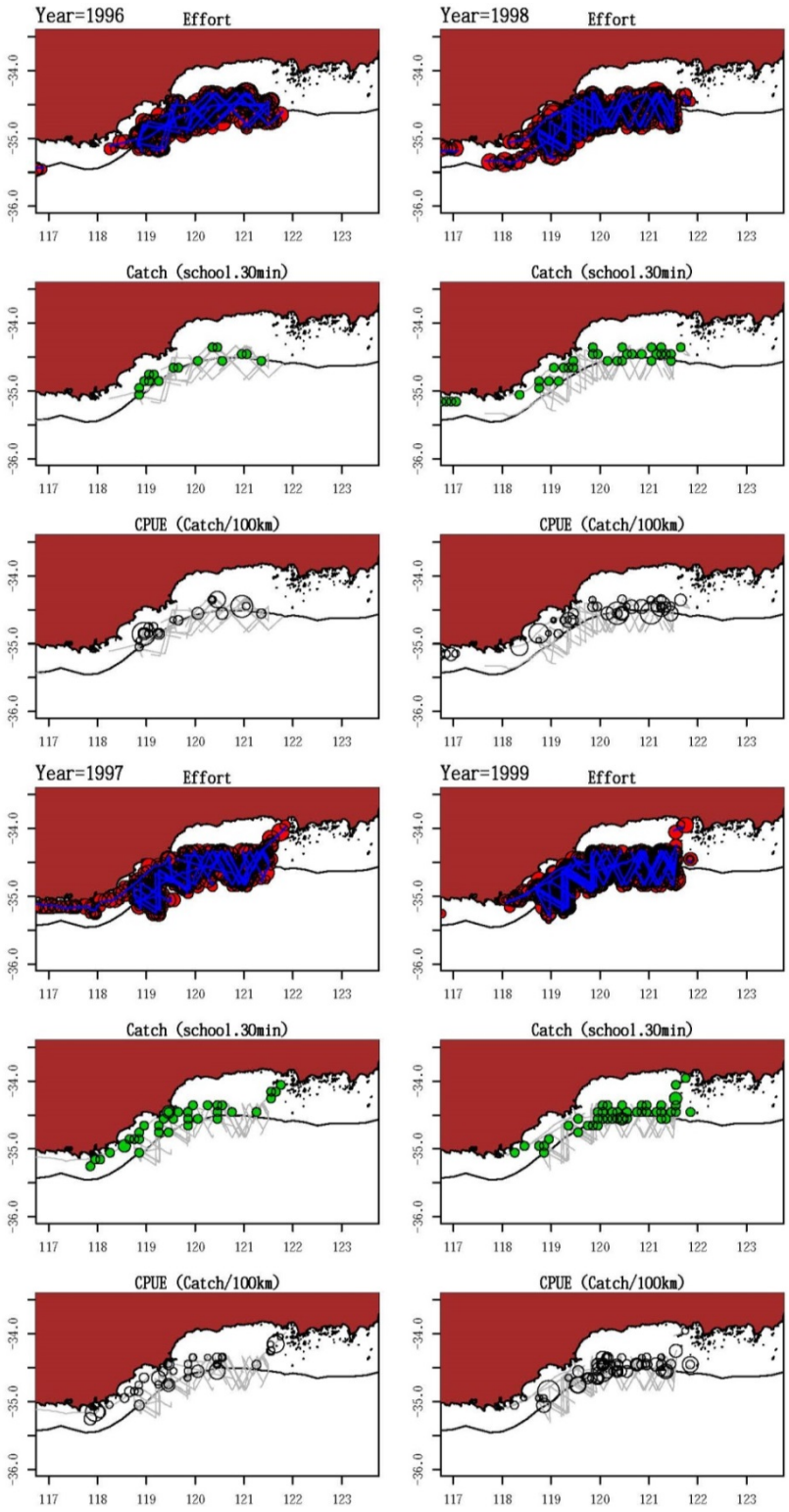

Fig. 7 Distributions of effort, SBT age-1 catch and CPUE by year

Blue line is trajectory of the vessel while trolling. Some points of anomalously high CPUE with little effort were not shown. Isobath of 200 m is drawn.

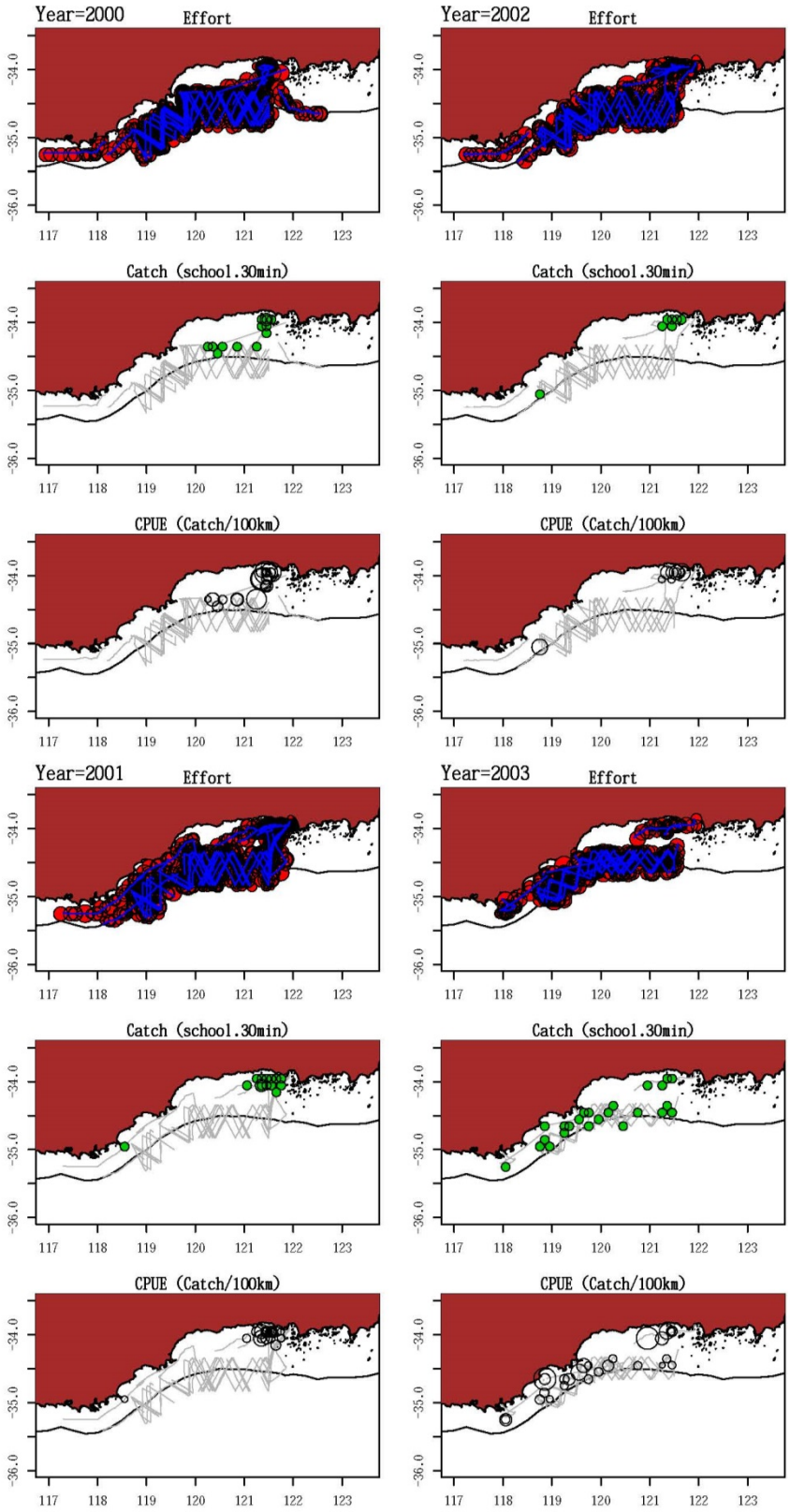
Year=2000
Effort
Year=2002
Effort
Catch (school.30min)
Catch (school.30min)
CPUE (Catch/100km)
CPUE (Catch/100km)
Year=2001
Effort
Year=2003
Effort
Catch (school.30min)
Catch (school.30min)
CPUE (Catch/100km)
CPUE (Catch/100km)
-34.0
-35.0
-36.0
117
118
119
120
121
122
123

