**CCSBT-ESC/2508/24**
**(ESC Agenda item 7.1)**

# ミナミマグロ 1 歳魚の曳縄指数：
# グリッドタイプ曳縄指数の更新 2025 年

# Trolling indices for age-1 southern bluefin tuna: update of the grid type trolling index in 2025

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## 要約

オーストラリア南西岸において実施したミナミマグロ 1 歳魚の科学加入量調査の曳縄漁獲データから、1996 年から現在までの 20 年以上に及ぶ加入量指数を求めた。本文書では、2025 年調査データを追加して計算した結果を示す。ピストンライン曳縄指数（TRP）は、既定の調査定線（ピストンライン）上における探索距離 100km 当たりの漁獲をモデルベースの標準化はせずに求めた。グリッドタイプ曳縄指数（TRG）は、より広範な海域のデータを使用してデルタログノーマルアプローチで一般化線形モデルで標準化して計算した。2025 年の TRG は 2024 年よりも増加し、28 年間の平均値の 90%であった。

## Summary

From the trolling catch data of the scientific recruitment monitoring surveys for the age-1 southern bluefin tuna (SBT) on the southwestern coast of Australia, the recruitment index for more than 20 years since 1996 to the present was calculated. This document shows updated indices by adding the 2025 survey data. The piston-line trolling index (TRP) was derived from catch per 100 km search distance on a pre-determined transect line (called piston-line) without model-based standardization. The grid-type trolling index (TRG) was calculated based on data from wider area and standardized by the generalized linier model with delta lognormal approach. TRG in 2025 increase from 2024 and 90% of the 28-year average.

## Introduction

Trolling survey for southern bluefin tuna (*Thunnus maccoyii* SBT) is a scientific research survey which aims to provide recruitment indices of the stock at age-1. The survey has been carried out in the southern coast of Western Australia since 2006, except 2015. It has provided an index named the piston-line trolling index (TRP) which have been reported to CCSBT since 2006 (Itoh and Kurota 2006, Itoh 2007, Itoh and Sakai 2007, 2008, 2009, 2010, Itoh et al. 2011, 2012, 2013, Itoh and Tokuda 2014, Itoh and Tsuda 2016, Tsuda and Itoh 2017, 2018, 2019, Itoh and Tsuda 2020, Itoh 2021, 2022, 2023, 2024). TRP is derived from catch per 100 km search distance on a pre-determined transect line (called piston-line) without model-based standardization. In addition, another recruitment index, the grid-type trolling index (TRG) which used data from wider area and standardized by the generalized linier model (GLM) has developed and has been reported to CCSBT since 2014 (Itoh and Takahashi 2014).

In 2021, while the trolling survey was conducted, the survey area was limited to off Esperance only due to the influence of COVID-19, which resulted in no surveys on the piston-line. We presented the updated TRG and provided a variation of TRG (TRG_esp) limited to the area off Esperance. In 2022, the trolling survey was carried out in full range scale including piston-line, though still under the influence of COVID-19 in some extent. Since 2023, the trolling survey has been able to be carried out in the same specification as before 2020. In this document, we provide updated TRP and TRG as of 2025.

## Materials and methods

1. Piston-line Trolling Index　TRP

For TRP, data used were the trolling catch data on the piston-line in the acoustic survey in 2005 and 2006 and that in the trolling survey from 2006 to 2014, 2016 to 2020, and 2022 to 2025. Details of the survey were described in other papers that submitted every year (e.g. Itoh 2025). It contains data in a total of 246 times on the piston-line (Table 1). Data of another 12 times were not included because the line was incomplete due to mainly rough sea conditions. Datasets were separated between the acoustic survey and trolling survey because there were differences in the two surveys, such as survey design, a vessel used especially in size and specification of trolling gears. Trolling operations on the piston-line were repeated from 8 to 20 times per year.

The piston-line was set off Bremer Bay, in the middle of the whole area for the acoustic and trolling surveys (Fig. 1). The exact locations and length of the line have been changed a few times since its first determination in 2005. The offshore part of the piston line, which had caught a small number of fish over the past years, was cut and extended towards the coast in

which available to enter for the small vessels used in the trolling survey in 2007. The data in 2005 and 2006 where locate offshore than the 2007 end points were eliminated (no SBT were caught in the eliminated data). The locations of the piston-line have been almost the same since 2008 to the present. Figure 2 shows the piston-line in 2025. The vessel proceeded almost without deviation on the piston line for all of 10 times.

The summary of data is shown in Table 2. It reached a total of 659 hours in search time and 8,263 km in search distance. The number of age-1 SBT caught was 834 individuals.

TRP was calculated as a catch of age-1 SBT per 100 km search distance. There were five types of catch definition and TRPs 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. TRP 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. TRP 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. TRP 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. TRP from this definition is "TRI_Times.

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

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

2. Grid-type Trolling Index　TRG

For TRG, data used were the trolling catch in the acoustic survey between 1996 and 2003, 2005 and 2006, and in the trolling survey between 2006 and 2014, and between 2016 and 2025. While the surveys were carried out from December in some years, the year was referred to that include January in the survey (e.g. the survey extended from December 2008 to January 2009 was referred to be the 2009 survey) in this analysis.

Search 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 four area types (described later). Data west of 117.5E were eliminated.

Time intervals of a recording of latitude and longitude during the surveys differed by year.

Up to the 2005 acoustic survey, latitude and longitude were only recorded when any events occurred, including hourly environmental observation, catch, detection of anything in sonar, the arrival of transect reflection point, CTD observation, etc. Then, locations at every one minute were calculated by interpolating two points of records available. Since the 2006 surveys, locations were recorded in a 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 the daytime from 6 AM to 6 PM. Actual times of start and end of trolling were not recorded. Some records of catch before 6 AM and after 6 PM were eliminated. In the trolling survey, all the times of start and end of trolling operations were recorded.

Catch was limited for age-1 SBT (estimated from fork length of 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 apart were from different schools. Other definition of a school (e.g. 20 minutes apart, 2 km apart) can be possible, however, it has already confirmed that it caused little difference in the previous analysis.

In the research area, SBT distribution was distinctly different by area type which categorized as follows (Fig. 1).

lump: Small seamounts or small islands. Its center position was measured on nautical charts.

shelfedge: A range near 200 m isobath. The range was determined from observing SBT catch records that 3.0 km toward inshore and 0.5 km toward offshore.

onshelf: the northern area of the shelfedge.

offshore: the southern area of the shelfedge.

The area for each grid was classified as follows. When a part of the shelfedge zone is included in the grid, it is classified as shelfedge, the coastal side is classified as onshelf, and the offshore side is classified as offshore. After that, those whose center position of any lump is included in the grid are classified as lump. Furthermore, in the case of four lumps (Figure of eight Island, Investigator Island, etc.) where the lump is large or the center of the lump is near the edge of the grid, the adjacent grid that is likely to be affected by the lump is also classified as lump. In the 2021 analysis, the number of lumps to be referred to was increased (170), so the data classification was different from the previous data.

Delta log-normal GLM was applied for CPUE standardization because of a high percentage of zero catch observations (Lo et al. 1992, Li and Jiao 2013). The delta model handles zero catch data and positive catch data in two separate sub-models, i.e. one sub-model to estimate

the probability of catching SBT age-1 with an assumption of binomial distribution and logit link function (binomial sub-model), and the other to fit the positive catch data with an assumption of lognormal distribution (CPUE sub-model).

Binomial sub-model:

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

error ~ binomial

CPUE sub-model:

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

error ~ gaussian

where p is the probability of positive catch, survey is either acoustic or trolling surveys, explanatory variables of year, month, hour, area and survey are treated as factors.

In this GLM standardization, the explanatory variables for the optimum model were selected based on the AIC using MuMIn package in R software v4.4.1 (R-core team 2012). The MuMIn package calculates the AIC for models of all combinations of the explanatory variables. The lowest AIC model containing the year explanatory variable was selected as the best model. Product of estimates from these two sub-models gives the final estimate of the TRG. Furthermore, the bootstrap method was applied to obtain a range of the estimate. 1000 datasets were made through stratified sampling by year.

Because the survey area in 2021 was limited to the offshore of Esperance due to the survey design temporarily revised in response to the situation of COVID-19, another TRG that limited to the off Esperance (TRG_esp) was calculated. Eliminated data before 2012 when there is little data for this calculation, the area east of longitude 121.4E was used. There are two types of areas, onshelf and lump. As with TRG, we used a delta model consisting of a binomial sub-model and a CPUE sub-model. The model structure used was similar except for the survey.

Binomial sub-model for TRG_esp:

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

error ~ binomial

where p is the probability of positive catch.

CPUE sub-model for TRG_esp:

log(catch) ~ year + month + hour + area + offset(log(distance)) + error

error ~ gaussian

## Results

1. Piston-line Trolling Index: TRP

Summary of data on piston-line is shown in Table 2. Figure 3 and Table 3 show the five types of estimated TRP by different school/catch definition. Figure 4 shows the median of the five types of indices that adjusted to the mean of each. Small differences were observed among the five type indices except 2013 where there was a large difference between school indices (TRI_20min, 30min and 2km) and catch indices (TRI_times and ind.). The relative index of TRI_30min was consistent with the index from the acoustic survey in 2006. The fluctuation in TRI_30min overtime was smaller among the five types of indices. Therefore, the TRI_30min index which was submitted to CCSBT data exchange is used as TRP. SBT age-1 of 43 individuals were caught in the 10 piston lines in 2025. The TRP in 2025 increased from 2024.

2. Grid-type Trolling Index: TRG

Summary of data aggregated by grid is shown in Table 4. It consists of 11,641 records in total that reach about 62,972 km search distance and 1,065 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 (90.9%).

Distributions of effort, catch and CPUE in 2025 are shown in Fig. 5. Those in previous years are available in previous document (e.g. Itoh 2024). It covers the area from Esperance to Albany through Bremer Bay as usual years. Probability of catch is different by the area type distinctively, the largest in lump (17%), followed by onshelf and shelfedge, and lowest in offshore (2.7%) (Table 5). In the positive catch, there is small difference in CPUE by area type.

Nominal CPUE is shown in Fig. 6. Note that a substantial part of the effort was made up offshore where few SBT caught from 1996 to 2005 in which to be expected to underestimate compared to the latter half period. In 2025, the nominal CPUE increased from 2024 and higher than the range in the past eight years.

The selected GLM models for TRG based on the AIC were as follows (Table 6):

Binomial sub-model:

log(p/(1-p)) ~ year + month + area + offset(log(distance)) + error

CPUE sub-model:

log(catch) ~ year + area + survey + offset(log(distance)) + error

Relationships between the probability of catch and various variables and between CPUE and various variables in terms of least square mean are shown in Fig.7 and Fig. 8, respectively. The estimated values of each variable are shown in Table 7 and Table 8. QQ plot of CPUE sub-model is shown in Fig. 9, which shows good fit in the lower and middle part though lack of fits in high values. LS-means of year trend in each sub-model are shown in Table 9 and Table 10. Indices of both sub-models and point estimation of TRG are shown in Table 11 and Fig. 10.

Table 12 and Figure 11 show TRG with confidence interval calculated through 1000 times bootstrap. TRG showed considerable low levels in 2000-2002, then increase in 2005-2008 and relatively high level in 2006-2016 with fluctuation from year to year. TRG values in recent eight years (2017-2024) have returned to relatively low levels, similar to those in 2000-2002. TRG value for 2025 increased from 2024, while the median is 90 % of the mean over 28 years.

