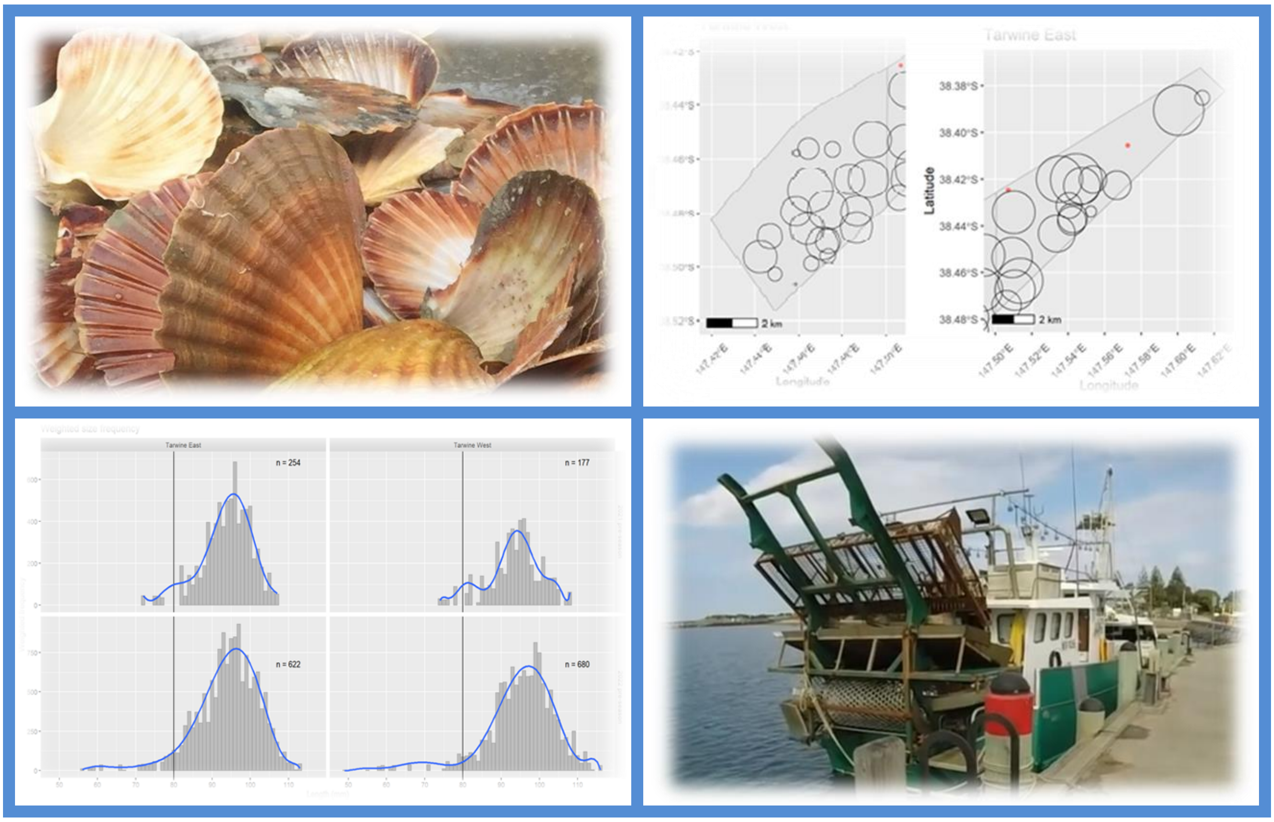
VFA Project 2021-23 0104

Eastern Victorian Ocean Scallop Fishery

2022 Pre-season Abundance Survey



Matt Koopman, Ian Knuckey and Russell Hudson

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Researcher Contact Details

Name: Matt Koopman
Address: Fishwell Consulting
27A Hesse St Queenscliff, VIC 3225
Phone: +61 3 5258 4399
Mobile: +61 4 0858 1599
Email: ian@fishwell.com.au
Web: www.fishwell.com.au

In submitting this report, the researcher has agreed to VFA publishing this material in its edited form.

Executive Summary

The main target species in the Victorian (Ocean) Scallop Fishery is the Commercial Scallop, *Pecten fumatus*, taken by dredging. The scallop fishery is managed using a statutory consultation process that involves fishers, fishery scientists and fishery managers. Information from a range of sources including scientific research, stock assessments and data from other Bass Strait scallop fisheries is considered in setting the annual total allowable commercial catch which is divided equally between each licence holder.

Since the commercial fishery began in the 1970's, catches have varied greatly from year to year. Continued low abundances during the mid- to late-2000's prompted a fishery independent survey during 2009 that showed there were no commercially viable scallop beds in the Fishery. As a result, DEDJTR (then DPI) and the scallop industry made a joint decision to set the TACC at zero for the 2010–11, 2011–12 and 2012–13 fishing seasons. A further survey conducted in 2012 showed little improvement in the status of the stocks, although there was some indication of recent recruitment of juvenile scallops into the fishery. It was estimated that these recruits should reach commercial size by 2014. The TACC was subsequently set at 136.5 tonnes in 2013/14 and 2014/15 and 135 tonnes for 2015/16.

An abundance survey covering historical fishing grounds in eastern Victoria was undertaken in late December 2017 and early January 2018 (Koopman *et al*. 2018). Results showed continued low levels of abundance and recruitment throughout the wide area surveyed. One scallop bed surveyed had an estimated biomass of 386 t of Commercial Scallop above the legal minimum length of 80 mm with a density of 0.5 individuals per m^2.

The 2021 pre-season survey focussed on a bed (the Tarwine bed) identified by Industry. Estimated biomass of Commercial Scallop on this bed above the legal minimum length was 7,876 t with a density of 1.15 individuals per m^2. This result prompted an increase in the TACC to 979 t (about 12% of available biomass) for the 2021-22 season, and a fishery closure of approximately half of that bed. A total of 630 t (as of 7th February 2022) of Commercial Scallop was landed in that season.

The Victorian Fisheries Authority committed to undertaking 2022 and 2023 pre-season surveys to inform management of the fishery. This report contains results of the first of these surveys.

Survey beds were identified through examination of previous surveys, analysis of catch and effort data, information provided by Industry and exploratory fishing (38 tows). This resulted in three survey beds identified:

- the Tarwine East bed is the eastern part of the Tarwine bed (from the 2000 survey) cut at the western boundary of the 2021 fishery closure (at longitude 147˚ 30́E)
- the Tarwine West bed is the remaining part of the Tarwine bed clipped in the west to exclude an area with low densities of scallops
- the Clonmel bed is a small bed located off Port Albert that was defined by exploratory fishing.

A total of 53 valid, random survey tows were undertaken across the three beds. Biomass was calculated for each bed using area swept calculated from the straight-line distance between the start and end tow points and the measured internal width of the dredges.

Biomass of Commercial Scallops greater than 80 mm was estimated to be 4,867 t at Tarwine East, 3,892 t at Tarwine West and 146 t at Clonmel. Total biomass greater than 80 mm at all sites combined was 8,904 t. The percent of Commercial Scallops greater than 80 mm was more than 98-98.4% at the two Tarwine beds and 72.8% at Clonmel. Densities in individuals per m^2 ranged from 1.13 at Clonmel to 1.53 at Tarwine East. Lengths measured at Clonmel were distributed over a wide size range indicating ongoing recruitment over a number of years. A tow within this bed was undertaken during the 2017/18 survey revealing a high density of scallops at 70.1 kg/1000 m^2 compared to the mean density of 74.5 kg/1000 m^2 from the Clonmel bed in the current survey.

An assessment of the stock in accordance with Status of Australian Fish Stocks criteria was undertaken, and words for inclusion in SAFS report recommended. The stock has undergone depletion as evidenced by reduced and contracted commercial catches, and multiple fishery-independent surveys that revealed only very low densities of scallops, negligible recruitment and no commercially viable scallop beds. However, recent surveys have identified one commercially viable bed. Based on the above, when assessed against the SAFS criteria, the Victorian coastal stock of scallops could be classified as “Recovering”, albeit from a heavily depleted state.

Funding for this project was made available under VFA Project Number 2021-23 0104.

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Acknowledgements

We would like to thank Andy Watts, Jake Watts and the crew of the Northern Star for all of their assistance and hard work in undertaking the survey. We appreciate the contributions made by other industry members in identifying potential survey areas.

We appreciate the assistance of the Victorian Fisheries Authority (VFA) scallop fishery manager, Mr Toby Jeavons and VFA data manager, Mrs Paula Baker.

Introduction

The main target species in the Victorian (Ocean) Scallop Fishery is the Commercial Scallop, *Pecten fumatus*. Commercial Scallops in wild populations live for between five and nine years, but have been observed to die-off rapidly after only three to five years in some situations (Haddon *et al.*, 2006). They are generally subject to high spatial and temporal variability in recruitment and abundance, variable growth and mortality, and rapidly changing meat yield and reproductive condition. This variability means that management of Commercial Scallops can be difficult due to the spatial and temporal patchiness of the resource. Although the Victorian (Ocean) Scallop Fishery extends twenty nautical miles out from the Victorian coastline, large portions of these waters are not suitable for Commercial Scallop fishing. Most commercial fishing is targeted towards high density scallop aggregations in spatially distinct 'beds' in eastern Victoria.

Commercial Scallops are taken using a dredge towed along the ocean floor with a tooth-bar to deflect scallops from the seabed into the dredge basket. The fishery is managed using a statutory consultation process that involves fishers, fishery scientists and fishery managers. Information from a range of sources including scientific research, stock assessments and data from other Bass Strait scallop fisheries is considered in setting the annual total allowable commercial catch (TACC). Although only 10–15 boats operate in the fishery, the number of commercial access licences is capped at 89 and each licence holder is given an equal share of the TACC. Transfer of quota between licence holders occurs during the season, under a system of "individual transferable quotas" (ITQs), facilitated by the Victorian Fisheries Authority (VFA) under the Department of Transport (DoT) (Victorian Fisheries Authority, 2021).