Fig. 7 (cont'd)

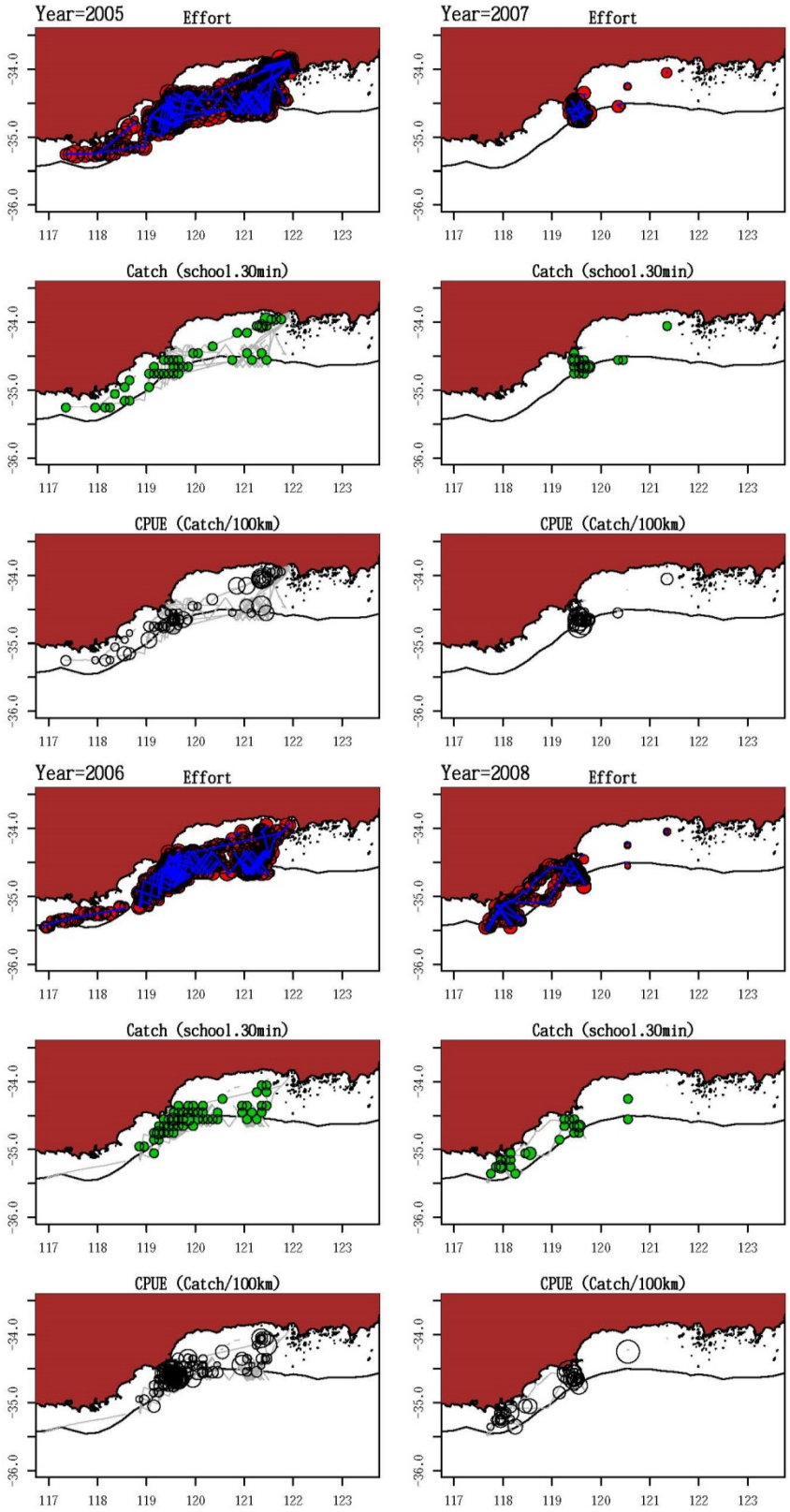
Year=2005
Effort
Year=2007
Effort
Catch (school.30min)
Catch (school.30min)
CPUE (Catch/100km)
CPUE (Catch/100km)
Year=2006
Effort
Year=2008
Effort
Catch (school.30min)
Catch (school.30min)
CPUE (Catch/100km)
CPUE (Catch/100km)
-34.0
-35.0
-36.0
117
118
119
120
121
122
123

Fig. 7 (cont'd)