3. Comparison among indices

We compared among TRG, TRP and TRG_esp. Trolling index from grid data limited to off Esperance (TRG_esp) was calculated between 2013 and 2025 (Fig. 12). From the full models, following models were selected by AIC.

Binomial sub-model:

log(p/(1-p)) ~ year + offset(log(distance)) + error

CPUE sub-model:

log(catch) ~ year + offset(log(distance)) + error

The TRG_esp in 2025 was in the middle of the variation among TRG_esp in 12 years. Figure 13 shows comparison between TRG and TRG_esp. Two indices are significantly correlated (Pearson's correlation coefficient, $r=0.716$, $p < 0.05$) and general trends are similar to each other, while the increase in 2023 was distinct in TRG_esp. It is suggested that the index derived from the survey area, reduced temporarily in 2021 only off Esperance, represents that from all survey areas.

Figure 14 shows comparison between TRG and TRP. Two indices are significantly correlated to each other (Pearson's correlation coefficient, $r=0.900$, $p < 0.001$).

## Discussion

The present paper provided updated Piston line trolling index (TRP) and Grid-type trolling index (TRG) of age-1 SBT recruitment indices. Both trolling indices are based on catch that is the number of schools. When we encountered SBT school in the survey, the numbers of fish

individuals caught and catch times could have increased if we handled the trolling line well and/or the vessel moved well to catch up or attract the fish school. The numbers of fish individuals caught and catch times were decreased when a suspended fishing operation such as several trolling lines was tangled at one catch and we needed several minutes to solve the tangling. The numbers of fish individuals or catch time can be depends on such crew skills of trolling. The number of schools was selected as a catch to avoid the influence of crew skill. However, the definition of catch as a school for index means to set an assumption that the probability distribution of the size of school (the number of individuals per school) is consistent over years.

TRG is a comprehensive index that includes not only on the piston-line but also all the area surveyed. TRG enabled to extend the years to as long as 28 years, by adding the trolling data in the acoustic survey from 1996 to 2003. The acoustic survey and the trolling survey were not originally designed to obtain TRG. However, because the acoustic survey was well designed to cruise randomly in the research area for sonar detection, the trolling catch operated simultaneously in the 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 the larger area since 2008 intending development of TRG. When trolling was operated on a lump, we tried to operate trolling also 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 a high percentage of zero observation was used. Area type was highly significant in the binomial 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. On the other hand, as Tsuda and Itoh (2017) showed, weather conditions have a negligible effect on the standardization of TRG.

## Acknowledgment

We thank skippers and crew of the vessels engaged in the survey and Mr. Totterdell in MIRG for his help. We thank AFMA given us scientific research permission in the Australian coastal waters (#1006167).

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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 | |
| 2016 | 14 | 14 | |
| 2017 | 10 | 10 | |
| 2018 | 9 | 9 | |
| 2019 | 8 | 8 | |
| 2020 | 10 | 10 | |
| 2022 | 15 | 13 | 2 |
| 2023 | 12 | 12 | |
| 2024 | 12 | 12 | |
| 2025 | 10 | 10 | |
| Total | 258 | 246 | 12 |

## Table 2. Summary data of the 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 numbser SBT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 6.53 | 6.36 |
| | 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 | 43:17 | 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 | 4.60 | 6.58 |
| | total | 38:16 | 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 numbser SBT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 2:24 | 28.6 | 2006/1/26 | 8:26 | 11:59 | 1.42 | 1.25 | 1.58 | 3 | 6 | 4.98 | 4.41 | 5.59 | 9.66 | 21.54 |
| | total | 28:37 | 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 | 5.1.43 | 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 | 20 | 2.36 | 3 | 7 | 6.13 | 4.55 | 7.51 | 9.84 | 22.53 |
| | total | 38:24 | 455.0 | | | | 27 | | 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 | 27:50 | 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 | 114 | 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 | 26:52 | 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 | 29:22 | 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 | 2001/1/31 | 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 | 33:17 | 402.8 | | | | 25 | 20 | 27 | 37 | 71 | | | | | |
| 2012 | min | 2:31 | 33.8 | 2012/1/25 | 5:21 | 5:21 | 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 | 13:27 | 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 | 7:50 | 0.57 | 0.57 | 0.64 | 0.64 | 0.93 | 1.63 | 1.63 | 1.83 | 1.83 | 2.66 |
| | total | 40:07 | 493.6 | | | | 8 | 8 | 9 | 9 | 13 | | | | | |
| 2013 | min | 2:38 | 33.8 | 2013/1/19 | 5:56 | 5:56 | 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 | 12:21 | 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 | 8:34 | 1.54 | 1.31 | 1.69 | 3.62 | 7.38 | 4.34 | 3.70 | 4.78 | 10.26 | 20.95 |
| | total | 36:43 | 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 | 38:45 | 490.0 | | | | 16 | 14 | 19 | 24 | 33 | | | | | |
| 2016 | min | 2:22 | 33.1 | 2016/1/27 | 5:40 | 8:09 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | max | 2:53 | 35.2 | 2016/2/8 | 12:30 | 16:54 | 3 | 3 | 3 | 3 | 9 | 8.74 | 8.74 | 8.74 | 8.74 | 25.60 |
| | mean | 2:37 | 34.6 | 2016/2/2 | 8:14 | 11:40 | 1.50 | 1.36 | 1.57 | 1.71 | 3.57 | 4.33 | 3.92 | 4.54 | 4.95 | 10.26 |
| | total | 36:42 | 484.5 | | | | 21 | 19 | 22 | 24 | 50 | | | | | |
| 2017 | min | 2:12 | 33.4 | 2017/1/31 | 6:22 | 9:12 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | max | 2:35 | 37.0 | 2017/2/7 | 9:05 | 11:40 | 2 | 2 | 2 | 2 | 5 | 5.76 | 5.76 | 5.76 | 5.76 | 14.96 |
| | mean | 2:24 | 34.9 | 2017/2/2 | 3:48 | 7:08 | 0.60 | 0.60 | 0.60 | 0.60 | 1.90 | 1.71 | 1.71 | 1.71 | 1.71 | 5.44 |
| | total | 24:07 | 349.2 | | | | 6 | 6 | 6 | 6 | 19 | | | | | |
| 2018 | min | 2:16 | 33.2 | 2018/2/4 | 6:15 | 9:16 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | max | 2:35 | 35.4 | 2018/2/12 | 14:53 | 17:12 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | mean | 2:23 | 34.6 | 2018/2/7 | 10:59 | 13:33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | total | 21:27 | 311.1 | | | | 0 | 0 | 0 | 0 | 0 | | | | | |
| 2019 | min | 2:37 | 34.8 | 2019/2/3 | 5:55 | 8:40 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | max | 4:10 | 36.2 | 2019/2/11 | 13:14 | 17:21 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | mean | 3:00 | 35.5 | 2019/2/5 | 8:29 | 11:29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | total | 24:00 | 284.2 | | | | 0 | 0 | 0 | 0 | 0 | | | | | |
| 2020 | min | 2:23 | 34.1 | 2020/2/1 | 6:17 | 9:15 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | max | 2:58 | 36.7 | 2020/2/11 | 13:41 | 16:22 | 2 | 2 | 2 | 2 | 8 | 5.86 | 5.86 | 5.86 | 5.86 | 22.76 |
| | mean | 2:37 | 35.1 | 2020/2/6 | 9:05 | 12:33 | 0.60 | 0.60 | 0.60 | 0.70 | 2.00 | 1.72 | 1.72 | 1.72 | 2.01 | 5.75 |
| | total | 26:11 | 351.3 | | | | 6 | 6 | 6 | 7 | 20 | | | | | |
| 2022 | min | 1:48 | 30.5 | 2022/2/13 | 6:38 | 9:00 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | max | 4:44 | 36.1 | 2022/2/20 | 16:14 | 18:08 | 1 | 1 | 1 | 2 | 5 | 3.11 | 3.11 | 3.11 | 5.54 | 13.85 |
| | mean | 2:30 | 33.9 | 2022/2/16 | 1:23 | 3:54 | 0.31 | 0.31 | 0.31 | 0.38 | 1.00 | 0.90 | 0.90 | 0.90 | 1.11 | 2.89 |
| | total | 32:37 | 441.2 | | | | 4 | 4 | 4 | 5 | 13 | | | | | |
| 2023 | min | 2:06 | 29.7 | 2023/2/2 | 5:55 | 8:18 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | max | 4:35 | 36.3 | 2023/2/10 | 13:34 | 16:02 | 1 | 1 | 1 | 1 | 1 | 2.88 | 2.88 | 2.88 | 2.88 | 2.88 |
| | mean | 2:56 | 34.0 | 2023/2/5 | 9:07 | 12:04 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| | total | 35:18 | 408.5 | | | | 1 | 1 | 1 | 1 | 1 | | | | | |
| 2024 | min | 2:41 | 34.4 | 2024/2/2 | 6:10 | 9:00 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | max | 6:44 | 36.4 | 2024/2/12 | 13:31 | 17:02 | 2 | 2 | 3 | 3 | 5 | 5.50 | 5.50 | 8.25 | 8.25 | 14.25 |
| | mean | 3:44 | 35.2 | 2024/2/6 | 8:46 | 12:31 | 0.33 | 0.33 | 0.42 | 0.42 | 1.00 | 0.93 | 0.93 | 1.16 | 1.16 | 2.82 |
| | total | 44:55 | 423.0 | | | | 4 | 4 | 5 | 5 | 12 | | | | | |
| 2025 | min | 2:26 | 34.5 | 2025/2/7 | 6:32 | 8:58 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | max | 6:05 | 35.4 | 2025/2/16 | 11:53 | 15:47 | 3 | 3 | 3 | 4 | 17 | 8.55 | 8.55 | 8.55 | 11.40 | 48.01 |
| | mean | 3:15 | 35.1 | 2025/2/11 | 8:50 | 12:06 | 0.80 | 0.70 | 1.20 | 1.40 | 4.30 | 2.28 | 1.99 | 3.41 | 3.98 | 12.21 |
| | total | 32:38 | 350.8 | | | | 8 | 7 | 12 | 14 | 43 | | | | | |

A part of data not used for TRP has already excluded.