Since the beginning of the commercial fishery in the 1970's, catches have varied from tens of tonnes to thousands of tonnes. Catches (and presumably stock abundance) declined in the mid- to late-2000's (Figure 1) and a lack of recovery prompted a survey to be undertaken during 2009 by the Tasmanian Aquaculture and Fisheries Institute (TAFI) for the then Department of Primary Industries (DPI) (Harrington *et al.*, 2010). This survey determined that there were no commercially viable scallop beds available and as a result, DPI and the scallop industry made a joint decision to set the TACC at zero for the 2010/11, 2011/12 and 2012/13 fishing seasons. A further survey conducted in 2012 (Semmens and Jones, 2012) showed little improvement in the status of the stocks, although there was some indication of recent recruitment of juvenile scallops that should have reached commercial size by 2014. The TACC was subsequently set at 136.5 t in 2013/14 and 2014/15 and 135 t for the period 2015/16 to 2020/21.

Anecdotal information from Danish seine fishermen working off Victoria's east coast during 2017 suggested that there had been some level of recovery of the stock and commercially viable beds may be available for fishing. Based on this, and significant scallop beds being found recently in Bass Strait (Knuckey *et al.*, 2015, 2016, 2017, 2018 and Koopman e*t al,*. 2019, 2021a), VFA considered that there was merit in conducting a 2018 pre-season biomass survey of the Victorian Scallop Fishery to inform management arrangements for the following season. A broad-area survey was designed and conducted based on depth limitations of scallop fishing, GIS habitat layers, past fishing effort and results of past surveys in areas from Point Hicks in the east to Wilsons Promontory in the west. Total biomass in the broad-area stratum was estimated to be 5,107 t (95% confidence intervals (CIs) ranged 2,226 t–14,372 t), and with 89% of the scallops greater than 80 mm length, estimated biomass greater than 80 mm was 4,545 t (95% CI 1,980 t–12,791 t). The overall density was 1.1 kg per 1000 m^2, or 0.06 individuals per m^2 (Koopman *et al*. 2018).

In response to additional information from industry members, a 2021 pre-season survey was undertaken at what is now known as the Tarwine bed during December 2020 (Koopman *et al*. 2021b). Results from this survey revealed a total biomass of 8,018 t (95% confidence intervals (CIs) ranged 4,706 t–12,020 t) of which 98.2% were greater than 80 mm. The density was 1.2 individuals per m^2. These results prompted the VFA to close the eastern half to the Tarwine bed to fishing to protect spawning potential and increase the 2021 TACC to 978 t.

In 2021, the VFA committed to undertaking two years of biomass surveys to inform management of the fishery for the 2022 and 2023 seasons. This report contains results from the 2022 pre-season survey conducted during December 2021.

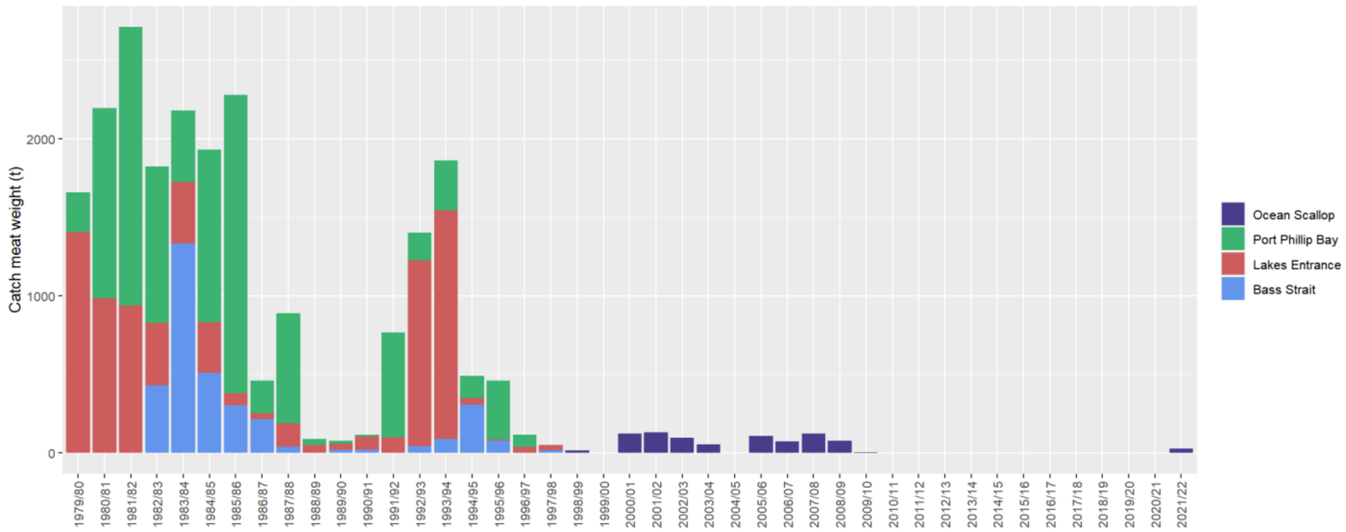

Figure 1. Time series of catch (meat weight, tonnes) in the Victorian Scallop Fishery. Note that the 2021 data only includes data to September. Minimum number of vessel contributing to any data point since 2000/01 is greater than five. Historical data (prior to 2000/01) from https://vfa.vic.gov.au/commercial-fishing/scallop (accessed February, 2022)

Objectives

1. Estimate the available (>80 mm) scallop biomass in the area of the Victorian (Ocean) Scallop Fishery.
2. Measure the size frequency distribution of scallops in each area to calculate discard rates.
3. Measure a range of biological information from the catch.
4. Report results to VFA to inform setting the 2022/23 Total Allowable Catch (TACC).

Methods

2022 Pre-season Survey Design

Determining appropriate catch weight measure

Raw catch and effort data from the fishery was provided by the VFA. The data spanned from 2000 to the most recent data available. Catch weights have historically been reported as meat weights, shell weight and bags of scallops. Each of those measurements were plotted against each other in Figure 1 to assess the most appropriate measure to use. There was good agreement between shell weight and meat weight, and apart from the zeros, there were few departures from main cluster of points. There were more zeros in the meat weight and one apparent outlier in the meat weight. The year 2021 in particular contained many zero catches. There was less agreement between either meat weight or shell weight and bags of scallops. Based on these comparisons, we used shell weight in all analyses.

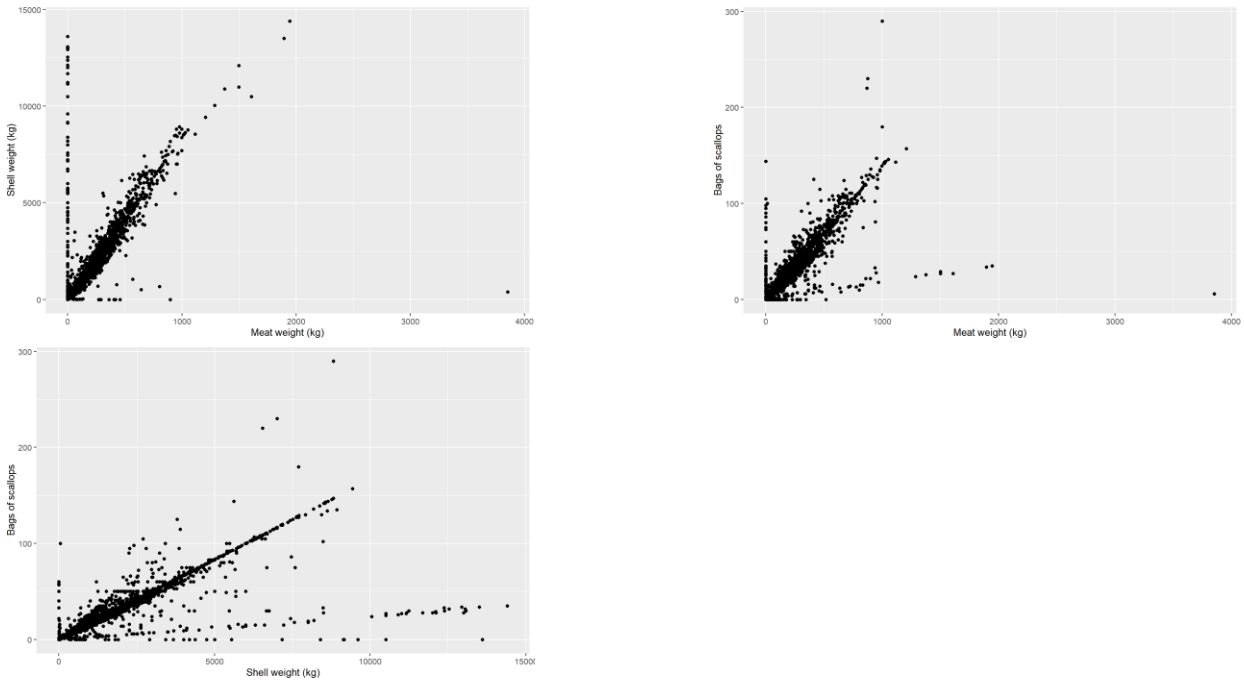

Figure 2. Comparison of different measurements of catch in the logbook data.

Determining survey area

The spatial distribution of fishing effort has largely contracted since 2000 when fishing occurred from Wilsons Promontory to 149°E (Figure 3). Since 2009, fishing effort was only reported from no more than five reporting grids except for in 2021 when the TACC was increased. In 2021, most of the effort was around the Tarwine bed. This was also the case in 2007. The distribution of catch largely reflects that of effort, with a large contraction in areas fished. The spatial distribution of catch cannot be presented because of the VFA's confidentiality policy. Catch was focussed around the Tarwine bed in 2005 to 2008 and again during 2021 following the results of the 2021 pre-season survey (Koopman et al. 2021). While historical catch and effort data provides insight into where future scallop beds might appear, the 2021 data is most useful in terms of setting priorities to survey in the current project. More than 400 t from 8 different vessels was reportedly caught in grid cell F39, and this concentration of fishing in F39 was reflected in the effort data (Figure 4). CPUE in F39 was higher than in any other year since 2000 at about 13 kg per minute. CPUE from other grid cells were also very high compared to previous years, and of the five area codes shown, catch rates were highest in G38 (data cannot be provided due to the VFA's confidentiality policy). These data clearly support the resurveying of the Tarwine bed during 2022.