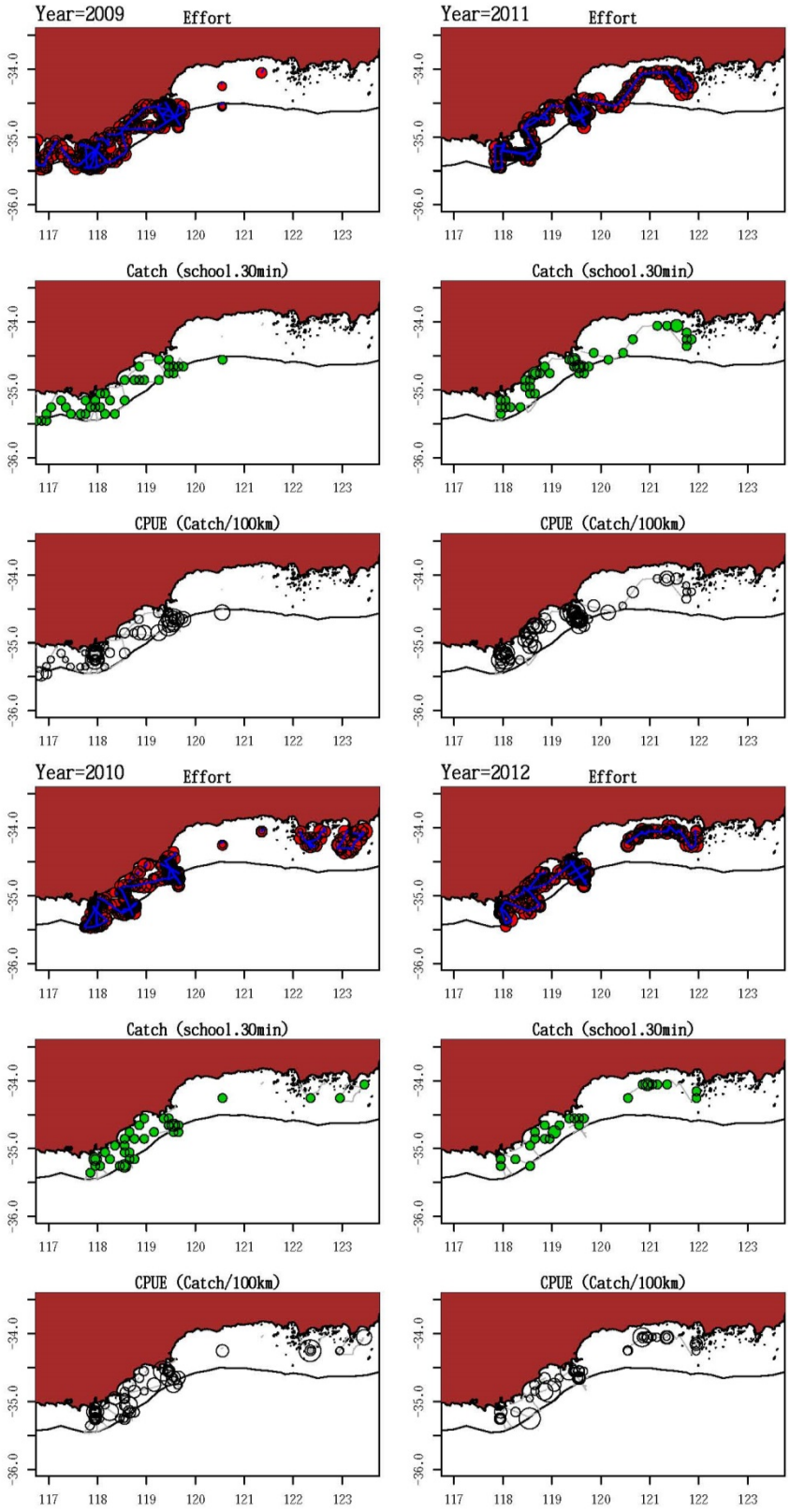
Year=2009
Effort
Year=2011
Effort
Catch (school.30min)
Catch (school.30min)
CPUE (Catch/100km)
CPUE (Catch/100km)
Year=2010
Effort
Year=2012
Effort
Catch (school.30min)
Catch (school.30min)
CPUE (Catch/100km)
CPUE (Catch/100km)
-34.0
-35.0
-36.0
117
118
119
120
121
122
123

Fig. 7 (cont'd)

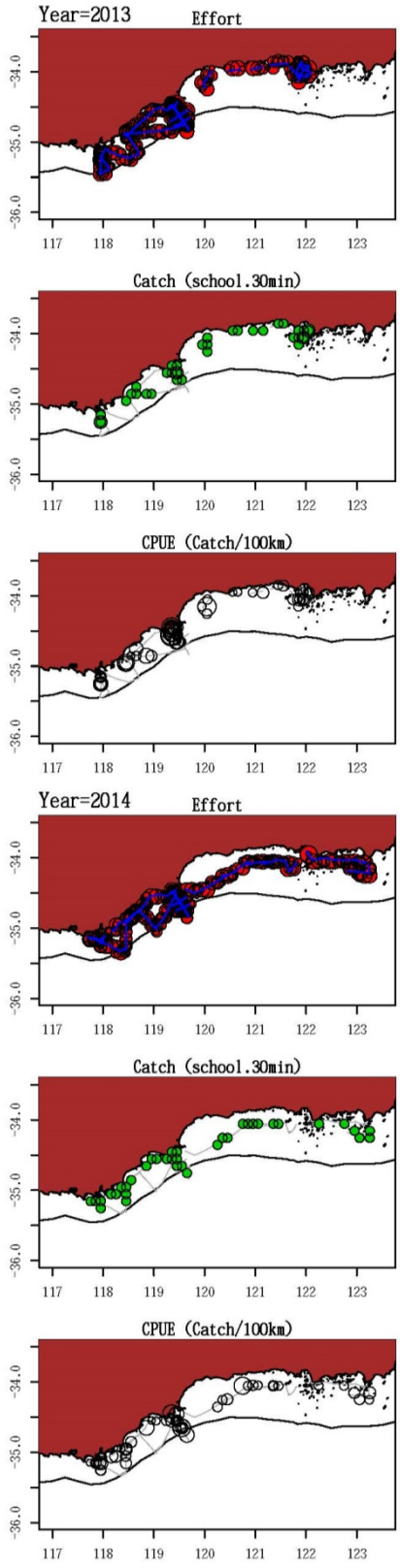
Year=2013
Effort
Catch (school.30min)
CPUE (Catch/100km)
Year=2014
Effort
Catch (school.30min)
CPUE (Catch/100km)
-34.0
-35.0
-36.0
117
118
119
120
121
122
123

Fig. 7 (cont'd)