Table 3. Piston-line Trolling Index value

| index | Survey | Year | Minimum | 5% | Median | 95% | Maximum |
|---|---|---|---|---|---|---|---|
| sch20min | 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 | 2.279 | 3.373 | 4.867 | 6.854 | 8.597 |
| | Trolling | 2007 | 2.826 | 4.244 | 6.149 | 8.186 | 10.487 |
| | Trolling | 2008 | 3.161 | 3.979 | 4.929 | 5.920 | 6.672 |
| | Trolling | 2009 | 1.134 | 2.310 | 3.837 | 5.519 | 7.904 |
| | Trolling | 2010 | 1.045 | 1.843 | 2.884 | 3.953 | 4.931 |
| | Trolling | 2011 | 1.699 | 4.598 | 6.333 | 8.346 | 9.972 |
| | Trolling | 2012 | 0.414 | 0.811 | 1.622 | 2.440 | 3.275 |
| | Trolling | 2013 | 2.580 | 3.478 | 4.346 | 5.180 | 5.641 |
| | Trolling | 2014 | 1.226 | 2.247 | 3.257 | 4.294 | 5.271 |
| | | 2015 | | | | | |
| | Trolling | 2016 | 1.450 | 2.845 | 4.349 | 5.796 | 6.984 |
| | Trolling | 2017 | 0.000 | 0.836 | 1.702 | 2.826 | 3.470 |
| | Trolling | 2018 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Trolling | 2019 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Trolling | 2020 | 0.000 | 0.849 | 1.723 | 2.850 | 4.059 |
| | Trolling | 2021 | | | | | |
| | Trolling | 2022 | 0.000 | 0.239 | 0.896 | 1.547 | 2.067 |
| | Trolling | 2023 | 0.000 | 0.000 | 0.240 | 0.719 | 1.199 |
| | Trolling | 2024 | 0.000 | 0.236 | 0.932 | 1.849 | 3.267 |
| | Trolling | 2025 | 0.000 | 0.855 | 2.276 | 3.700 | 5.702 |
| sch30min | 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 | 1.968 | 3.127 | 4.297 | 5.429 | 6.294 |
| | Trolling | 2007 | 1.524 | 2.796 | 4.461 | 6.660 | 9.465 |
| | Trolling | 2008 | 3.119 | 3.989 | 4.894 | 5.880 | 6.631 |
| | Trolling | 2009 | 1.141 | 2.280 | 3.582 | 5.079 | 6.788 |
| | Trolling | 2010 | 0.534 | 1.584 | 2.623 | 3.650 | 4.721 |
| | Trolling | 2011 | 1.957 | 3.416 | 5.085 | 6.791 | 9.192 |
| | Trolling | 2012 | 0.397 | 0.811 | 1.618 | 2.432 | 3.269 |
| | Trolling | 2013 | 2.379 | 2.841 | 3.697 | 4.562 | 5.027 |
| | Trolling | 2014 | 1.225 | 2.030 | 2.859 | 3.690 | 4.335 |
| | | 2015 | | | | | |
| | Trolling | 2016 | 1.440 | 2.679 | 4.046 | 5.333 | 7.091 |
| | Trolling | 2017 | 0.279 | 0.839 | 1.711 | 2.848 | 4.017 |
| | Trolling | 2018 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Trolling | 2019 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Trolling | 2020 | 0.000 | 0.842 | 1.718 | 2.623 | 4.066 |
| | Trolling | 2021 | | | | | |
| | Trolling | 2022 | 0.000 | 0.239 | 0.887 | 1.559 | 2.036 |
| | Trolling | 2023 | 0.000 | 0.000 | 0.240 | 0.719 | 1.439 |
| | Trolling | 2024 | 0.000 | 0.236 | 0.932 | 1.862 | 2.764 |
| | Trolling | 2025 | 0.000 | 0.848 | 1.991 | 3.422 | 5.416 |
| sch2km | 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 | 2.314 | 3.421 | 5.151 | 6.952 | 8.815 |
| | Trolling | 2007 | 2.825 | 4.978 | 7.591 | 10.118 | 12.226 |
| | Trolling | 2008 | 3.532 | 4.565 | 5.450 | 6.482 | 7.502 |
| | Trolling | 2009 | 1.154 | 2.300 | 3.819 | 5.584 | 7.080 |
| | Trolling | 2010 | 0.793 | 2.098 | 3.413 | 4.753 | 6.888 |
| | Trolling | 2011 | 3.127 | 4.604 | 6.656 | 9.284 | 11.686 |
| | Trolling | 2012 | 0.596 | 1.007 | 1.835 | 2.828 | 3.873 |
| | Trolling | 2013 | 2.619 | 3.693 | 4.780 | 5.851 | 6.704 |
| | Trolling | 2014 | 1.627 | 2.643 | 3.862 | 5.298 | 7.278 |
| | | 2015 | | | | | |
| | Trolling | 2016 | 1.640 | 3.130 | 4.561 | 5.832 | 6.821 |
| | Trolling | 2017 | 0.000 | 0.849 | 1.709 | 2.819 | 4.036 |
| | Trolling | 2018 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Trolling | 2019 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Trolling | 2020 | 0.000 | 0.586 | 1.723 | 2.620 | 3.763 |
| | Trolling | 2021 | | | | | |
| | Trolling | 2022 | 0.000 | 0.239 | 0.899 | 1.562 | 2.243 |
| | Trolling | 2023 | 0.000 | 0.000 | 0.240 | 0.719 | 1.199 |
| | Trolling | 2024 | 0.000 | 0.236 | 0.949 | 2.320 | 3.909 |
| | Trolling | 2025 | 0.000 | 1.431 | 3.411 | 5.144 | 7.383 |
| hit.times | 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 | 3.394 | 5.484 | 9.628 | 13.706 | 17.193 |
| | Trolling | 2007 | 2.939 | 6.440 | 9.719 | 13.388 | 15.746 |
| | Trolling | 2008 | 3.721 | 4.818 | 6.050 | 7.295 | 8.442 |
| | Trolling | 2009 | 1.451 | 2.882 | 4.903 | 7.331 | 11.517 |
| | Trolling | 2010 | 1.039 | 3.109 | 6.070 | 9.891 | 15.019 |
| | Trolling | 2011 | 2.903 | 5.700 | 9.007 | 13.378 | 16.874 |
| | Trolling | 2012 | 0.397 | 1.005 | 1.824 | 2.837 | 3.669 |
| | Trolling | 2013 | 4.116 | 6.261 | 9.959 | 15.029 | 18.748 |
| | Trolling | 2014 | 1.846 | 3.031 | 4.697 | 7.126 | 9.059 |
| | | 2015 | | | | | |
| | Trolling | 2016 | 2.073 | 3.493 | 4.956 | 6.589 | 8.206 |
| | Trolling | 2017 | 0.270 | 0.836 | 1.709 | 2.835 | 3.460 |
| | Trolling | 2018 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Trolling | 2019 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Trolling | 2020 | 0.277 | 0.863 | 1.997 | 3.185 | 4.927 |
| | Trolling | 2021 | | | | | |
| | Trolling | 2022 | 0.000 | 0.426 | 1.110 | 1.976 | 3.032 |
| | Trolling | 2023 | 0.000 | 0.000 | 0.240 | 0.719 | 1.199 |
| | Trolling | 2024 | 0.000 | 0.236 | 1.159 | 2.535 | 3.909 |
| | Trolling | 2025 | 0.000 | 1.709 | 3.988 | 6.511 | 8.511 |
| number SBT | 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 | 5.616 | 11.017 | 18.836 | 27.063 | 35.499 |
| | Trolling | 2007 | 8.904 | 14.059 | 22.285 | 31.846 | 41.926 |
| | Trolling | 2008 | 7.960 | 10.538 | 13.522 | 16.220 | 17.449 |
| | Trolling | 2009 | 1.852 | 5.726 | 10.456 | 16.452 | 22.357 |
| | Trolling | 2010 | 2.574 | 5.028 | 9.551 | 14.879 | 18.782 |
| | Trolling | 2011 | 5.347 | 9.269 | 18.249 | 28.709 | 42.850 |
| | Trolling | 2012 | 0.404 | 1.206 | 2.622 | 4.513 | 5.788 |
| | Trolling | 2013 | 9.448 | 14.846 | 20.892 | 27.582 | 35.290 |
| | Trolling | 2014 | 2.421 | 4.138 | 6.661 | 9.600 | 12.271 |
| | | 2015 | | | | | |
| | Trolling | 2016 | 3.515 | 6.612 | 10.276 | 14.342 | 18.443 |
| | Trolling | 2017 | 0.000 | 2.471 | 5.353 | 8.595 | 11.456 |
| | Trolling | 2018 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Trolling | 2019 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Trolling | 2020 | 0.277 | 2.003 | 5.521 | 9.489 | 13.765 |
| | Trolling | 2021 | | | | | |
| | Trolling | 2022 | 0.000 | 0.922 | 2.892 | 5.180 | 7.660 |
| | Trolling | 2023 | 0.000 | 0.000 | 0.240 | 0.719 | 1.439 |
| | Trolling | 2024 | 0.000 | 0.687 | 2.575 | 5.194 | 8.026 |
| | Trolling | 2025 | 0.859 | 4.791 | 11.901 | 21.267 | 27.478 |

Table 4. Data summary for Grid-type Trolling Index (TRG)

| Survey | Year | N_Record | Time_Min | Time_Max | Range | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | South | North | West | East |
| Acoustic | 1996 | 385 | 21 Jan. 1996 06:00 | 13 Feb. 1996 17:00 | -35.2 | -34.4 | 118.2 | 121.7 |
| | 1997 | 459 | 26 Jan. 1997 09:00 | 26 Feb. 1997 12:00 | -35.3 | -34.0 | 117.5 | 121.8 |
| | 1998 | 469 | 19 Jan. 1998 06:00 | 24 Feb. 1998 17:00 | -35.4 | -34.4 | 117.7 | 121.7 |
| | 1999 | 596 | 21 Jan. 1999 06:00 | 14 Mar. 1999 17:00 | -35.4 | -34.0 | 118.0 | 121.8 |
| | 2000 | 626 | 19 Jan. 2000 06:00 | 14 Mar. 2000 14:00 | -35.4 | -34.0 | 117.5 | 122.5 |
| | 2001 | 686 | 22 Jan. 2001 06:00 | 14 Mar. 2001 16:00 | -35.4 | -33.9 | 117.5 | 121.9 |
| | 2002 | 578 | 22 Jan. 2002 06:00 | 14 Mar. 2002 15:00 | -35.4 | -33.9 | 117.5 | 121.9 |
| | 2003 | 463 | 25 Dec. 2002 08:00 | 28 Jan. 2003 15:00 | -35.3 | -33.9 | 117.9 | 121.9 |
| | 2005 | 806 | 14 Jan. 2005 06:00 | 04 Mar. 2005 16:00 | -35.3 | -33.9 | 117.5 | 121.9 |
| | 2006 | 756 | 12 Jan. 2006 06:00 | 18 Feb. 2006 13:00 | -35.4 | -34.0 | 117.5 | 121.9 |
| Trolling | 2006 | 180 | 22 Jan. 2006 08:00 | 31 Jan. 2006 15:00 | -34.8 | -34.1 | 119.3 | 121.3 |
| | 2007 | 181 | 21 Jan. 2007 10:00 | 29 Jan. 2007 07:00 | -34.8 | -34.1 | 119.3 | 121.3 |
| | 2008 | 294 | 20 Jan. 2008 09:00 | 01 Feb. 2008 08:00 | -35.5 | -34.1 | 117.6 | 121.3 |
| | 2009 | 317 | 03 Dec. 2008 10:00 | 29 Jan. 2009 07:00 | -35.5 | -34.1 | 117.5 | 121.3 |
| | 2010 | 334 | 19 Jan. 2010 08:00 | 04 Feb. 2010 17:00 | -35.5 | -34.1 | 117.7 | 123.4 |
| | 2011 | 334 | 25 Jan. 2011 08:00 | 11 Feb. 2011 10:00 | -35.5 | -34.1 | 117.8 | 121.8 |
| | 2012 | 332 | 24 Jan. 2012 08:00 | 10 Feb. 2012 11:00 | -35.5 | -34.0 | 117.9 | 121.9 |
| | 2013 | 354 | 19 Jan. 2013 06:00 | 04 Feb. 2013 12:00 | -35.5 | -33.9 | 117.9 | 122.1 |
| | 2014 | 360 | 25 Jan. 2014 08:00 | 11 Feb. 2014 10:00 | -35.4 | -34.0 | 117.6 | 123.2 |
| | 2016 | 344 | 26 Jan. 2016 08:00 | 12 Feb. 2016 12:00 | -35.5 | -34.0 | 117.7 | 122.3 |
| | 2017 | 321 | 27 Jan. 2017 06:00 | 13 Feb. 2017 11:00 | -34.9 | -33.9 | 118.8 | 122.4 |
| | 2018 | 382 | 31 Jan. 2018 06:00 | 17 Feb. 2018 13:00 | -34.9 | -33.9 | 118.8 | 122.3 |
| | 2019 | 325 | 31 Jan. 2019 07:00 | 18 Feb. 2019 12:00 | -35.5 | -34.0 | 117.7 | 122.5 |
| | 2020 | 299 | 30 Jan. 2020 07:00 | 15 Feb. 2020 10:00 | -35.3 | -34.0 | 117.8 | 122.2 |
| | 2021 | 173 | 03 Feb. 2021 06:00 | 20 Feb. 2021 14:00 | -34.4 | -33.9 | 121.5 | 122.2 |
| | 2022 | 293 | 31 Jan. 2022 06:00 | 26 Feb. 2022 15:00 | -34.9 | -33.9 | 119.3 | 122.2 |
| | 2023 | 332 | 31 Jan. 2023 07:00 | 14 Feb. 2023 10:00 | -35.3 | -33.9 | 117.8 | 122.2 |
| | 2024 | 384 | 30 Jan. 2024 07:00 | 16 Feb. 2024 10:00 | -35.5 | -33.9 | 117.8 | 122.2 |
| | 2025 | 278 | 04 Feb. 2025 07:00 | 21 Feb. 2025 12:00 | -35.3 | -33.9 | 117.8 | 122.2 |