A large part of the eastern half of the Tarwine bed was closed to fishing in 2021 to protect a portion of the spawning biomass (Figure 5). Given the significant fishing pressure and catches taken from the western portion of the Tarwine bed fished during 2021, we considered that splitting the Tarwine bed into eastern and western strata along the closure line would provide information on the benefits of closing an area to fishing and provide data with a lower level of uncertainty around the biomass estimate than surveying the Tarwine bed as a whole. Further, industry provided information that scallop densities in the south-western part of the Tarwine bed were not commercially viable and should be excluded in the survey (see the red line in (Figure 5). This was supported by results of the 2021 pre-season survey. The resulting polygons of each Tarwine Stratum are shown in Figure 6. We considered these two strata to be the highest priority for the 2022 pre-season survey.

Industry members provided nine marks considered to potentially contain commercially viable beds to explore during the 2022 pre-season survey (Figure 6, Figure 7 and Figure 8). Three were near Wilsons Promontory where Danish seine fishers reported incidental catches of Commercial Scallops (Figure 7). Two sites were within the "Star of the South" wind farm exploratory area that were close to a site that had high catches of Commercial Scallops during the 2018 pre-season (Figure 7). Another was near the southern-eastern border of that exploratory area (Figure 7). One exploratory site was west of the Tarwine bed where commercial catches of 1540 kg per tow were taken during the 2021 season (Figure 6). Two positions were provided in the north-east of the fishery between which catches of small scallops were anecdotally reported in recent years (Figure 8). This area is considered a historically important area to the fishery, and relatively high levels of catch and effort were reported in 2000 and 2005.

We considered that there was value in fishing at each of those exploratory points. We also considered that there was potential value in undertaking exploratory fishing at the Main bed surveyed in the 2018 pre-season survey (Figure 4).

Based on this information, the survey vessel was asked to undertake exploratory fishing at the positions in Table 1, in the areas between positions 8 and 9 in Table 1 and to mark out survey beds where appropriate. The vessel was also provided 20 randomly allocated primary sites and five randomly allocated backup sites (using QGIS (v 2.18.15) Random Points Inside Polygons tool) in the east and west Tarwine strata to survey (see Appendix 5 – Tarwine bed and Clonmel bed tow locations).

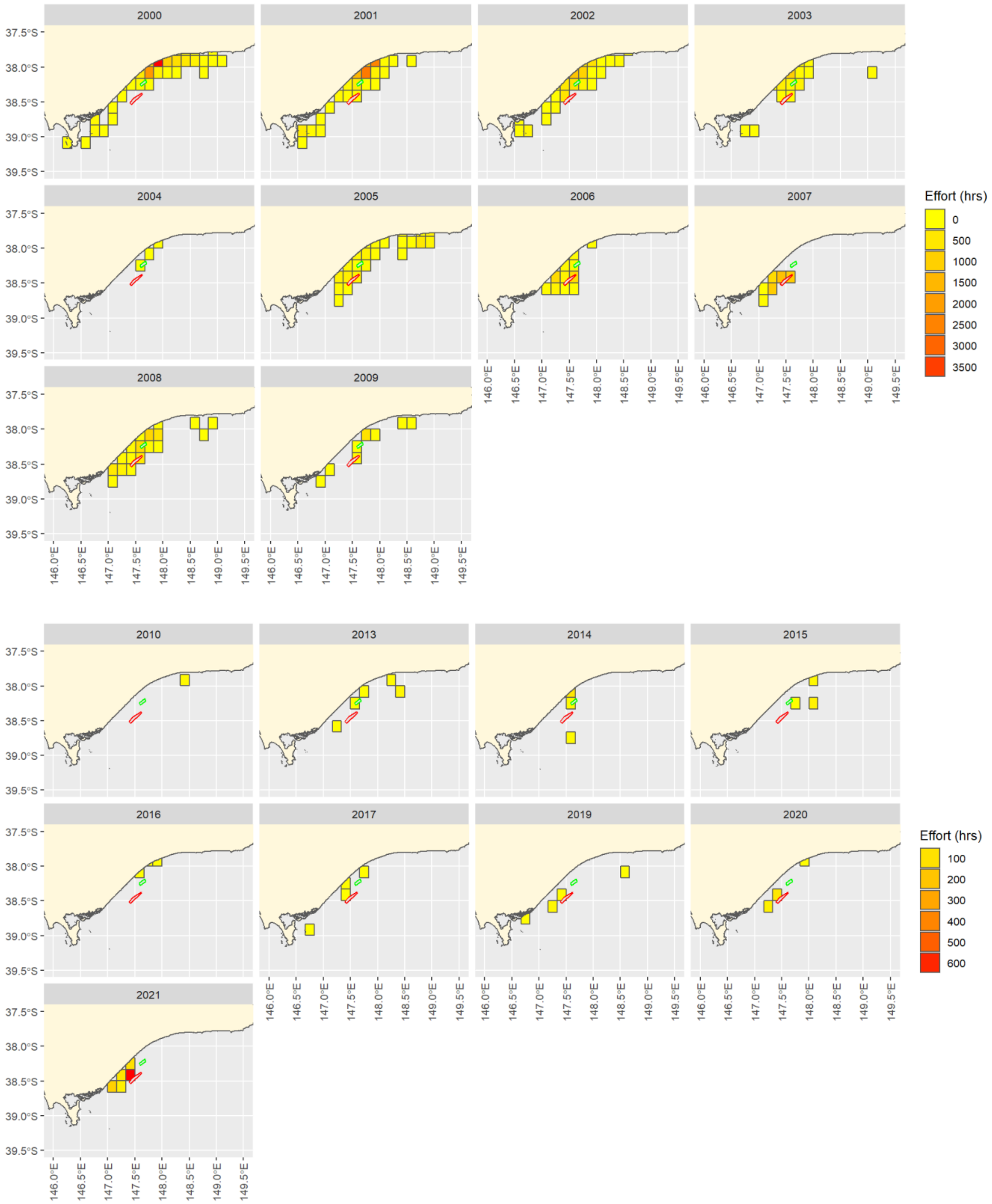

Figure 3. Time-series of fishing effort (hours) in the Victorian (Ocean) Scallop Fishery from 2000 to 2021. Locations of the 2017 pre-season (green) and 2021 pre-season (red) surveys are shown.

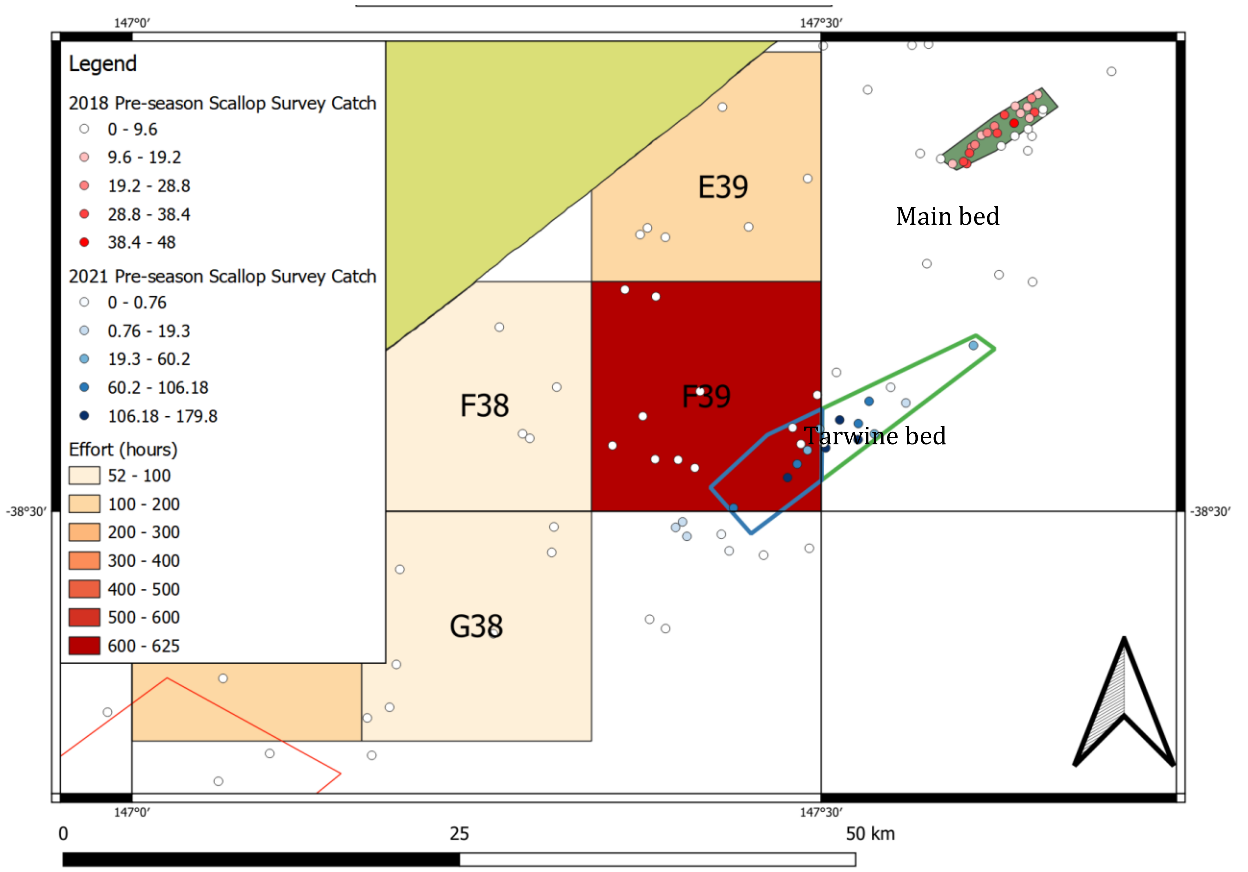

Figure 4. Tarwine and Main beds showing Commercial Scallop catches (kg / tow) from the 2018 pre-season and 2021 pre-season survey, commercial effort (hours per reporting grid cell) from the 2021 season. Labels show report grid cell names.