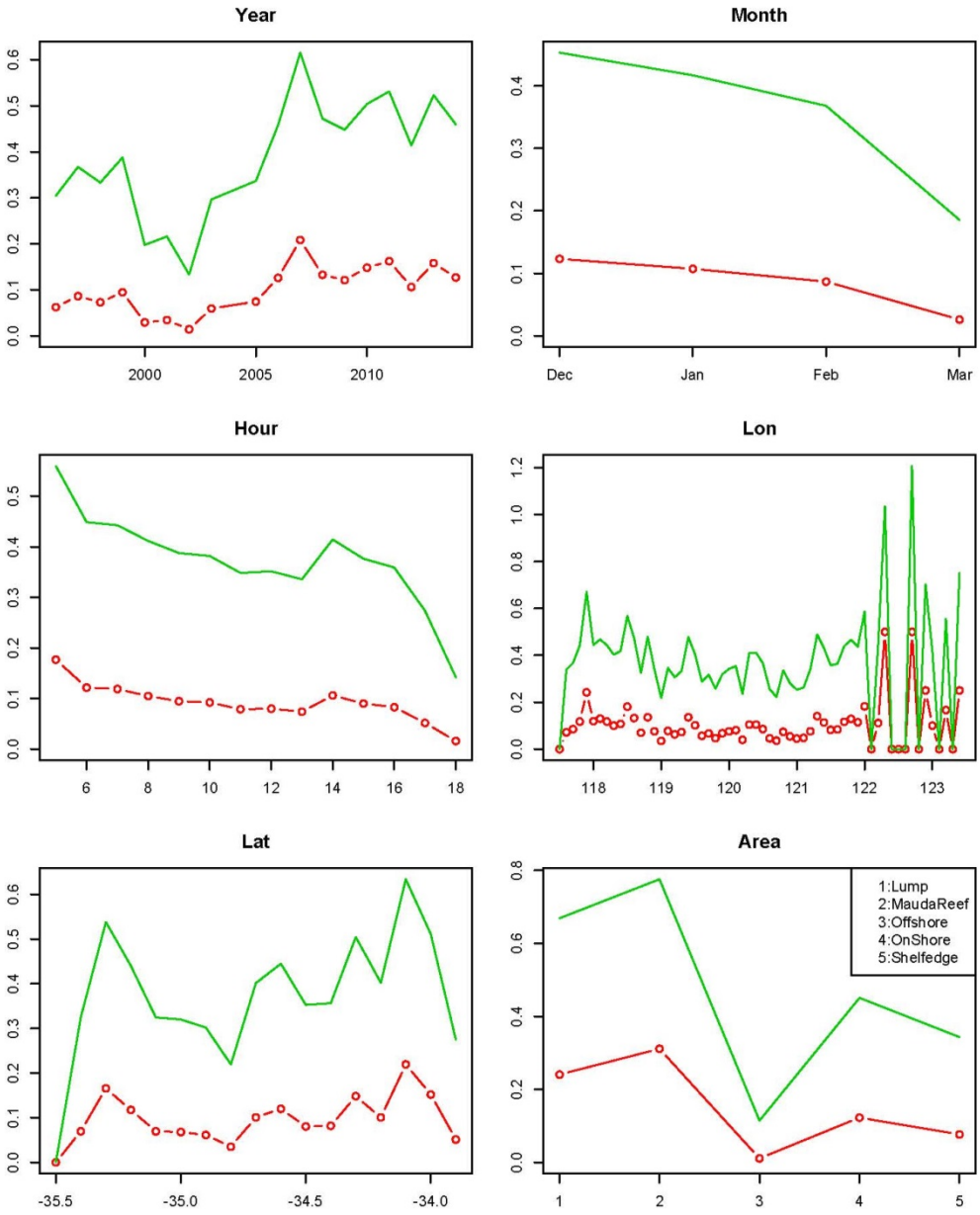

Fig. 8 Probability of catch for variables.

Red is mean and green is mean+SD. Catch was defined as school with definition of 30 minutes is necessary for different school.

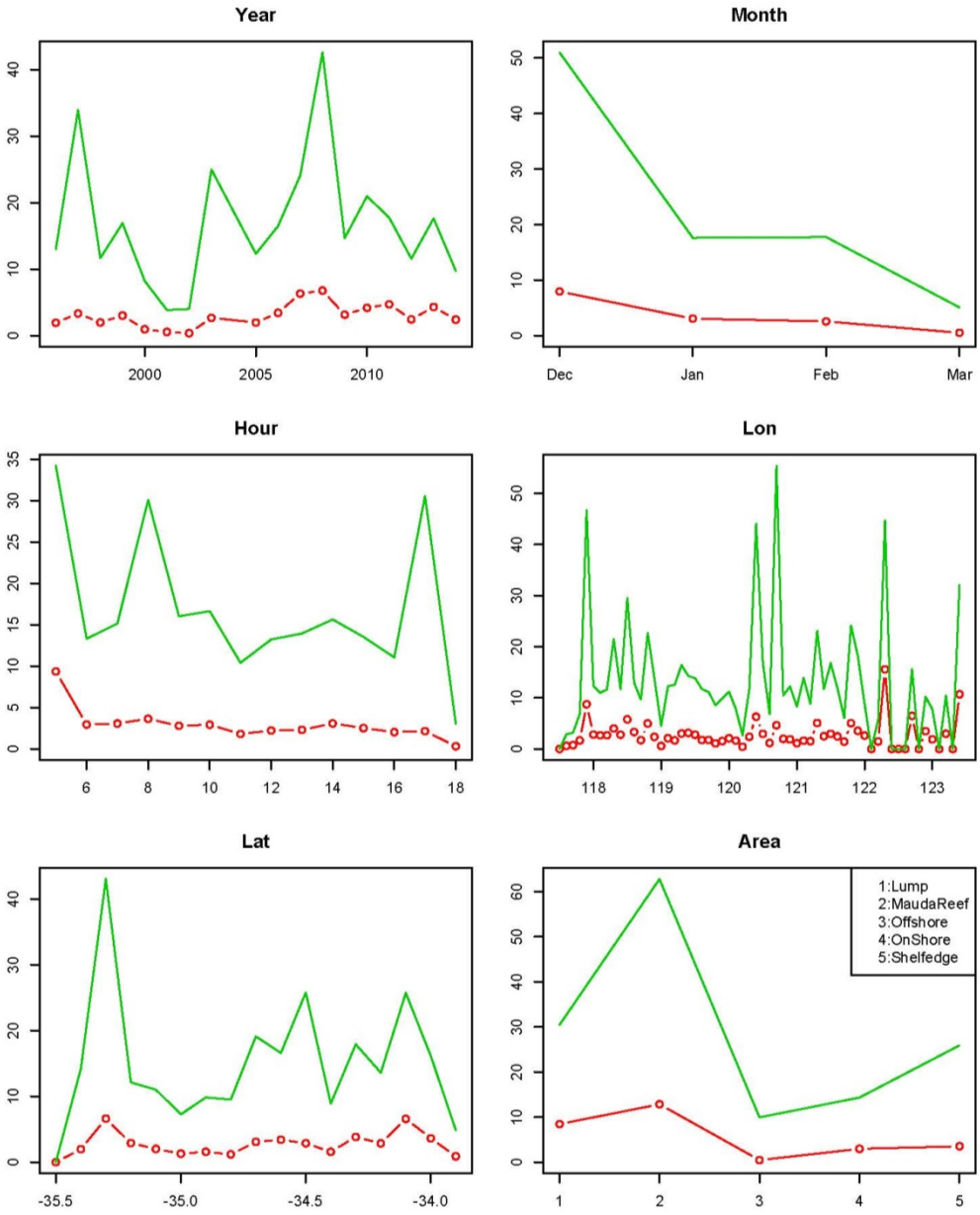

Fig. 9 CPUE in positive catch for variables.

Red is mean and green is mean±SD. Catch was defined as school with definition of 30 minutes is necessary for different school.