| Survey | Year | Distance searched (km) | | | | | SBT Catch |
|---|---|---|---|---|---|---|---|
| | | Total | Offshore | Shelfedge | On Shore | Lump | |
| Acoustic | 1996 | 2,765 | 1,498 | 1,192 | 75 | | 21 |
| | 1997 | 3,134 | 1,589 | 1,019 | 438 | 88 | 38 |
| | 1998 | 3,214 | 1,657 | 1,184 | 324 | 49 | 34 |
| | 1999 | 3,961 | 2,080 | 1,317 | 493 | 71 | 56 |
| | 2000 | 4,049 | 1,906 | 1,375 | 685 | 82 | 17 |
| | 2001 | 4,388 | 1,809 | 1,125 | 954 | 501 | 20 |
| | 2002 | 3,783 | 1,699 | 1,055 | 815 | 214 | 9 |
| | 2003 | 2,865 | 854 | 1,220 | 649 | 143 | 29 |
| | 2005 | 5,054 | 1,418 | 1,624 | 1,348 | 665 | 62 |
| | 2006 | 3,884 | 1,380 | 1,584 | 817 | 103 | 84 |
| Trolling | 2006 | 911 | 237 | 380 | 252 | 42 | 27 |
| | 2007 | 903 | 192 | 401 | 300 | 9 | 33 |
| | 2008 | 1,149 | 213 | 408 | 347 | 181 | 44 |
| | 2009 | 1,402 | 245 | 479 | 398 | 280 | 41 |
| | 2010 | 1,499 | 262 | 465 | 309 | 463 | 56 |
| | 2011 | 1,392 | 252 | 461 | 332 | 347 | 58 |
| | 2012 | 1,394 | 214 | 393 | 469 | 318 | 38 |
| | 2013 | 1,516 | 226 | 401 | 464 | 426 | 50 |
| | 2014 | 1,597 | 176 | 427 | 540 | 454 | 50 |
| | 2016 | 1,508 | 258 | 365 | 420 | 464 | 68 |
| | 2017 | 1,471 | 131 | 194 | 465 | 681 | 27 |
| | 2018 | 1,734 | 319 | 270 | 596 | 549 | 26 |
| | 2019 | 1,445 | 155 | 156 | 360 | 774 | 16 |
| | 2020 | 1,342 | 212 | 265 | 376 | 489 | 34 |
| | 2021 | 916 | | | 147 | 769 | 19 |
| | 2022 | 1,352 | 296 | 263 | 368 | 426 | 16 |
| | 2023 | 1,449 | 303 | 283 | 319 | 544 | 28 |
| | 2024 | 1,659 | 299 | 232 | 427 | 702 | 27 |
| | 2025 | 1,233 | 138 | 165 | 267 | 663 | 37 |
| Total | | 62,972 | 20,015 | 18,703 | 13,756 | 10,498 | 1,065 |

SBT Catch is the number of school with the definition of 30 minutes is necessary to be a different school from last catch.

Table 5. Summary data by area type

| Area | N_records | Catch | CPUE | | |
|---|---|---|---|---|---|
| | All | positive catch | % positive | Mean | SD |
| Lump | 2,003 | 345 | 17.22% | 23.9 | 36.6 |
| Offshore | 3,516 | 94 | 2.67% | 28.2 | 32.4 |
| OnShelf | 2,834 | 298 | 10.52% | 28.0 | 37.5 |
| Shelfedge | 3,288 | 328 | 9.98% | 24.1 | 24.5 |
| Total | 11,641 | 1,065 | 9.1% | | |

Table 6. AIC and selected models for two sub-models in TRG

| | model | AIC | Model |
|---|---|---|---|
| Binomial sub-model | full | 6184.4 | pn~fyear + fmonth + fhour + farea + survey + offset(log(dist)) |
| | AIC selected | 6168.6 | pn~fyear + fmonth + farea + offset(log(dist)) |
| CPUE sub-model | full | 2268.4 | catch~fyear + fmonth + fhour + farea + survey + offset(log(dist)) |
| | AIC selected | 2245.3 | catch~fyear + farea + survey + offset(log(dist)) |

Table 7. Estimated value by GLM for binomial sub-model of TRG

| | Estimate | Std. Error | z value | Pr (>\| z \|) | Significance |
|---|---|---|---|---|---|
| (Intercept) | -3.53404 | 0.25675 | -13.76460 | 4.16.E-43 | *** |
| fyear1997 | 0.33749 | 0.29320 | 1.15105 | 2.50.E-01 | |
| fyear1998 | 0.30552 | 0.29469 | 1.03672 | 3.00.E-01 | |
| fyear1999 | 0.84537 | 0.27752 | 3.04618 | 2.32.E-03 | ** |
| fyear2000 | -0.69018 | 0.34007 | -2.02954 | 4.24.E-02 | * |
| fyear2001 | -0.65306 | 0.33193 | -1.96749 | 4.91.E-02 | * |
| fyear2002 | -1.24352 | 0.41317 | -3.00968 | 2.62.E-03 | ** |
| fyear2003 | -0.17453 | 0.32031 | -0.54487 | 5.86.E-01 | |
| fyear2005 | 0.06354 | 0.27114 | 0.23434 | 8.15.E-01 | |
| fyear2006 | 0.91584 | 0.25636 | 3.57253 | 3.54.E-04 | *** |
| fyear2007 | 1.32124 | 0.31941 | 4.13654 | 3.53.E-05 | *** |
| fyear2008 | 1.17949 | 0.30021 | 3.92884 | 8.54.E-05 | *** |
| fyear2009 | 0.81879 | 0.30555 | 2.67972 | 7.37.E-03 | ** |
| fyear2010 | 1.02817 | 0.28848 | 3.56408 | 3.65.E-04 | *** |
| fyear2011 | 1.28225 | 0.28118 | 4.56029 | 5.11.E-06 | *** |
| fyear2012 | 0.74222 | 0.29697 | 2.49927 | 1.24.E-02 | * |
| fyear2013 | 0.90412 | 0.28963 | 3.12168 | 1.80.E-03 | ** |
| fyear2014 | 0.85409 | 0.28552 | 2.99138 | 2.78.E-03 | ** |
| fyear2016 | 1.34596 | 0.27821 | 4.83788 | 1.31.E-06 | *** |
| fyear2017 | 0.00985 | 0.32004 | 0.03077 | 9.75.E-01 | |
| fyear2018 | -0.04635 | 0.31975 | -0.14496 | 8.85.E-01 | |
| fyear2019 | -0.61544 | 0.36164 | -1.70183 | 8.88.E-02 | |
| fyear2020 | 0.59131 | 0.30591 | 1.93292 | 5.32.E-02 | |
| fyear2021 | -0.04635 | 0.35120 | -0.13197 | 8.95.E-01 | |
| fyear2022 | -0.29535 | 0.36149 | -0.81704 | 4.14.E-01 | |
| fyear2023 | 0.31028 | 0.31608 | 0.98166 | 3.26.E-01 | |
| fyear2024 | -0.02540 | 0.31861 | -0.07971 | 9.36.E-01 | |
| fyear2025 | 0.58095 | 0.30773 | 1.88785 | 5.90.E-02 | |
| fmonth2 | -0.05079 | 0.08704 | -0.58347 | 5.60.E-01 | |
| fmonth3 | -0.84708 | 0.25788 | -3.28479 | 1.02.E-03 | ** |
| fmonth12 | 0.29316 | 0.32479 | 0.90263 | 3.67.E-01 | |
| fareaOffshore | -2.02954 | 0.13629 | -14.89091 | 3.78.E-50 | *** |
| fareaOnShore | -0.51278 | 0.09635 | -5.32209 | 1.03.E-07 | *** |
| fareaShelfedge | -0.75419 | 0.10062 | -7.49568 | 6.60.E-14 | *** |

Significances are *** < 0.001, ** < 0.01 and * < 0.05.