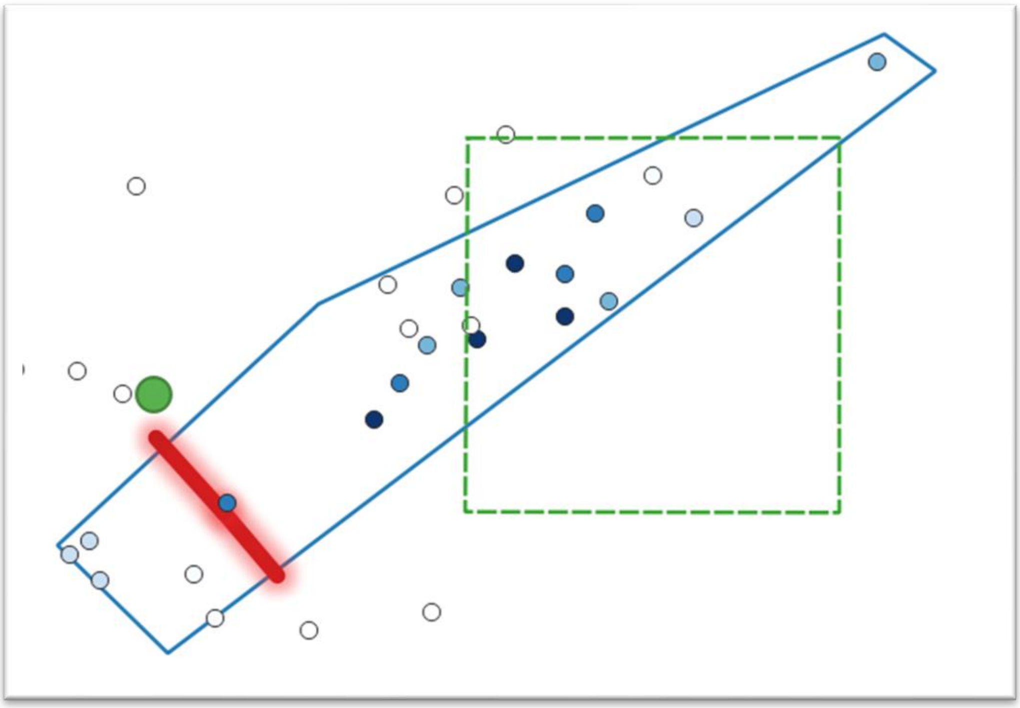

Figure 5. Tarwine bed showing Commercial Scallop catches from the 2021 pre-season survey, the 2021 fishery closure (green dashed polygon) and the line provided by industry below which scallop densities are low (red line).

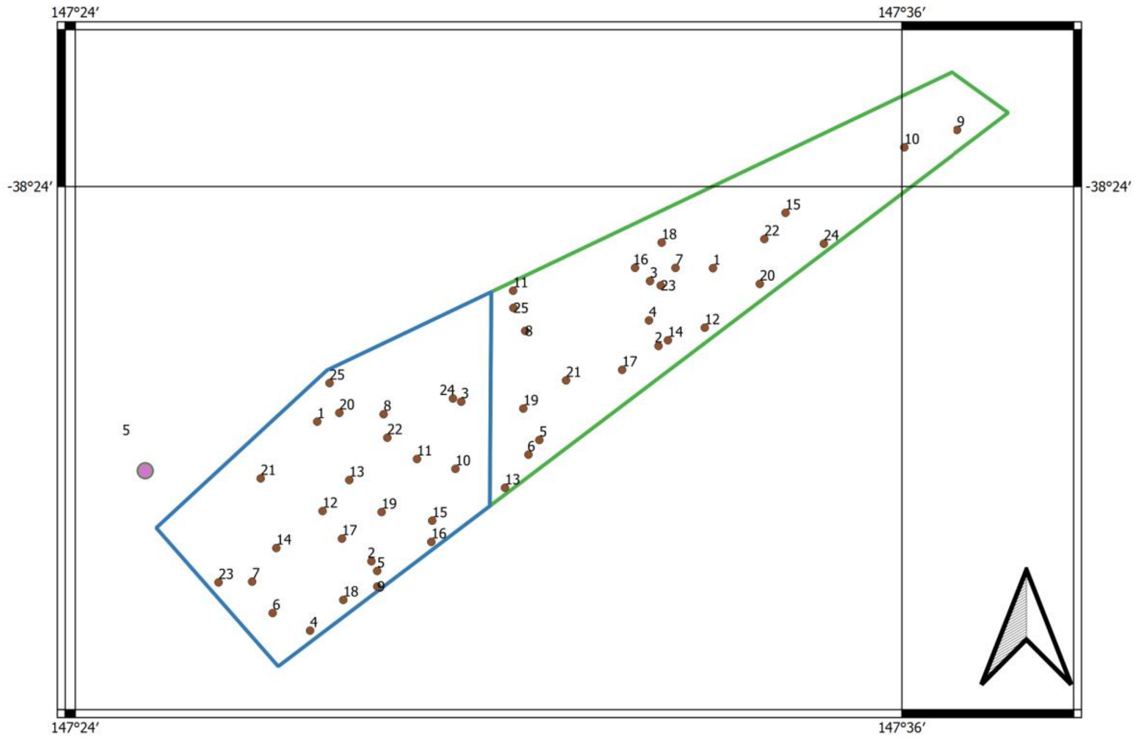

Figure 6. Tarwine bed split into eastern and western stratum and the south-western corner removed. Brown dots tow allocated tow locations and the purple dot is an exploratory mark provided by industry.

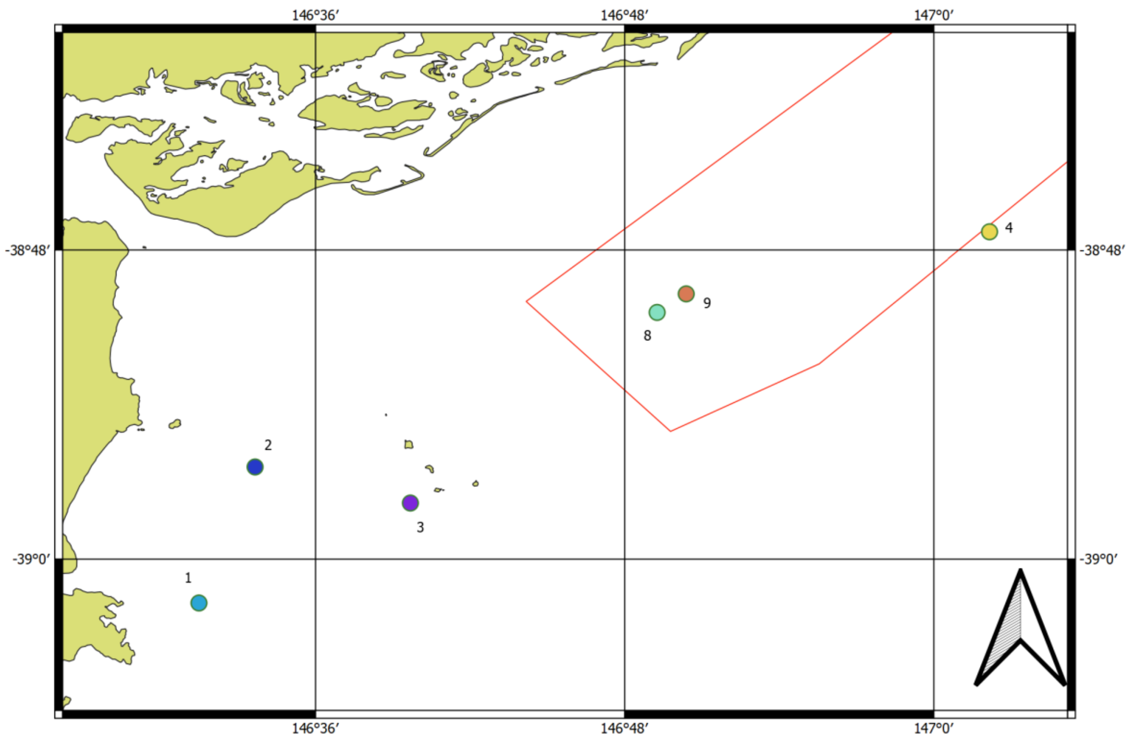

Figure 7. Exploratory marks provided by industry. The red polygon shows the Star of the South wind farm exploratory area.

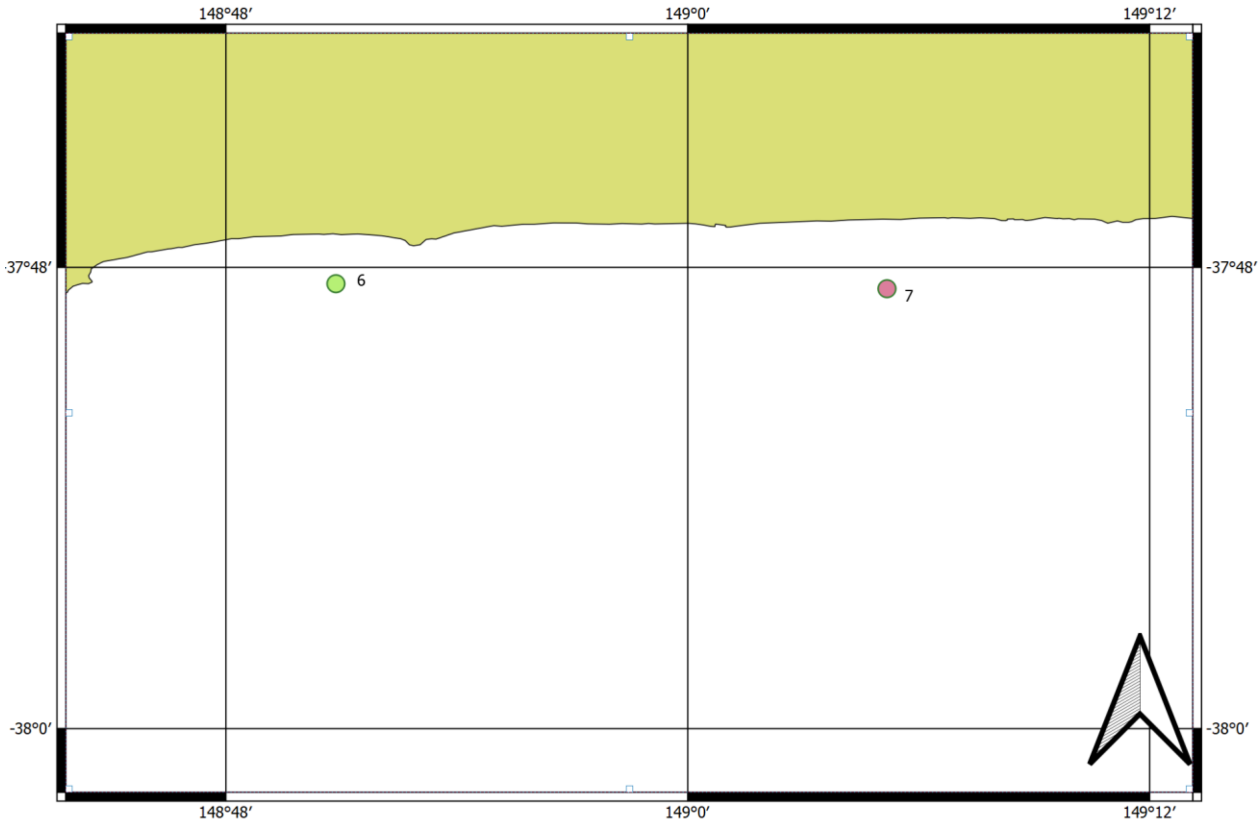

Figure 8. Exploratory marks provided by industry.