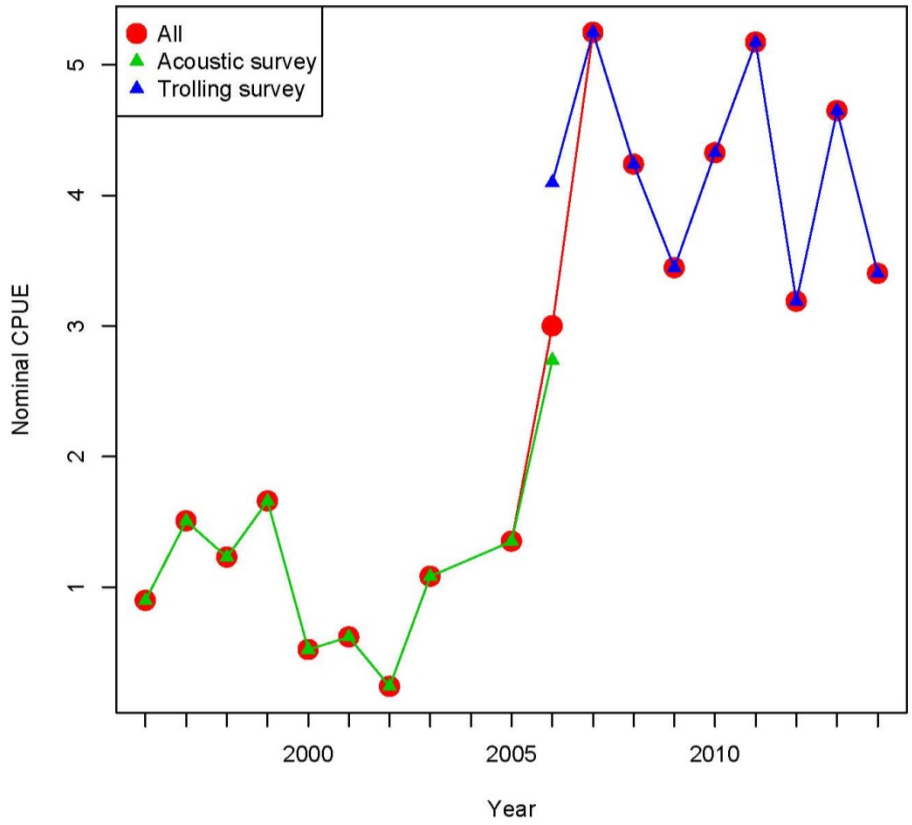

Fig. 10 Nominal CPUE of Grid-type Trolling Index

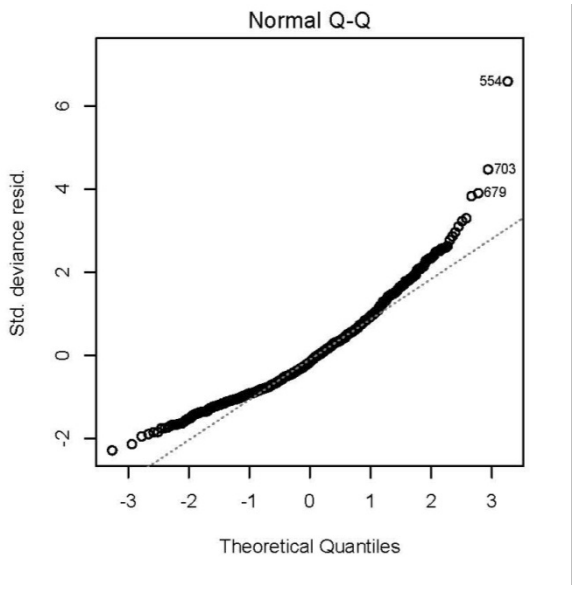

Fig. 11 QQ plot of GLM for positive catch sub-model

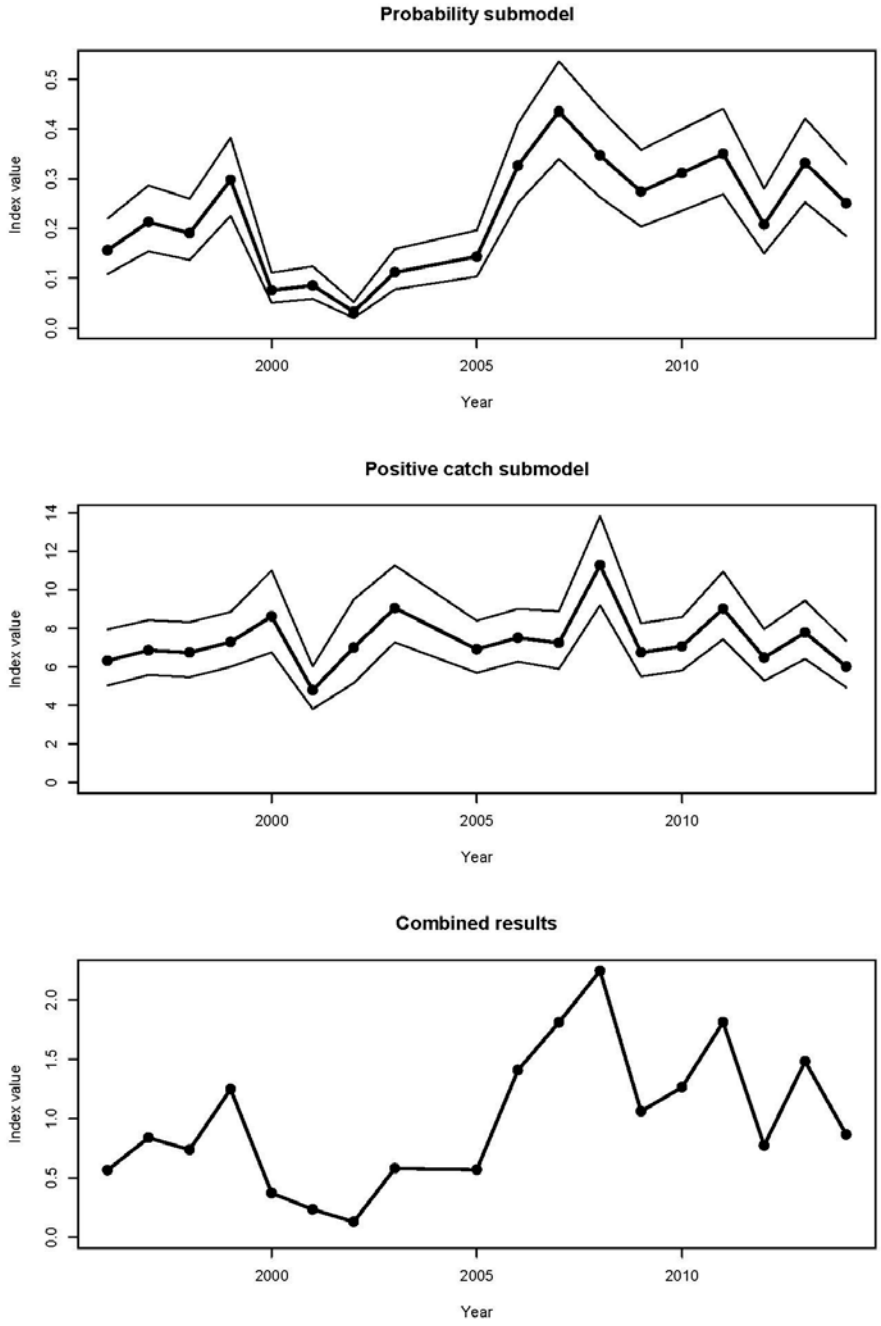

Fig. 12 Grid-type Trolling Index

Upper panel shows year trend from the probability sub-model. Mean ± 1SD. Middle panel shows year trend from the positive catch sub-model. Mean ± 1SD. Lower panel shows GTI which is product of above two year trends.