Table 8. Estimate values by GLM for CPUE sub-model of TRG

| | Estimate | Std. Error | t value | Pr (>\| t \|) | Significance |
|---|---|---|---|---|---|
| (Intercept) | -0.15296 | 0.16519 | -0.92595 | 3.55.E-01 | |
| fyear1997 | -0.59720 | 0.19496 | -3.06313 | 2.25.E-03 | ** |
| fyear1998 | -0.72380 | 0.19477 | -3.71620 | 2.13.E-04 | *** |
| fyear1999 | -0.43928 | 0.18021 | -2.43769 | 1.50.E-02 | * |
| fyear2000 | -0.24410 | 0.23078 | -1.05768 | 2.90.E-01 | |
| fyear2001 | -0.69883 | 0.22474 | -3.10951 | 1.93.E-03 | ** |
| fyear2002 | -0.69703 | 0.28270 | -2.46562 | 1.38.E-02 | * |
| fyear2003 | -0.27548 | 0.20201 | -1.36367 | 1.73.E-01 | |
| fyear2005 | -0.36663 | 0.17855 | -2.05338 | 4.03.E-02 | * |
| fyear2006 | -0.62823 | 0.17153 | -3.66257 | 2.63.E-04 | *** |
| fyear2007 | -0.99907 | 0.25241 | -3.95810 | 8.08.E-05 | *** |
| fyear2008 | -0.77524 | 0.24471 | -3.16795 | 1.58.E-03 | ** |
| fyear2009 | -1.18650 | 0.24538 | -4.83543 | 1.54.E-06 | *** |
| fyear2010 | -0.99827 | 0.24064 | -4.14843 | 3.63.E-05 | *** |
| fyear2011 | -0.84915 | 0.23868 | -3.55774 | 3.91.E-04 | *** |
| fyear2012 | -1.12400 | 0.24892 | -4.51560 | 7.06.E-06 | *** |
| fyear2013 | -0.99425 | 0.24368 | -4.08012 | 4.86.E-05 | *** |
| fyear2014 | -1.18648 | 0.24279 | -4.88689 | 1.19.E-06 | *** |
| fyear2016 | -0.99773 | 0.23707 | -4.20862 | 2.80.E-05 | *** |
| fyear2017 | -1.25719 | 0.26247 | -4.78985 | 1.92.E-06 | *** |
| fyear2018 | -0.88182 | 0.26325 | -3.34981 | 8.39.E-04 | *** |
| fyear2019 | -0.97199 | 0.28895 | -3.36391 | 7.97.E-04 | *** |
| fyear2020 | -1.30097 | 0.25271 | -5.14800 | 3.16.E-07 | *** |
| fyear2021 | -1.43769 | 0.27655 | -5.19869 | 2.43.E-07 | *** |
| fyear2022 | -0.83755 | 0.28618 | -2.92669 | 3.50.E-03 | ** |
| fyear2023 | -1.28770 | 0.25993 | -4.95410 | 8.52.E-07 | *** |
| fyear2024 | -1.02405 | 0.26100 | -3.92349 | 9.32.E-05 | *** |
| fyear2025 | -1.16466 | 0.25196 | -4.62240 | 4.28.E-06 | *** |
| fareaOffshore | 0.06558 | 0.09130 | 0.71829 | 4.73.E-01 | |
| fareaOnShore | 0.02548 | 0.05999 | 0.42484 | 6.71.E-01 | |
| fareaShelfedge | -0.10428 | 0.06614 | -1.57665 | 1.15.E-01 | |
| surveyTR | 0.48508 | 0.15518 | 3.12590 | 1.82.E-03 | ** |

Significances are *** < 0.001, ** < 0.01 and * < 0.05

Table 9. Year trends of binomial sub-model of TRG

| Year | Mean | Mean-SE | Mean+SE |
|---|---|---|---|
| 1996 | 0.1232 | 0.0910 | 0.1553 |
| 1997 | 0.1617 | 0.1267 | 0.1968 |
| 1998 | 0.1577 | 0.1233 | 0.1922 |
| 1999 | 0.2356 | 0.1949 | 0.2763 |
| 2000 | 0.0676 | 0.0476 | 0.0875 |
| 2001 | 0.0699 | 0.0502 | 0.0895 |
| 2002 | 0.0405 | 0.0252 | 0.0559 |
| 2003 | 0.1063 | 0.0814 | 0.1313 |
| 2005 | 0.1298 | 0.1040 | 0.1556 |
| 2006 | 0.2473 | 0.2097 | 0.2849 |
| 2007 | 0.3209 | 0.2636 | 0.3783 |
| 2008 | 0.2941 | 0.2436 | 0.3445 |
| 2009 | 0.2313 | 0.1888 | 0.2737 |
| 2010 | 0.2667 | 0.2211 | 0.3122 |
| 2011 | 0.3134 | 0.2649 | 0.3620 |
| 2012 | 0.2191 | 0.1764 | 0.2617 |
| 2013 | 0.2453 | 0.2017 | 0.2889 |
| 2014 | 0.2370 | 0.1945 | 0.2795 |
| 2016 | 0.3257 | 0.2772 | 0.3743 |
| 2018 | 0.1185 | 0.0886 | 0.1483 |
| 2019 | 0.0723 | 0.0498 | 0.0947 |
| 2020 | 0.1963 | 0.1550 | 0.2376 |
| 2021 | 0.1185 | 0.0854 | 0.1516 |
| 2022 | 0.0958 | 0.0670 | 0.1247 |
| 2023 | 0.1583 | 0.1214 | 0.1953 |
| 2024 | 0.1206 | 0.0906 | 0.1506 |
| 2025 | 0.1948 | 0.1534 | 0.2361 |

Table 10. Year trends of CPUE sub-model of TRG

| Year | Mean | Mean-SE | Mean+SE |
|---|---|---|---|
| 1996 | 2.3889 | 2.1949 | 2.5828 |
| 1997 | 1.7917 | 1.6270 | 1.9563 |
| 1998 | 1.6651 | 1.4986 | 1.8315 |
| 1999 | 1.9496 | 1.8027 | 2.0965 |
| 2000 | 2.1448 | 1.9380 | 2.3516 |
| 2001 | 1.6900 | 1.4933 | 1.8867 |
| 2002 | 1.6918 | 1.4292 | 1.9544 |
| 2003 | 2.1134 | 1.9397 | 2.2871 |
| 2005 | 2.0222 | 1.8786 | 2.1659 |
| 2006 | 1.7606 | 1.6426 | 1.8787 |
| 2007 | 1.3898 | 1.2193 | 1.5603 |
| 2008 | 1.6136 | 1.4572 | 1.7700 |
| 2009 | 1.2024 | 1.0451 | 1.3596 |
| 2010 | 1.3906 | 1.2418 | 1.5394 |
| 2011 | 1.5397 | 1.3940 | 1.6855 |
| 2012 | 1.2649 | 1.1032 | 1.4266 |
| 2013 | 1.3946 | 1.2425 | 1.5467 |
| 2014 | 1.2024 | 1.0513 | 1.3535 |
| 2016 | 1.3911 | 1.2498 | 1.5325 |
| 2018 | 1.5070 | 1.3251 | 1.6889 |
| 2019 | 1.4169 | 1.1987 | 1.6350 |
| 2020 | 1.0879 | 0.9208 | 1.2549 |
| 2021 | 0.9512 | 0.7500 | 1.1523 |
| 2022 | 1.5513 | 1.3355 | 1.7671 |
| 2023 | 1.1012 | 0.9236 | 1.2788 |
| 2024 | 1.3648 | 1.1847 | 1.5449 |
| 2025 | 1.2242 | 1.0586 | 1.3898 |

Table 11. Point estimates of TRG

| Year | Prob*Pos | Standardized |
|---|---|---|
| 1996 | 0.2942 | 1.1068 |
| 1997 | 0.2898 | 1.0901 |
| 1998 | 0.2626 | 0.9880 |
| 1999 | 0.4593 | 1.7278 |
| 2000 | 0.1449 | 0.5450 |
| 2001 | 0.1181 | 0.4441 |
| 2002 | 0.0685 | 0.2578 |
| 2003 | 0.2247 | 0.8454 |
| 2005 | 0.2625 | 0.9875 |
| 2006 | 0.4354 | 1.6379 |
| 2007 | 0.4460 | 1.6779 |
| 2008 | 0.4745 | 1.7850 |
| 2009 | 0.2781 | 1.0460 |
| 2010 | 0.3709 | 1.3951 |
| 2011 | 0.4826 | 1.8155 |
| 2012 | 0.2771 | 1.0423 |
| 2013 | 0.3421 | 1.2871 |
| 2014 | 0.2850 | 1.0721 |
| 2016 | 0.4531 | 1.7046 |
| 2018 | 0.1786 | 0.6718 |
| 2019 | 0.1024 | 0.3851 |
| 2020 | 0.2135 | 0.8032 |
| 2021 | 0.1127 | 0.4240 |
| 2022 | 0.1487 | 0.5593 |
| 2023 | 0.1743 | 0.6559 |
| 2024 | 0.1646 | 0.6191 |
| 2025 | 0.2384 | 0.8969 |

Table 12. TRG with confidence intervals calculated by 1000 times bootstrap

| Year | 5 percentile | 25 percentile | Median | 75 percentile | 95 pecentile |
|---|---|---|---|---|---|
| 1996 | 0.893 | 1.017 | 1.103 | 1.197 | 1.329 |
| 1997 | 0.901 | 1.002 | 1.082 | 1.172 | 1.300 |
| 1998 | 0.799 | 0.908 | 0.983 | 1.067 | 1.201 |
| 1999 | 1.455 | 1.608 | 1.721 | 1.830 | 2.017 |
| 2000 | 0.435 | 0.497 | 0.543 | 0.593 | 0.648 |
| 2001 | 0.353 | 0.405 | 0.443 | 0.485 | 0.550 |
| 2002 | 0.204 | 0.235 | 0.258 | 0.279 | 0.313 |
| 2003 | 0.706 | 0.791 | 0.844 | 0.905 | 0.986 |
| 2004 | | | | | |
| 2005 | 0.851 | 0.927 | 0.985 | 1.045 | 1.143 |
| 2006 | 1.433 | 1.552 | 1.635 | 1.718 | 1.841 |
| 2007 | 1.458 | 1.586 | 1.673 | 1.768 | 1.893 |
| 2008 | 1.574 | 1.700 | 1.780 | 1.875 | 2.009 |
| 2009 | 0.896 | 0.982 | 1.044 | 1.104 | 1.187 |
| 2010 | 1.229 | 1.325 | 1.394 | 1.458 | 1.550 |
| 2011 | 1.642 | 1.753 | 1.817 | 1.890 | 1.983 |
| 2012 | 0.889 | 0.988 | 1.042 | 1.095 | 1.183 |
| 2013 | 1.132 | 1.223 | 1.290 | 1.355 | 1.442 |
| 2014 | 0.942 | 1.017 | 1.070 | 1.121 | 1.194 |
| 2015 | | | | | |
| 2016 | 1.475 | 1.613 | 1.711 | 1.794 | 1.909 |
| 2017 | 0.431 | 0.484 | 0.525 | 0.569 | 0.625 |
| 2018 | 0.562 | 0.623 | 0.665 | 0.717 | 0.787 |
| 2019 | 0.330 | 0.364 | 0.386 | 0.407 | 0.438 |
| 2020 | 0.663 | 0.745 | 0.798 | 0.860 | 0.947 |
| 2021 | 0.335 | 0.387 | 0.423 | 0.462 | 0.510 |
| 2022 | 0.436 | 0.511 | 0.565 | 0.615 | 0.699 |
| 2023 | 0.514 | 0.603 | 0.656 | 0.714 | 0.795 |
| 2024 | 0.494 | 0.570 | 0.621 | 0.668 | 0.739 |
| 2025 | 0.772 | 0.848 | 0.902 | 0.954 | 1.028 |

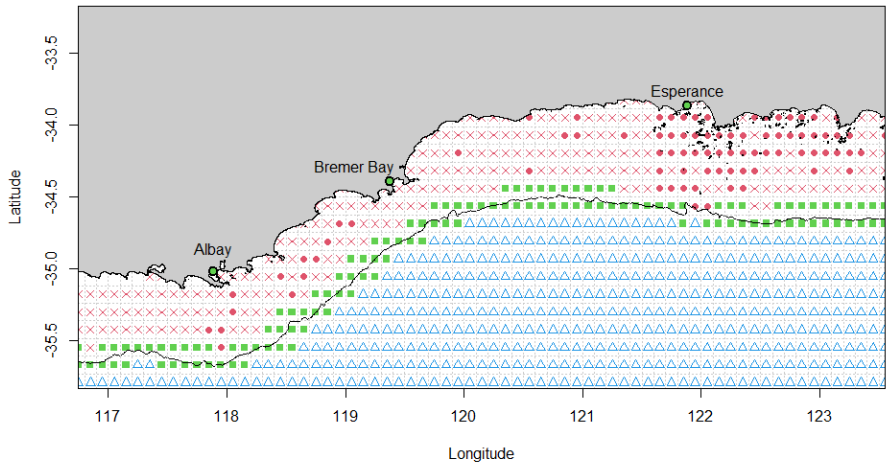


Fig. 1. Map and area classified.