Table 1. Exploratory marks provided to the vessel.

Mark	Longitude	Latitude
1	146˚ 31.46	39˚ 01.71
2	146˚ 33.64	38˚ 56.43
3	146˚ 39.67	38˚ 57.83
4	147˚ 47.30	38˚ 47.30
5	147˚ 25.01	38˚ 28.13
6	148˚ 50.85	37˚ 48.433
7	149˚ 05.17	37˚ 48.56
8	146˚ 49.251	38˚ 50.43
9	146˚ 50.38	38˚ 49.71
MainBed	147˚ 38.410	38˚ 13.097

Sampling methods

Survey methods follow those of (Knuckey *et al.*, 2015), modified from those described in Harrington *et al.* (2009).

The survey vessel was selected from a pool of respondents to an expression of interest. Criteria used to evaluate vessel included safety, history of cooperation with management of the fishery, skipper experience in the fishery and in undertaking surveys, workspace and accommodation facilities and availability.

For each tow, estimates were made of weight of: total live scallop catch, dead shell and all bycatch by species / species group. Dead shell was separated into:

- Clappers (both valves still connected at the hinge)
- Old single (single valve – inside appears old and overgrown with epiphytes / epifauna)
- New single (single valve – inside appears new without any epiphytes / epifauna)

A random sample of at least 35 scallops (where available) was collected from each tow before they went through the tumbler (a device used to remove small bycatch and scallops from the sorted catch). The observer measured the length of those scallops using a Scielex ™ electronic measuring board. Either the first or last (or both) scallop from each tow measured using the measuring board was also measured by hand using digital callipers or a metal ruler. This was done to ensure accuracy and consistency of the measuring board throughout the survey. The sample weight of scallops measured was also recorded.

From every fifth tow, an additional 10 random scallops were taken before passing through the tumbler to collect biological information. First, the whole scallop was weighed, then split and the gonad condition staged according to the scale based on Semmens, *et al.* (2019) (Table 12). Adductor meat and gonad were removed from the shell and weighed together to calculate number of meats per kg. Shell height and width were also measured for morphometric analyses.

Data analysis

All data processing and analysis was undertaken in R (R Core Team, 2021), and density plots were created using the package QGIS (version 2.18.15). Estimates of biomass followed the methods of Semmens and Jones (2014).

Biomass

The internal widths of the dredges used during the survey were measured in accordance with Semmens and Jones (2014). Dredge width used by the Northern Star was 4.02 m. A dredge efficiency of 33% was assumed (see Harrington *et al*. 2008 for origin of the 33%).

Swept area (S) of each tow was calculated as follows:

$$S = L \times W$$

Where L is the tow distance (m) and W is the width of the dredge (m). Tow distance was calculated from the straight-line distance between start and end tow positions for most tows. In two cases the GPS fix was lost, and so distance was calculated from the vessel speed and tow duration.

Scallop catch in each tow ($C^{standardised}$ in kg/1000 m^2) was calculated as follows:

$C^{standardised} = (C/S) \times 1000$

Where C is the estimated catch in a tow (kg).

Assuming a 33% dredge efficiency, biomass (B) in tonnes and 95% confidence limits (CL) were estimated for each stratum (bed) as follows:

B = meanD × A × 3.03 / 1000

Upper 95% CL= ((meanD + (t_{n-1} × SE_{meanD})) × A) × 3.03 / 1000

Lower 95% CL= ((meanD - (t_{n-1} × SE_{meanD})) × A) × 3.03 / 1000

Where meanD is the mean density (kg) of scallops per m^2 swept, t_{n-1} is the t –value for the number of tows (n) -1, SE_{meanD} is the standard error of meanD and A is the total stratum area (m^2). The area of each bed was calculated using the package QGIS (version 3.10.10).

Biomass and upper and lower 95% CL of scallops greater than 80 mm were calculated as follows:

$B_{>80mm}$ = B × (1-discard rate)

Upper 95% $CL_{>80mm}$ = Upper 95% CL × (1-discard rate)

Lower 95% $CL_{>80mm}$ = Lower 95% CL × (1-discard rate)

where the discard rate was calculated using catch weighted length frequencies converted to weight.

An estimate of density in individuals per square metre (*I*) was obtained as follows

$$I = \sum_{len} WLf \,/\, S$$

Where *WLf* is the weighted length frequency for each length class *len*, and *S* is the swept area (m^2).

All densities (kg / m^2 and individuals per m^2) reported have been adjusted for the 33% assumed dredge efficiency.

Biological measurements

Length-weight relationships were calculated for each stratum separately, and the parameters of the relationship are provided in the results. The length-weight relationship was applied to catch-weighted size frequencies to calculate the discard rate at 80 mm. The discard rate was used in calculations of biomass of scallops greater than 80 mm. Number of meats per kg was calculated separately for each bed by dividing 1000 by the mean meat and gonad weight in grams.

Quality Assurance

The survey was undertaken following Standard Operating Procedures. All tow and scallop catch data were recorded in ORLAC Dynamic Data Logger (DDL), which contains quality assurance protocols including automatic data capture (time, date and position), field restrictions, range checks, mandatory fields and lookup tables. These data are maintained in the ORLAC Dynamic Data Manager (DDM) database on a cloud-based server from which data are extracted for analyses. Data were manually error-checked against data sheets. Analyses were undertaken using R (R Core Team, 2021), and a subset of outputs were reproduced and compared using an alternative software package. Scallops were measured using Scielex™ electronic measuring boards, or callipers in the event of measuring board failure. The first or last (or both) scallop from each tow was measured by both the measuring board and by hand using either digital callipers or a metal ruler. This was done to ensure accuracy and consistency of the measuring board throughout the survey.

Results and their interpretations and conclusions were discussed amongst the research team, and draft reports were reviewed by co-authors and VFA managers. Where required, comments were addressed in preparation of the final report.

Results

Exploratory tows

Exploratory and survey tows were undertaken during two trips that took place over 17/12/2021 to 19/12/2921 and 20/12/2021 to 21/12/2021 (Table 2).

A total of 38 exploratory tows were undertaken on or around the exploratory marks the vessel was asked to fish (Figure 9, Figure 10, Figure 11 and Table 16). Notes made for each exploratory tow are shown in Table 3. Exploratory marks fished near Wilsons Promontory found no scallops, however one scallop was caught between marks 1 and 2 and lots of dead shell was caught at mark 3. Catches of up to 73 kg of Commercial Scallops were caught around marks 8 and 9, however catches were variable with some tows having no scallops. It was decided that it was worth marking a bed in this area to survey. The bed, called the Clonmel bed, will be discussed in the next section. No scallops were caught at marks 4, 5 or MainBed. Exploratory tows were undertaken west of marks 6 and 7 with no scallops caught. One scallop was caught at mark 6, but none were caught between there and mark 7.

Table 2. Trip summaries showing start and end times and dates and number of survey tows.

Trip	Start date	Start time	End date	End time	Number of valid survey tows
1	17/12/2021	17:12:06	19/12/2021	16:48:32	34
2	20/12/2021	05:58:12	21/12/2021	15:31:08	19
Total					53

Table 3. Notes made on exploratory marks.

Mark	Notes
1	No scallops, just seaweed.
2	No scallops, pinned up in reef.
3	Lots of dead shell.
4	No scallops.
5	No scallops.
6	1 scallop
7	No scallops on other tows from marks 6 to 7.
8	73 kg of scallops
9	60 kg of scallops
MainBed	No scallops.

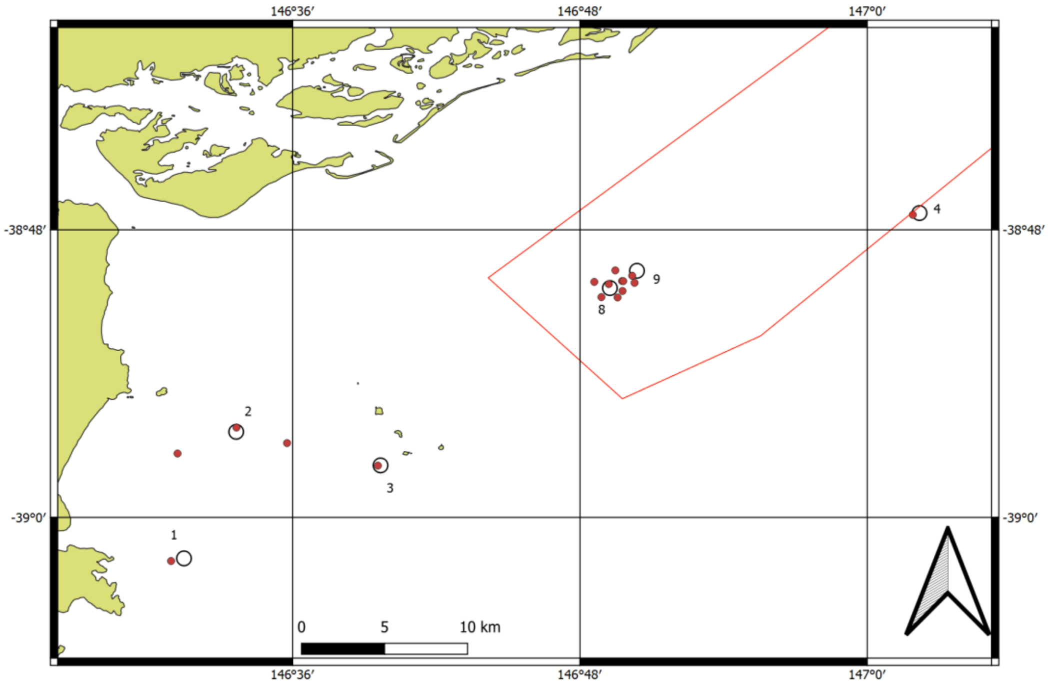

Figure 9. Exploratory marks provided by industry (open black dots) and exploratory tows undertaken showing start positions (green dots), path (blue line) and end positions (red dots). The red polygon shows the Star of the South wind farm exploratory area.