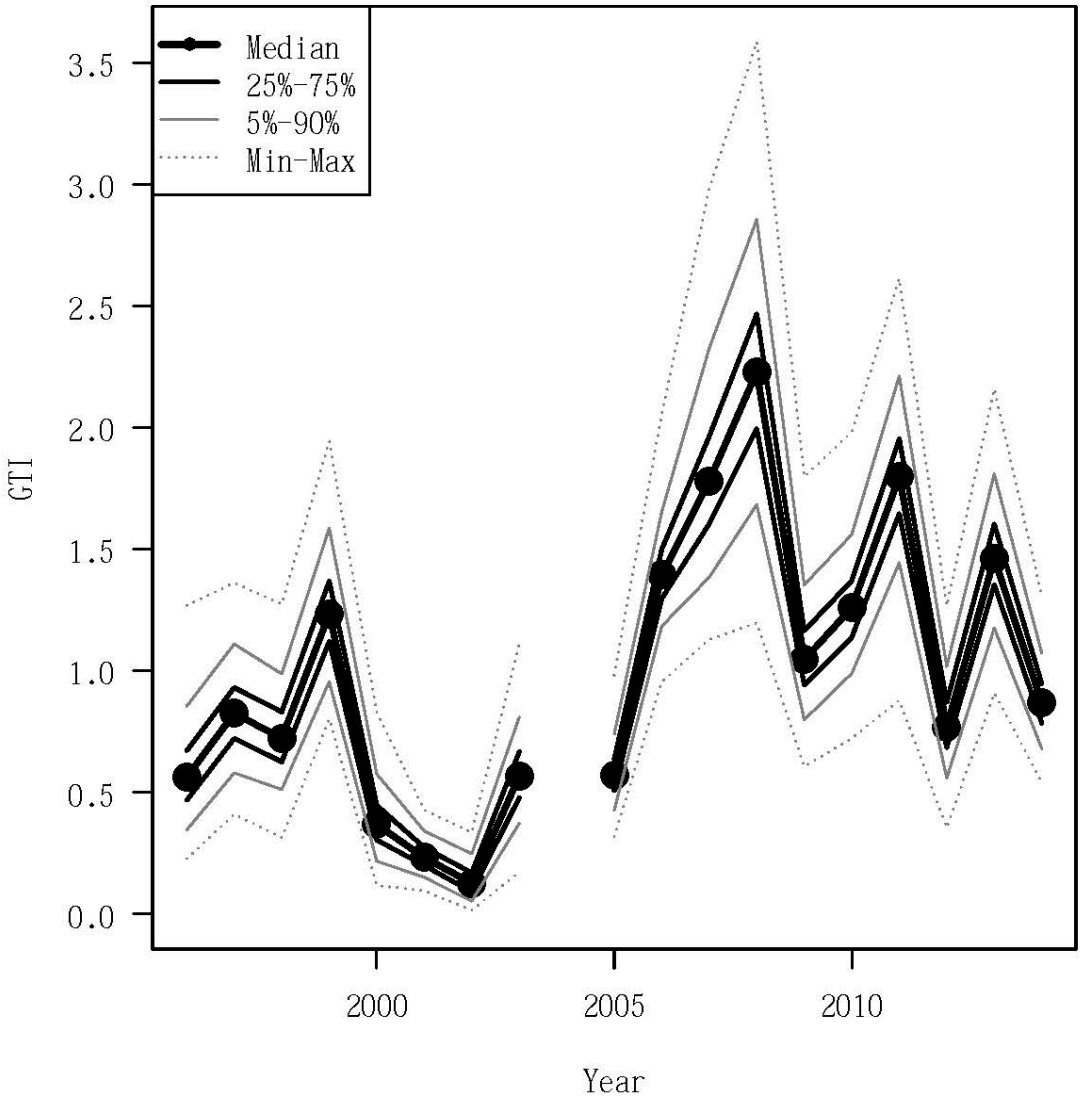

Fig. 13 Grid-type Trolling Index with confidence intervals

Estimate was simulated with 1000 times bootstrapping.

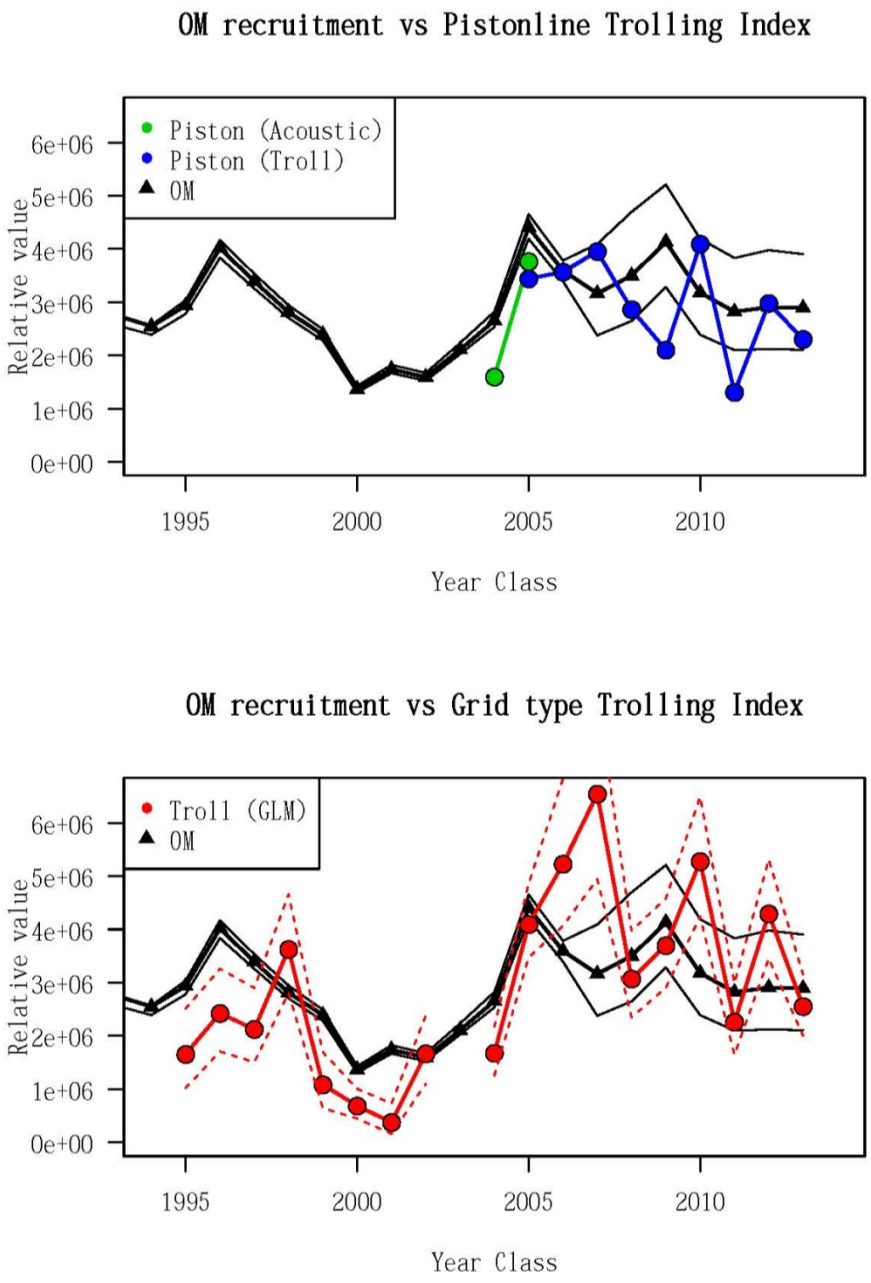

Fig. 14 Comparison between OM recruitment and trolling indices

Upper panel shows PTI and lower panel shows GTI. Range of OM recruitment is 25-75 percentiles.