Red cross denotes on-shore, red solid circle denotes lump, green solid square denotes shelf-edge, and open blue triangle denotes offshore.

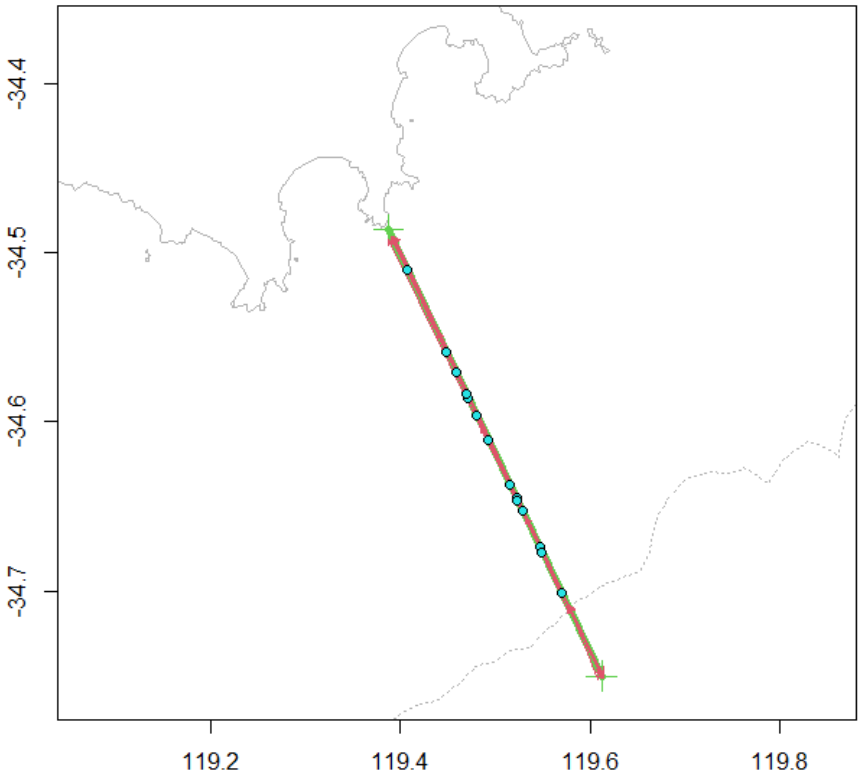


Fig. 2. Locations of the piston-line off Bremer Bay in the 2025 survey.

Green cross marks are defined end points of the piston line. Red arrow denotes each of piston line and direction. Circles denote location where age-1 SBT caught. Dotted line is the 200 m isobath.

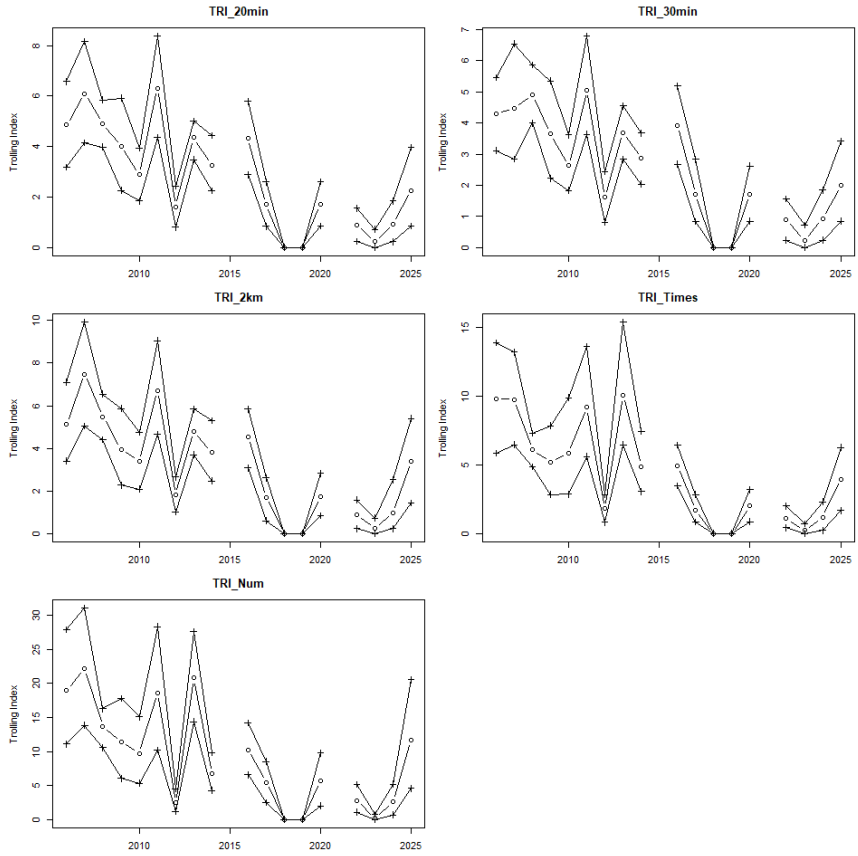


Fig. 3. Five types of the piston-line trolling index (TRP) by different school/catch definition.
Showing median, 5 and 95 percentiles.

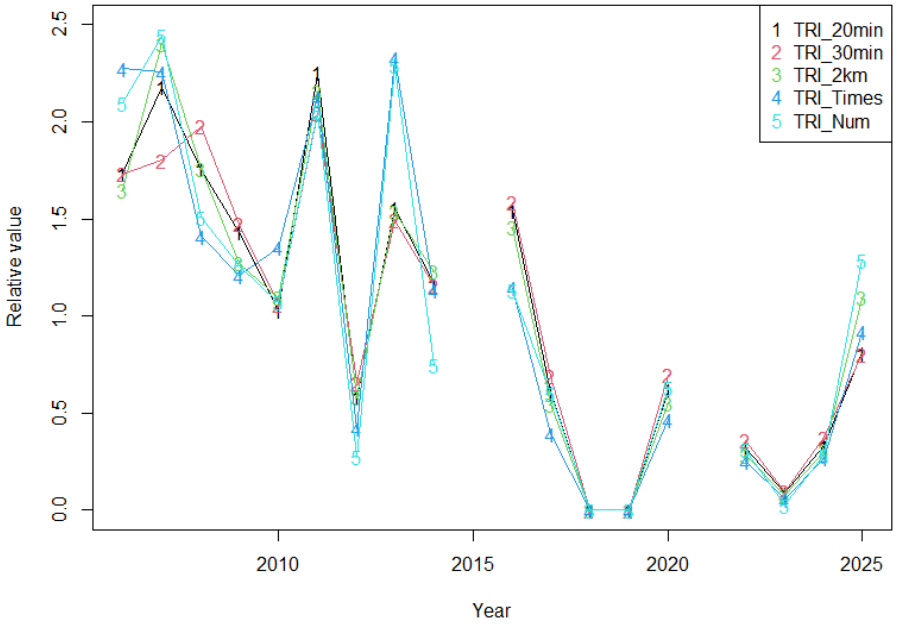


Fig. 4. Comparison of the median from five types of piston-line trolling index (TRP) by different school/catch definition.
Standardized with the mean of each index.

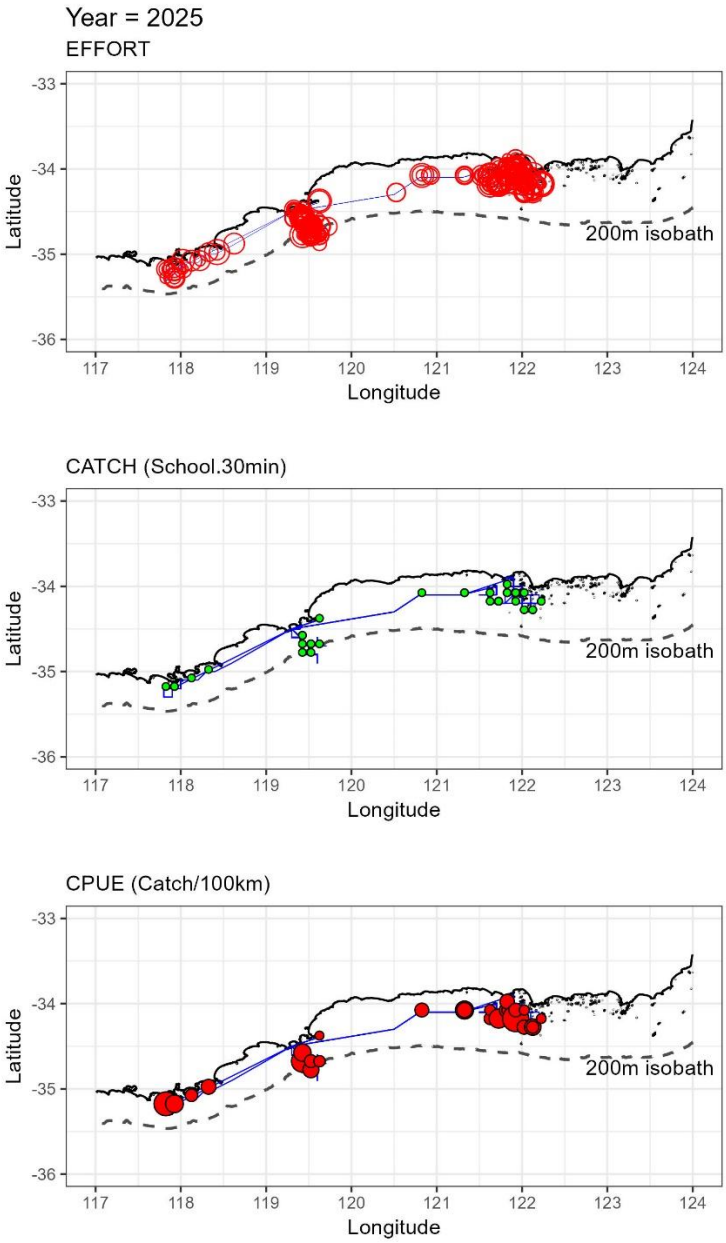


Fig. 5. Distributions of effort, age-1 SBT catch and CPUE in the 2025 survey

Blue line is the trajectory of the vessel while trolling.