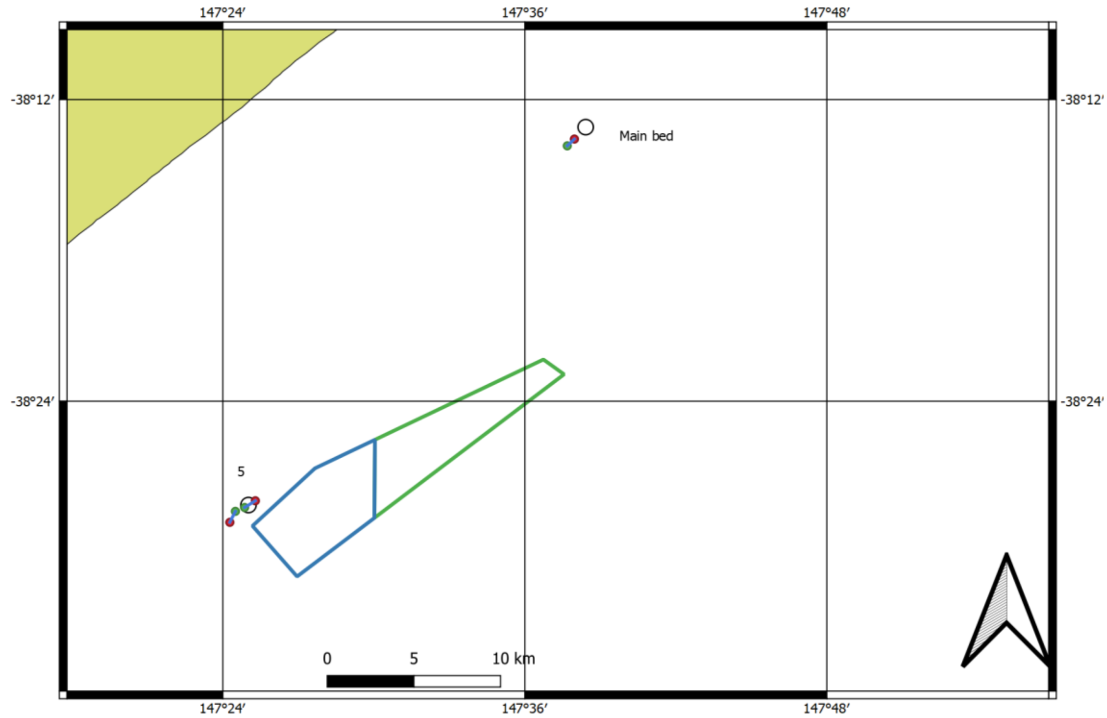

Figure 10. Exploratory marks provided by industry (open black dots) and exploratory tows undertaken showing start positions (green dots), path (blue line) and end positions (red dots). Tarwine East (green polygon) and Tarwine West (blue polygon) are also shown.

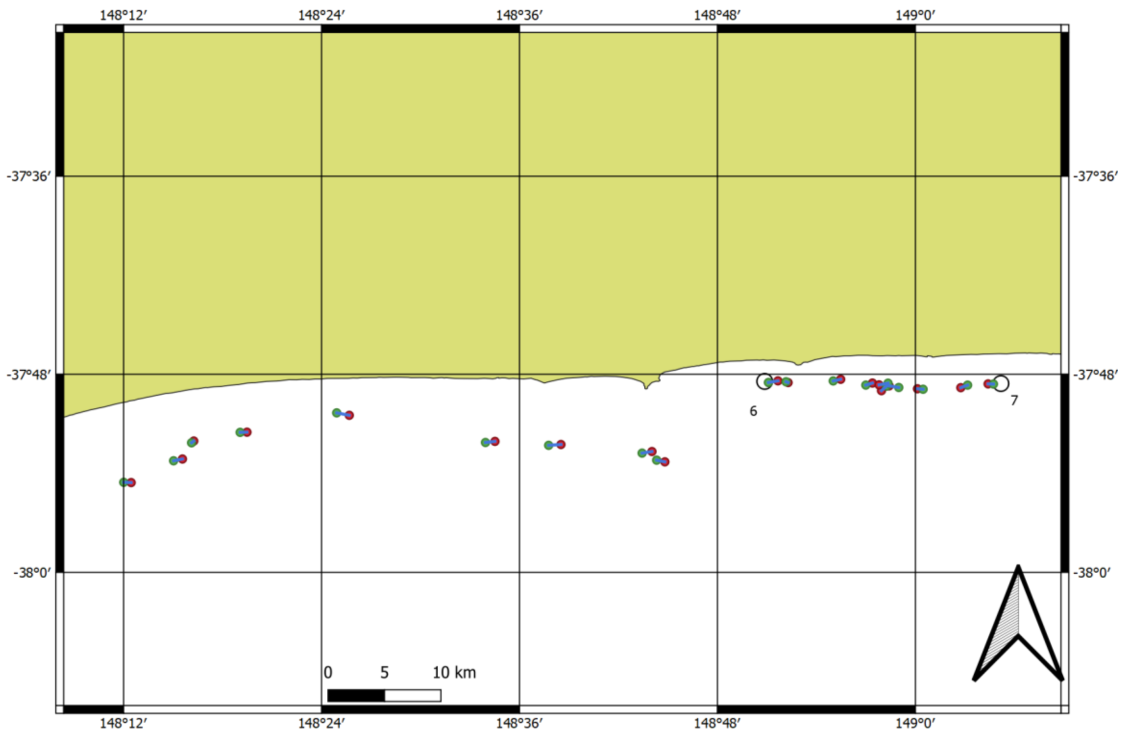

Figure 11. Exploratory marks provided by industry (open black dots) and exploratory tows undertaken showing start positions (green dots) and end positions (red dots).

Biomass estimates

A bed around marks 8 and 9 was defined from exploratory fishing, and 15 primary (1-15) and 5 backup (15-20) tows randomly allocated (Figure 12). This bed was called the "Clonmel bed" and has a total area of 2.69 km^2 (Table 4). A total of 14 survey tows were undertaken on 18 December 2021 (Table 5), with tow number 8 dropped because it was within 10 m of tow 10 and not replaced because of time constraints. Mean densities of Commercial Scallops in survey tows were 74.5 kg/1000 km^2 and 1.13 individuals per m^2 and an estimated biomass of 200 t (95% confidence intervals CIs; 136–265 t). With 72.9% of Commercial Scallops greater than 80 mm length, estimated biomass greater than that size was 146 t (95%CI; 99–193 t) (Table 6). Medium to high densities of Commercial Scallops were found throughout the bed, with some relatively low density tows in the north-east and south of the bed (Figure 13).

A total of 19 valid tows were undertaken in the Tarwine East stratum, which has an area of 40.23 km^2 (Table 4, Table 5). One tow that was undertaken (of the 20 allocated) was later declared invalid because it was undertaken in the wrong position. Commercial Scallops in survey tows had mean densities of 123.4 kg/1000 km^2 and 1.53 individuals per m^2 and a biomass of 4,966 t (95%CI; 3,203–6,729 t). Using the 98.0% of Commercial Scallops greater than 80 mm, estimated biomass greater than 80 mm was 4,867 (95%CI; 3,139–6,594 t) (Table 6). Two tows undertaken in the Tarwine East stratum contained no Commercial Scallops. High, medium and low densities were observed throughout the areas surveyed (Figure 13).

All 20 tows undertaken in the 37.66 km^2 Tarwine West bed were valid (Table 4, Table 5). Densities of Commercial Scallops were 105 kg/1000 km^2 and 1.14 individuals per m^2. More than 98% of Commercial Scallops were greater than 80 mm length resulting in and estimated biomass greater than 80 mm of 3,892 t (95%CI; 2,588–5,197 t) (Table 6). Some very low density tows were observed, one in the south of the bed and another in the north (Figure 13). High, medium and low densities were observed throughout the areas surveyed.

Length frequency

Mean length of Commercial Scallops at Clonmel was 85.2 mm compared to 95.9 mm at Tarwine East and 96.5 mm at Tarwine West (Table 7). The sizes of scallops at Clonmel were relatively evenly distributed across a wide range of lengths, with no obvious mode (Figure 14). Length frequencies from the two Tarwine strata were similar to each other, differing slightly in that Tarwine West had more Commercial Scallops 89–93 mm, while Tarwine East has more in the 85–88 mm size range. Mean number of meats per kg were 90.3, 90.7 and 86.6 per 1 kg at Tarwine East, Tarwine West and Clonmel respectively (Table 7). Distribution of meat and gonad weights is shown in Figure 15.