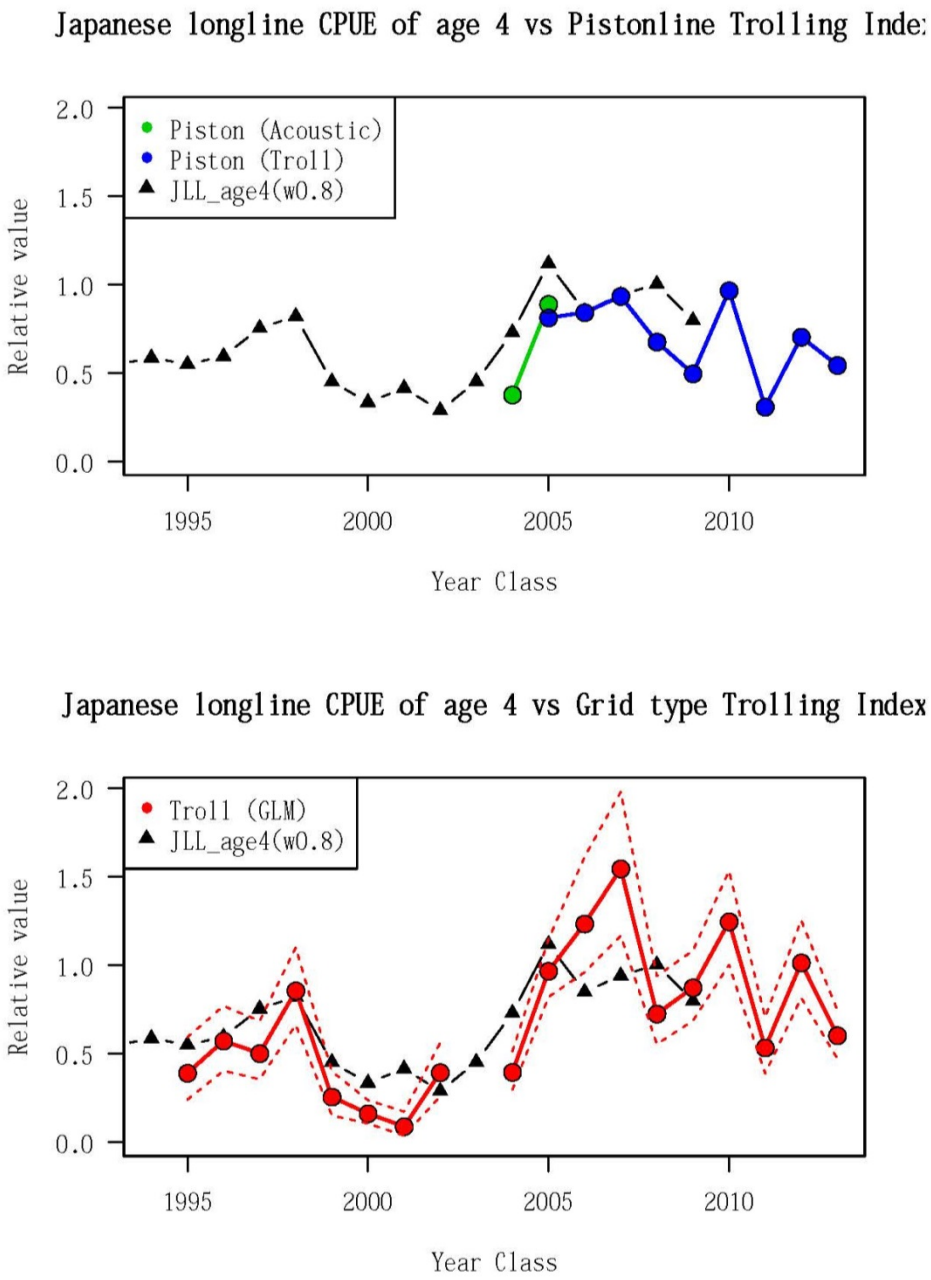

Fig. 15 Comparison between age-4 standardized CPUE (W0.8) of Japanese longline and trolling indices

Upper panel shows PTI and lower panel shows GTI.

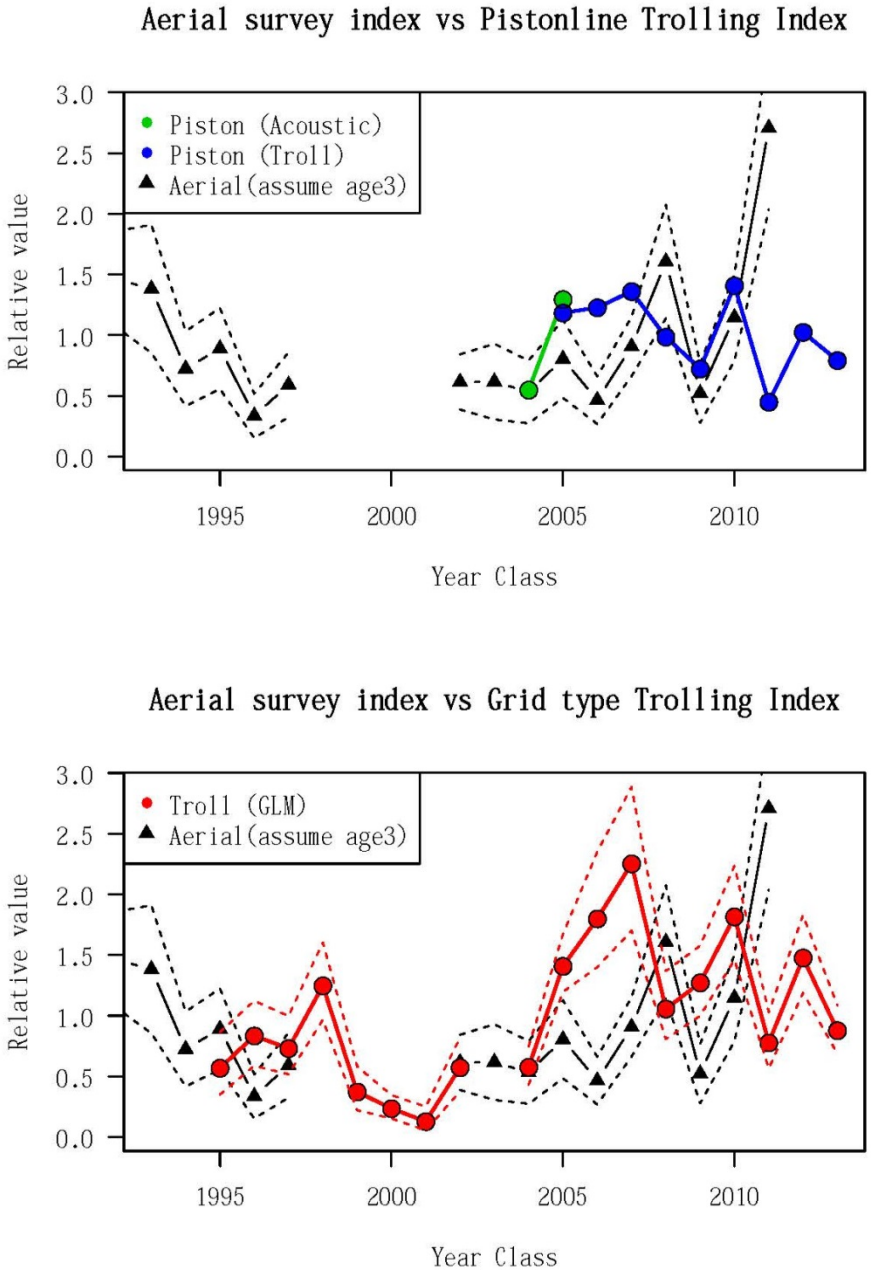

Fig. 16 Comparison between aerial survey index and trolling indices

Upper panel shows PTI and lower panel shows GTI. Assigned year class for aerial survey assuming age-3 fish observed. Range of aerial index is ±2SE.