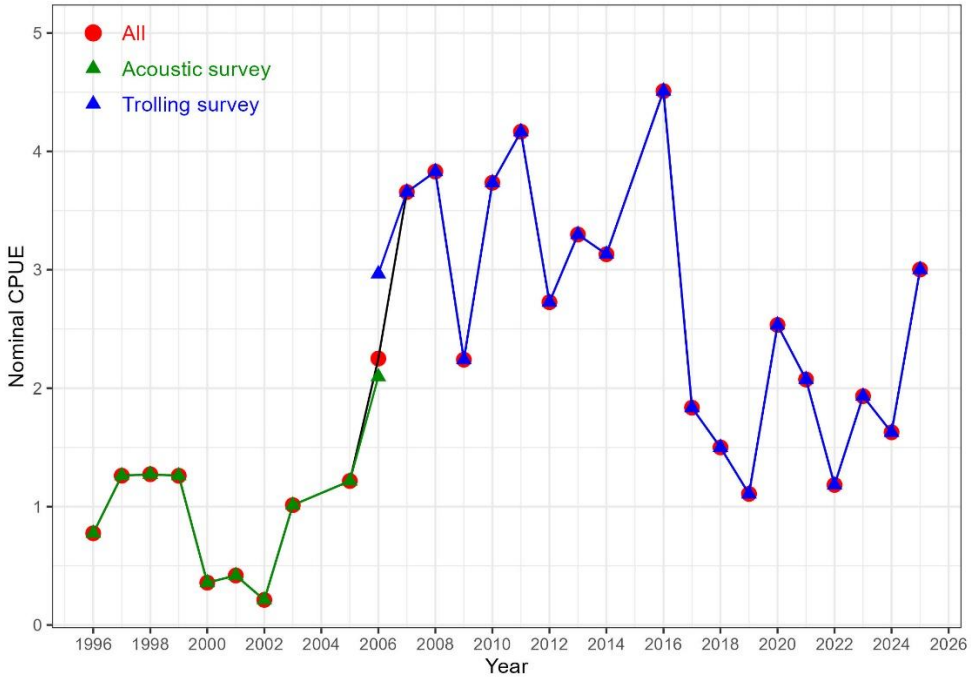


Fig. 6. Nominal CPUE of TRG.

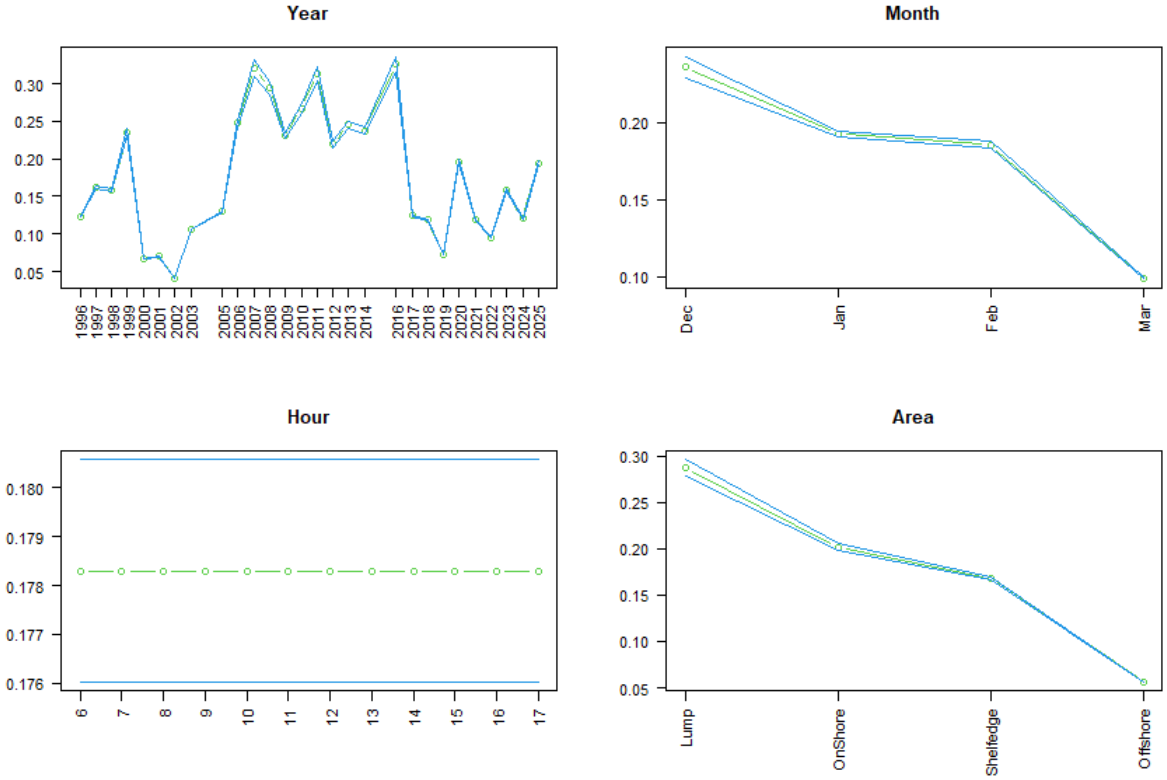


Fig. 7. Least square means of variables in binomial sub-model for TRG.

Green is mean and blue is mean±SD. Catch was defined as schools with a definition of 30 minutes is necessary for a different school. Note that hour term was not selected in the optimal model formula.

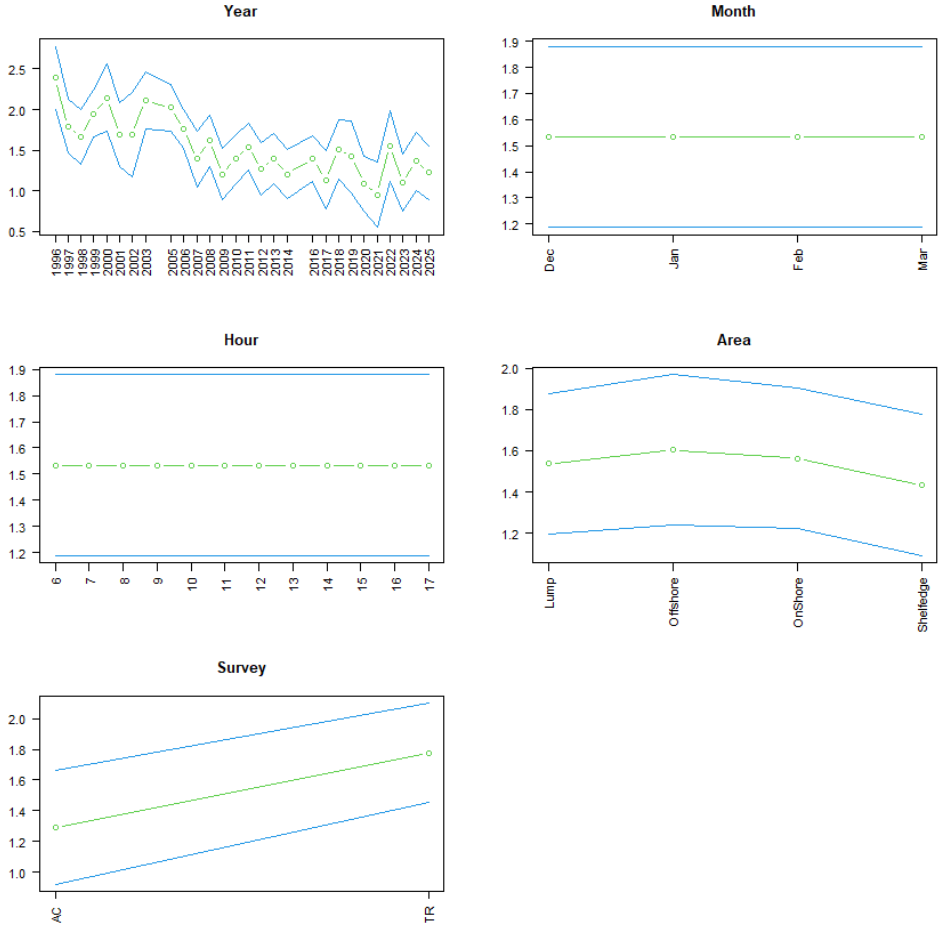


Fig. 8. Least square means of variables in catch in the CPUE sub-model for TRG.

Green is mean and blue is mean±+SD. Catch was defined as schools with a definition of 30 minutes is necessary for a different school. Note that month and hour terms were not selected in the optimal model formula.

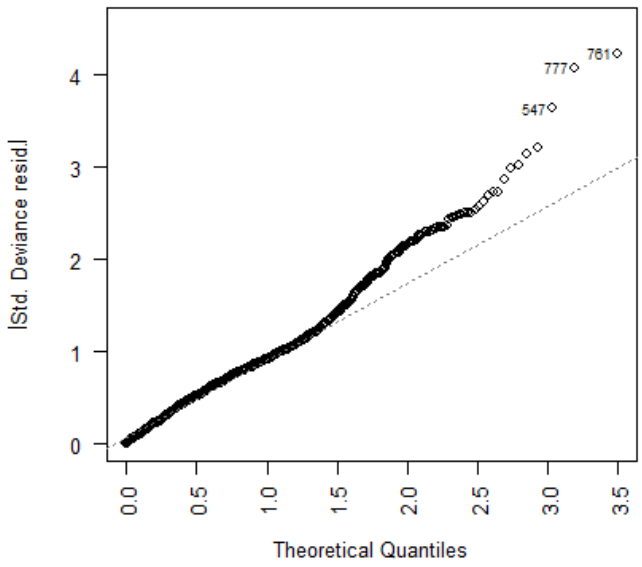


Fig. 9. QQ plot of GLM for CPUE sub-model for TRG.

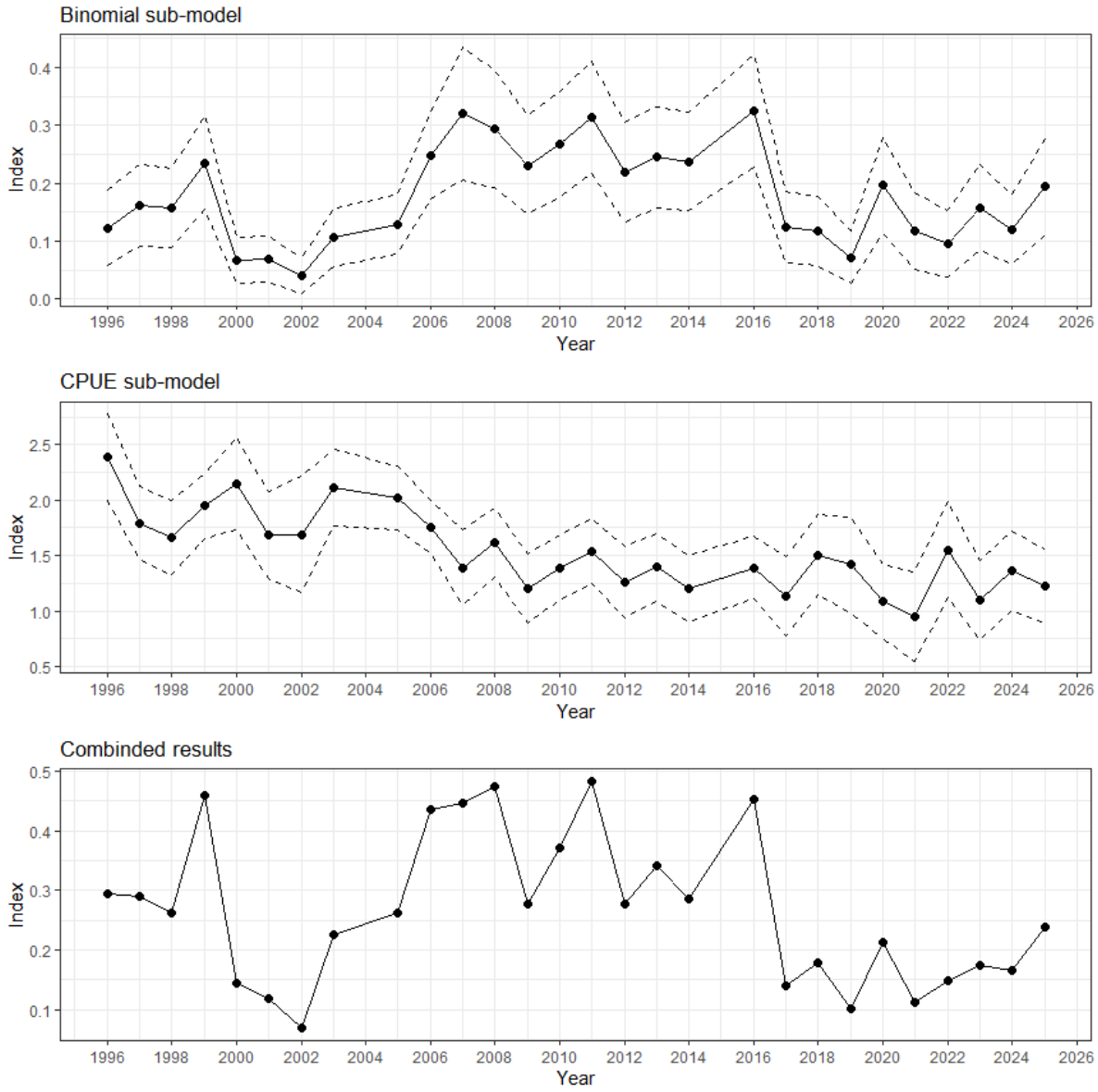


Fig. 10. Binomial sub-model, CPUE sub-model, and combined index from two sub-models (point estimation standardized TRG).