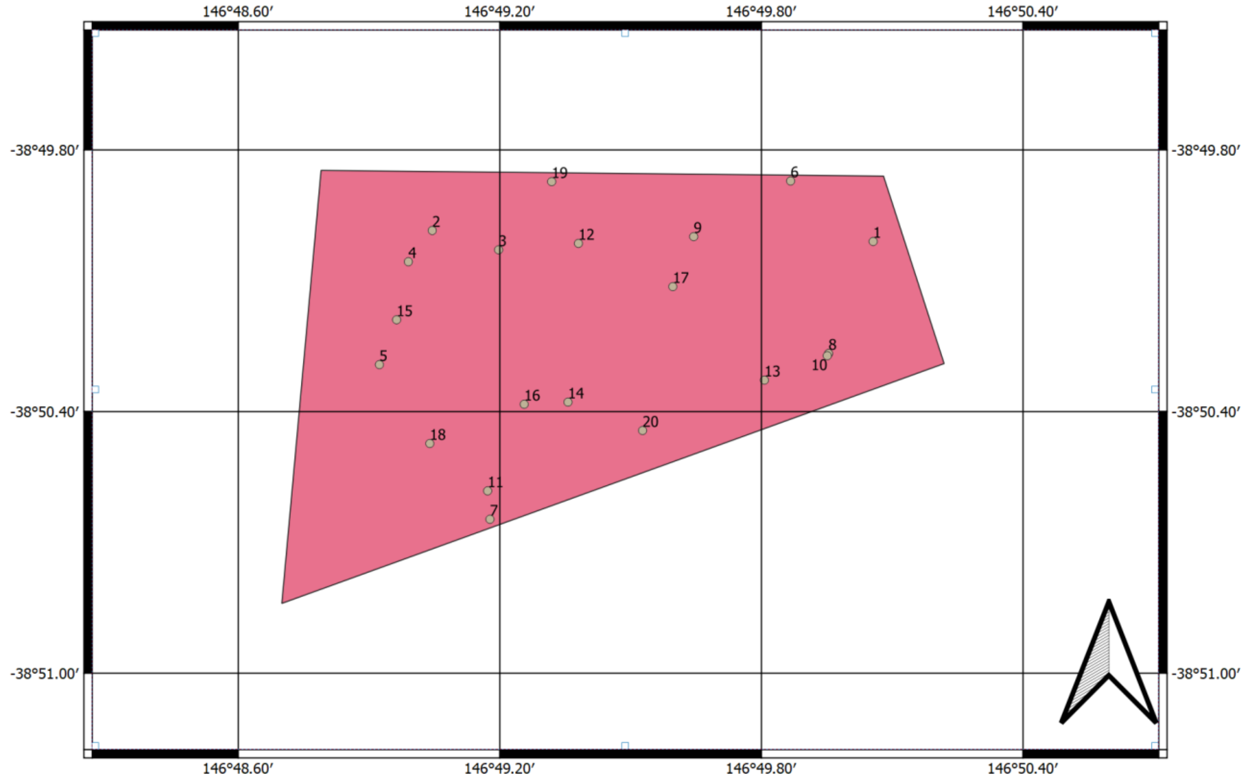

Figure 12. The Clonmel Bed showing randomly allocated tow locations provided to the vessel. Tow numbers 1 to 15 were primary tows and 16 to 20 backup tows.

Table 4. Total area of each bed surveyed.

Bed	Total Area (km^2)
Tarwine East	40.23
Tarwine West	37.66
Clonmel	2.69

Table 5. Biomass estimates, 95% confidence limits and number of tows included in analyses. Note that both densities have been adjusted for a 33% assumed dredge efficiency.

	Tarwine East	Tarwine West	Clonmel		Total
Number of tows	19	20	14		53
Mean density (kg/1000 m^2)	123.4	105.0	74.5		
Standard deviation (kg/1000 m^2)	90.9	75.2	41.7		
Lower 95% CL (t)	3203	2630	136		5968
Estimated biomass (t)	4966	3955	200		9121
Upper 95% CL (t)	6729	5281	265		12275
Density (ind/m^2)	1.53	1.14	1.13		

Table 6. Percent weight of scallops > 80 mm (catch weighted by weight), and biomass estimates 95% confidence limits for scallops greater than 80 mm.

	Tarwine East	Tarwine West	Clonmel		Total
% weight > 80 mm	98.0	98.4	72.8		
Lower 95% CL (t)	3139	2588	99		5826
Estimated Biomass (t)	4867	3892	146		8904
Upper 95% CL (t)	6594	5197	193		11984

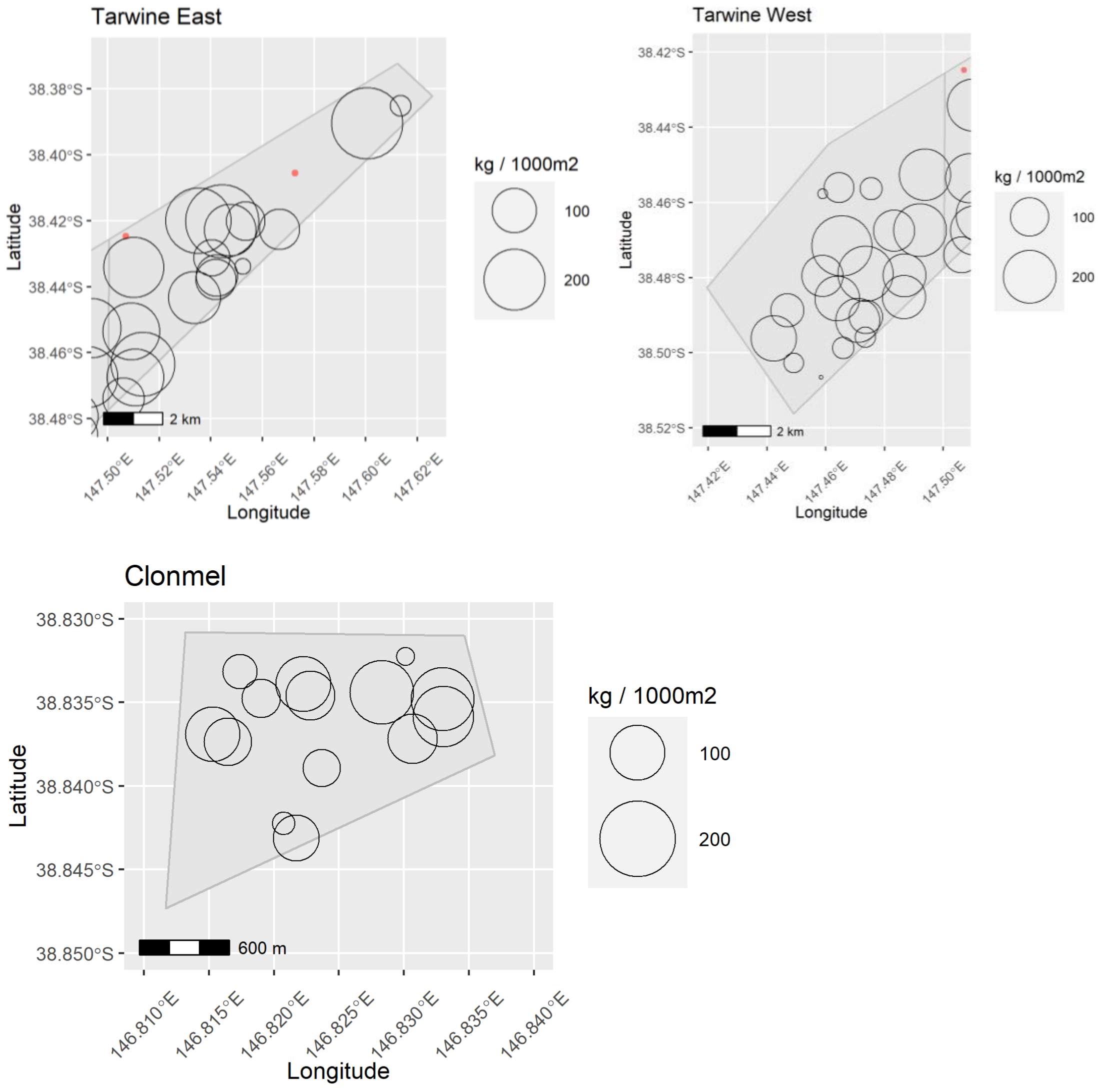

Figure 13. Scallop density (kg / 1000 m^2) within each bed. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red dots denote zero catches.

Table 7. Number of length measurements (N), median, mean and standard error (SE) of scallops measured, and % of scallops measured (catch weighted by weight) less than and greater than 80 mm and mean number of meats per kg of scallops greater than 80 mm from each bed.

Trip	Tarwine East	Tarwine West	Clonmel
N	622.0	680.0	556.0
Median length (mm)	95.1	95.8	83.8
Mean length (mm)	95.9	96.5	85.2
SE length (mm)	0.3	0.3	0.5
% <80 mm	2.0	1.6	27.2
% >80 mm	98.0	98.4	72.8
Mean meats per kg	90.3	90.7	86.6

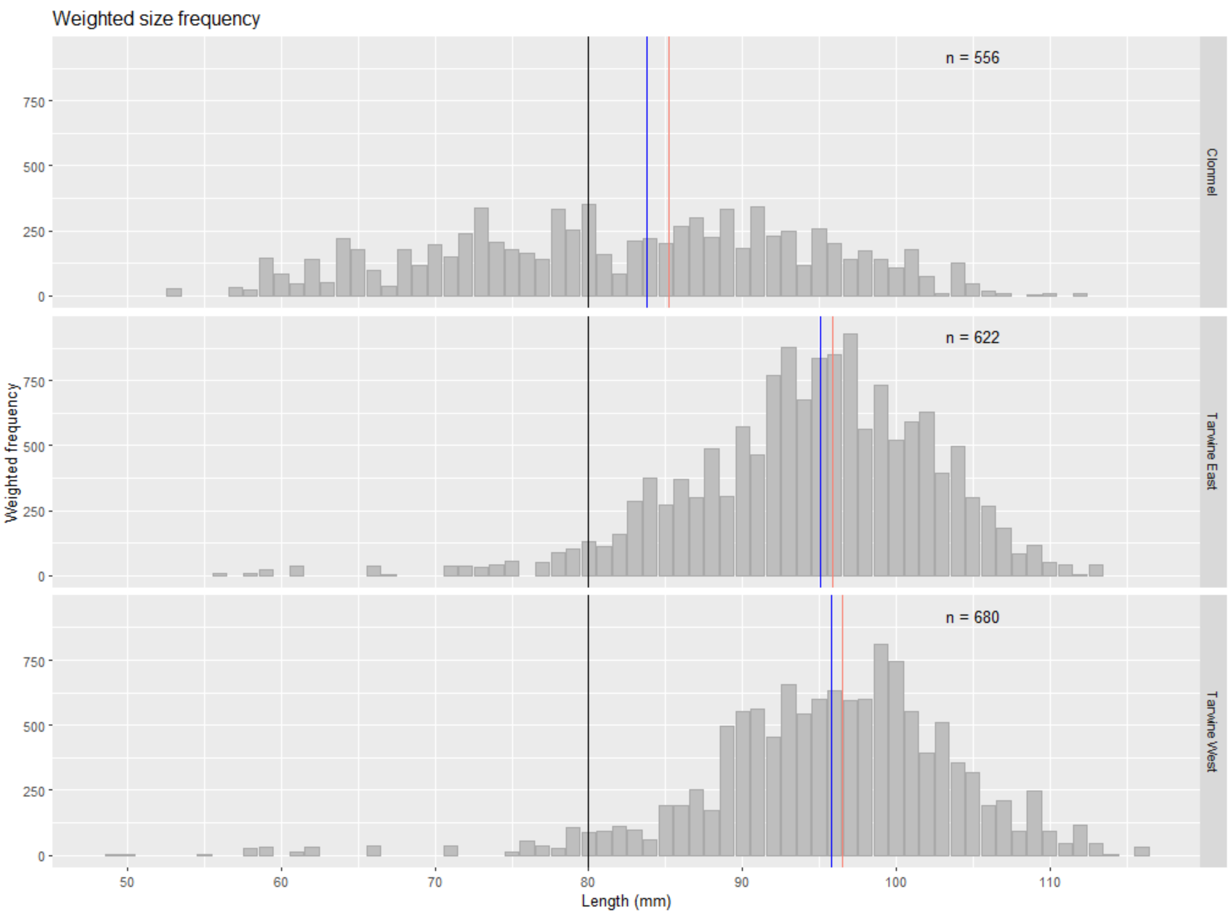

Figure 14. Catch weighted size frequency from tows included in biomass estimates from each bed. The black vertical line is at 80 mm, blue line shows median length and orange line is the mean length.