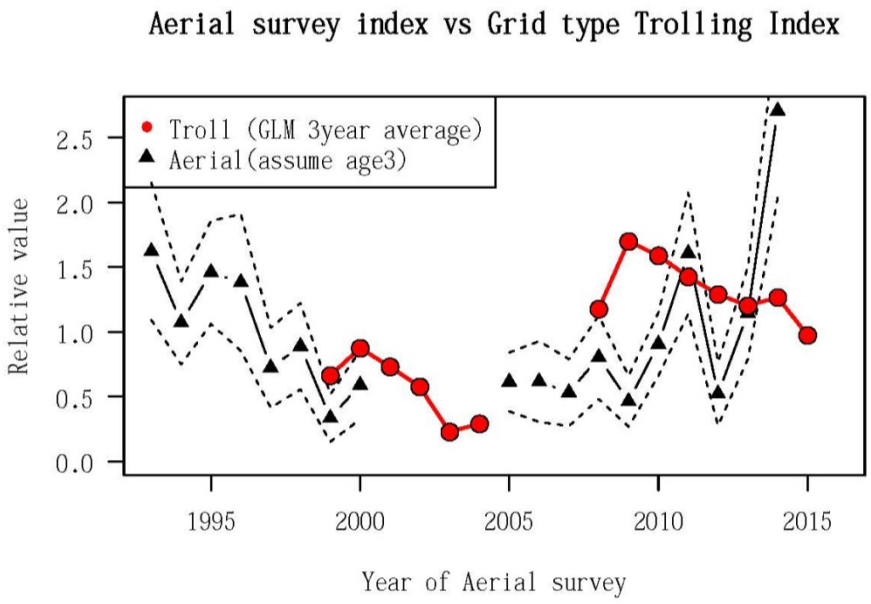

Fig. 17 Comparison between aerial survey index and trolling indices in three years running average

Range of aerial index is ±2SE. Trolling index was plotted two years later of it operated assuming that aerial survey index for age 3 and trolling survey for age 1.

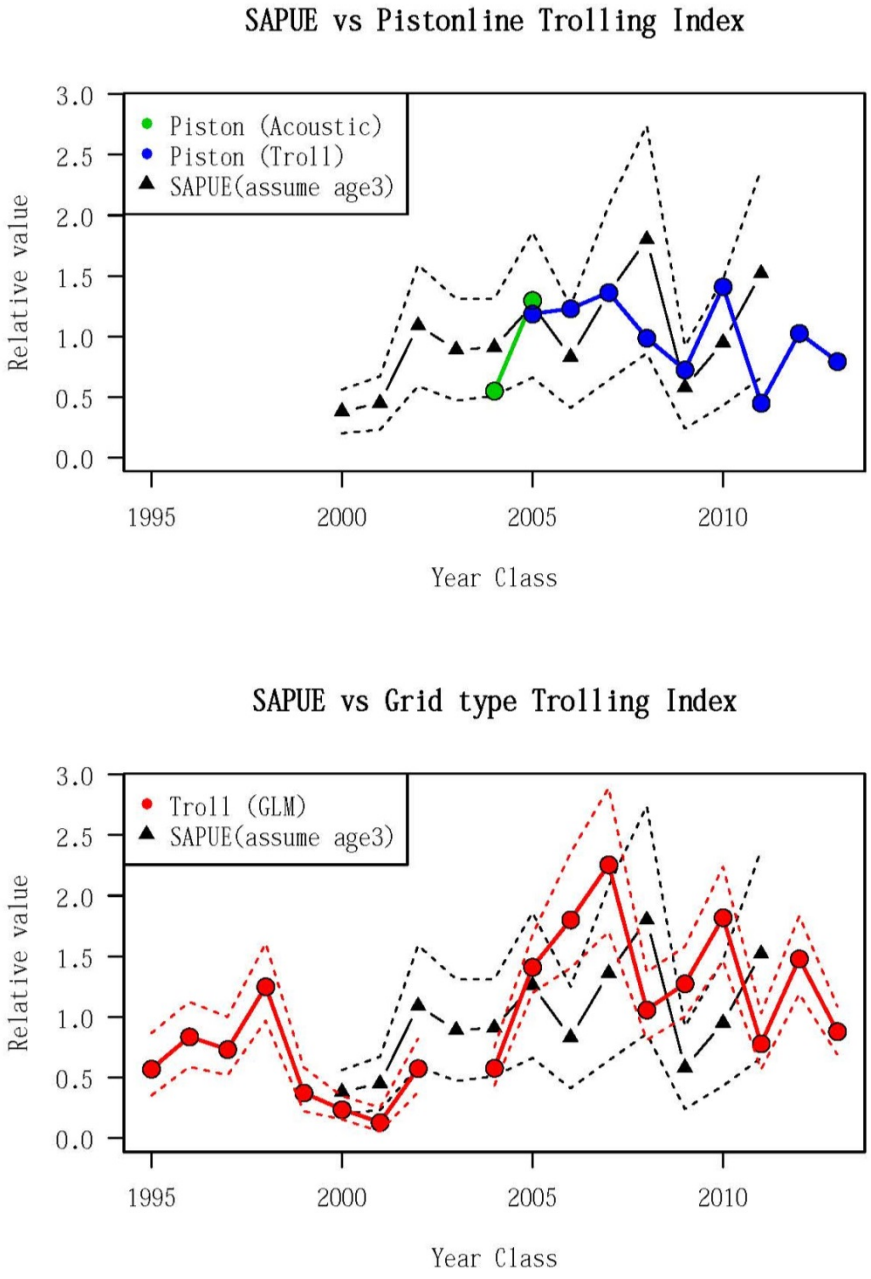

Fig. 18 Comparison between SAPUE and trolling indices

Upper panel shows PTI and lower panel shows GTI. Assigned year class for SAPUE assuming age-3 fish observed. Range of SAPUE is ±2SE.

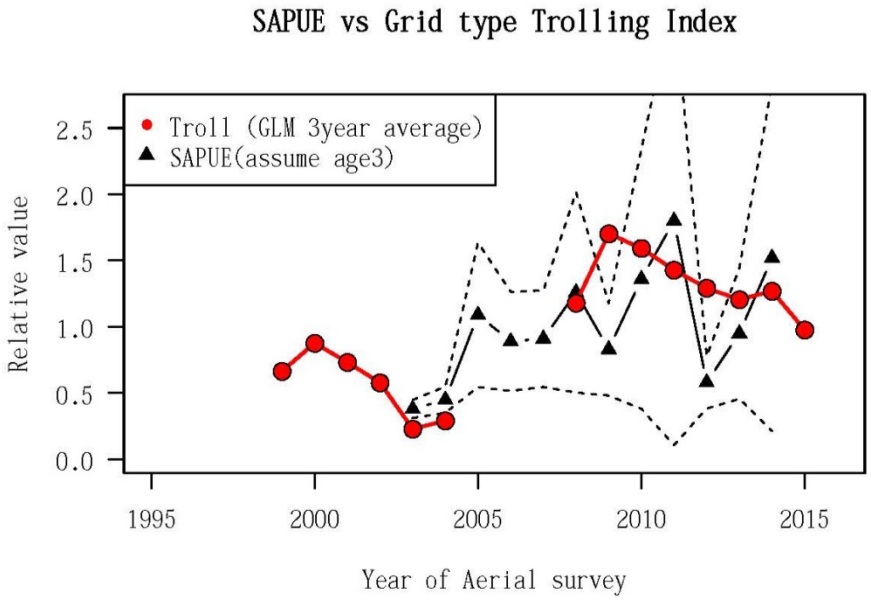

Fig. 19 Comparison between SAPUE and trolling indices in three years running average

Range of aerial index is ±2SE. Trolling index was plotted two years later of it operated assuming that SAPUE for age 3 and trolling survey for age 1.