Upper panel shows the year trend from the binomial sub-model. Mean±1SD. The middle panel shows the year trend form the CPUE sub-model. Mean±1SD. Lower panel shows TRG which is a product of two sub-models.

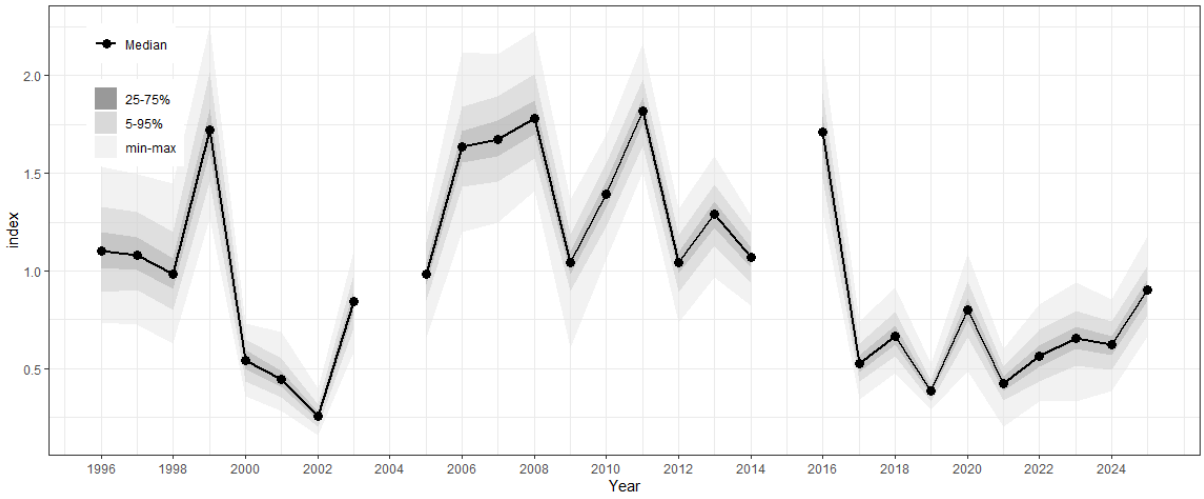


Fig. 11. TRG with confidence intervals.

Estimate was simulated with 1000 times bootstrapping.

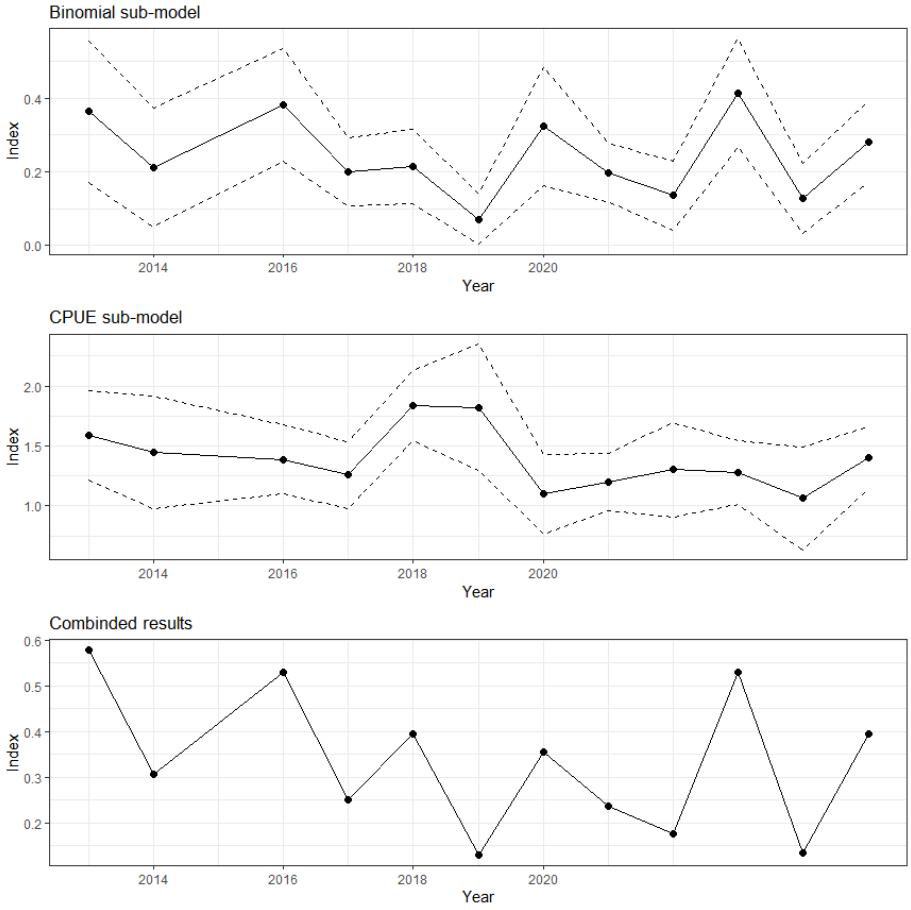


Fig. 12. TRG off Esperance only (TRG_esp) with confidence intervals.

Upper panel shows the year trend from the binomial sub-model. Mean±1SD. The middle panel shows the year trend form the CPUE sub-model. Mean±1SD. Lower panel shows TRG_esp which is a product of two sub-models.

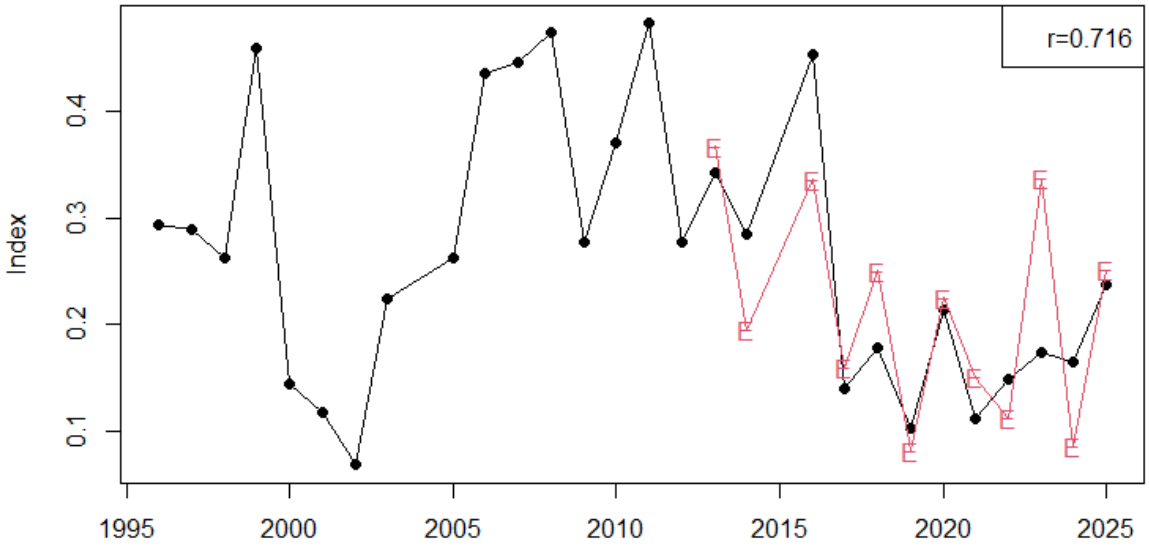


Fig. 13. Comparison between TRG and TRG_esp where data are limited off Esperance only.

Values of TRG_esp are standardized to the mean of TRG between 2013 and 2025. Pearson's correlation *r* is 0.716 ($p<0.05$).

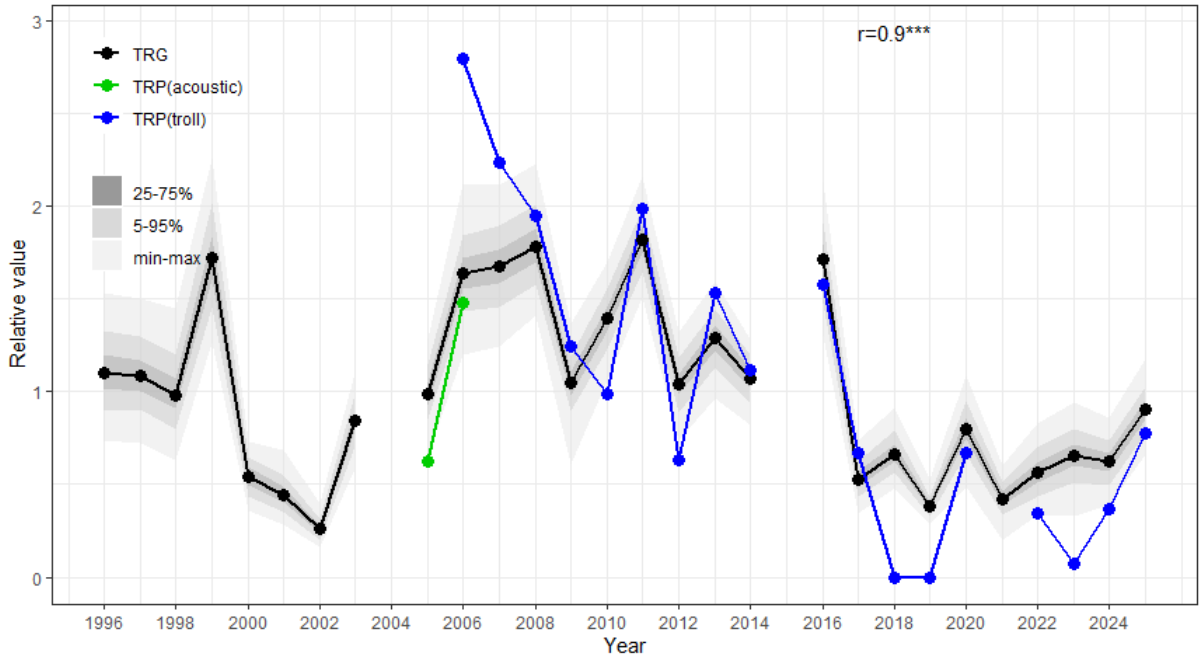


Fig. 14. Comparison between TRG and TRP.

r is Pearson's correlation.