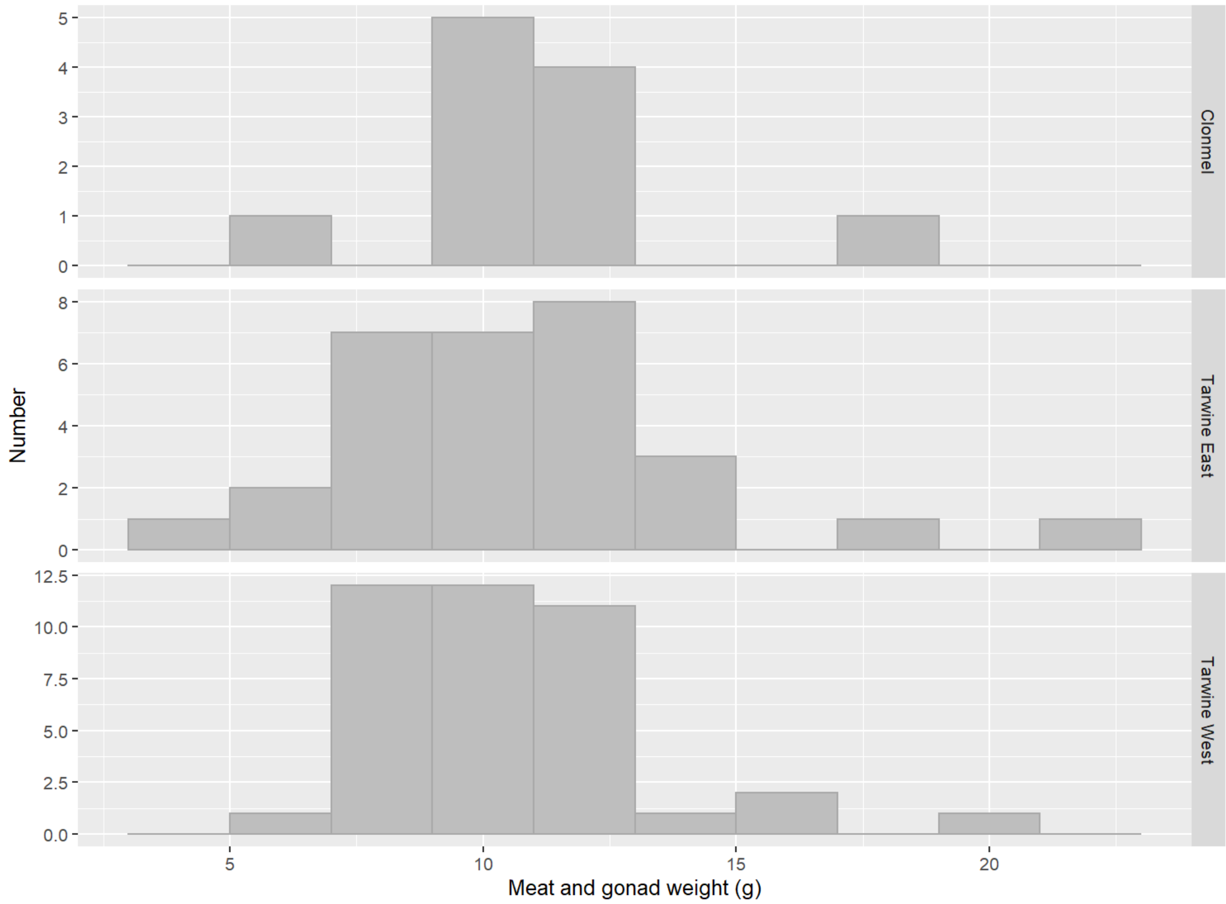

Figure 15. Frequency of combined meat and gonad weights of scallops >80 mm measured from each bed binned into 2 g weight categories.

Biological measurements

Comparison of length-weight regressions revealed that the interaction term was not significant (p>0.05), indicating that there was no detectable difference in slopes in the length-weight relationship between beds (Figure 16 A and Table 8). The p-value for the indicator variable (p<0.0001) suggests that there is a difference in intercepts, and that there are differences in length-weight relationships between beds. However, because of the small sample size and very small influence that the differences in intercepts make (at 80 mm there is a 1.4 gram maximum difference in weights calculated using parameters from each individual bed, and a maximum difference of 3.5 grams at 90 mm), data from beds were pooled in further calculations. Parameters of the length-weight relationships are shown in Table 8.

Morphometric measurements are plotted in Figure 16. Data from the different beds overlap and the only combinations of measurements with different slopes were height × width (p<0.05) and length × width (p<0.05). It appears that this difference is mostly influenced the much larger size range in the Tarwine West samples compared to the Tarwine East samples (Figure 16)

The majority of scallops sampled were at stage 2 and a small proportion of stage 1 scallops were in samples from the two Tarwine beds (Figure 17).

Table 8. Number of scallops retained for biological sampling, and parameter estimates for length-weight relationships.

Stratum	N	a	b	Adjusted R^2
Tarwine East	33	-6.906	2.454	0.877
Tarwine West	50	-7.594	2.607	0.964
Clonmel	19	-8.486	2.817	0.943
Combined	102	-7.537	2.593	0.948

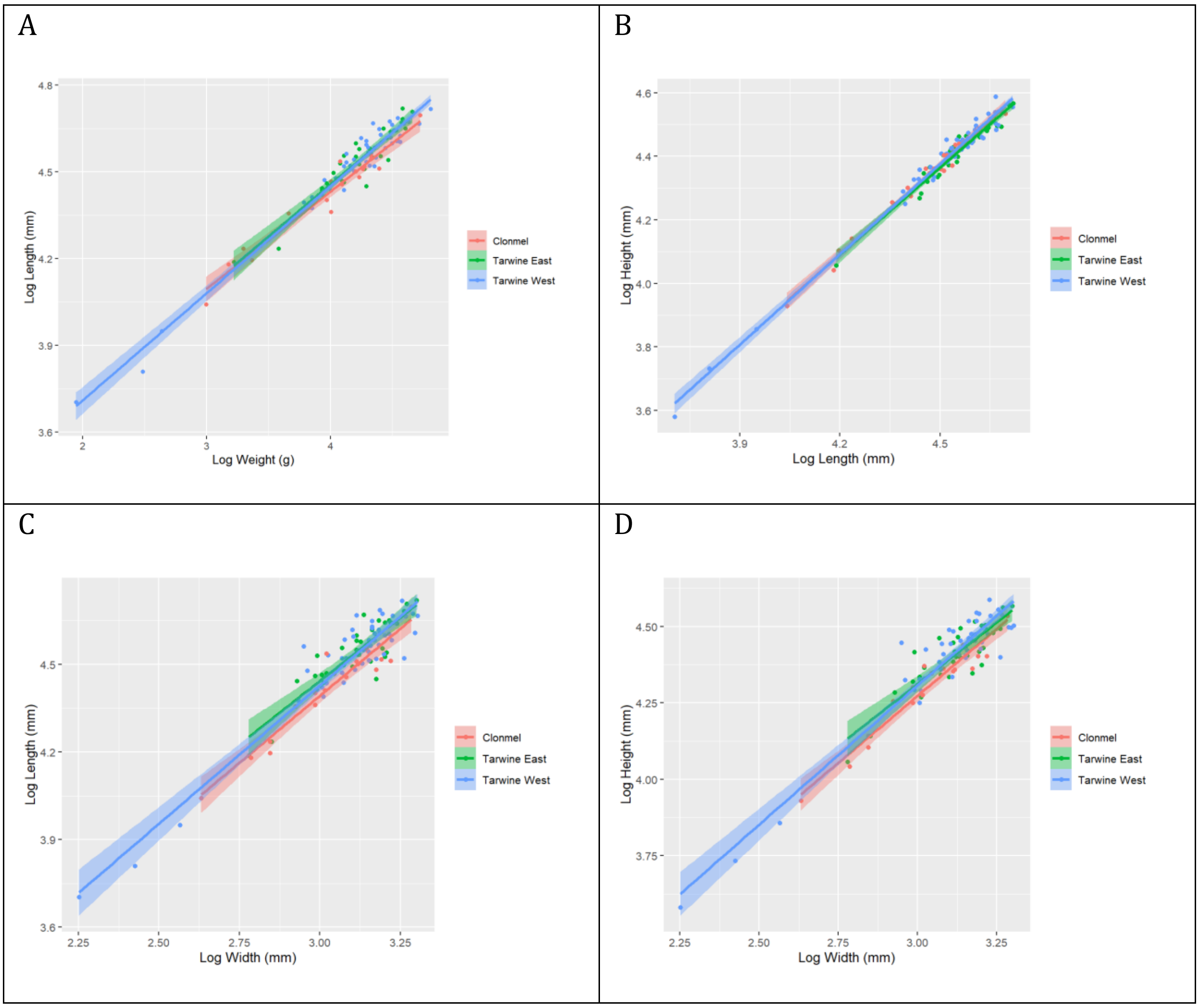

Figure 16. Log transformed A) length and weight, B) length and height, C) length and width and D) height and width from each bed.

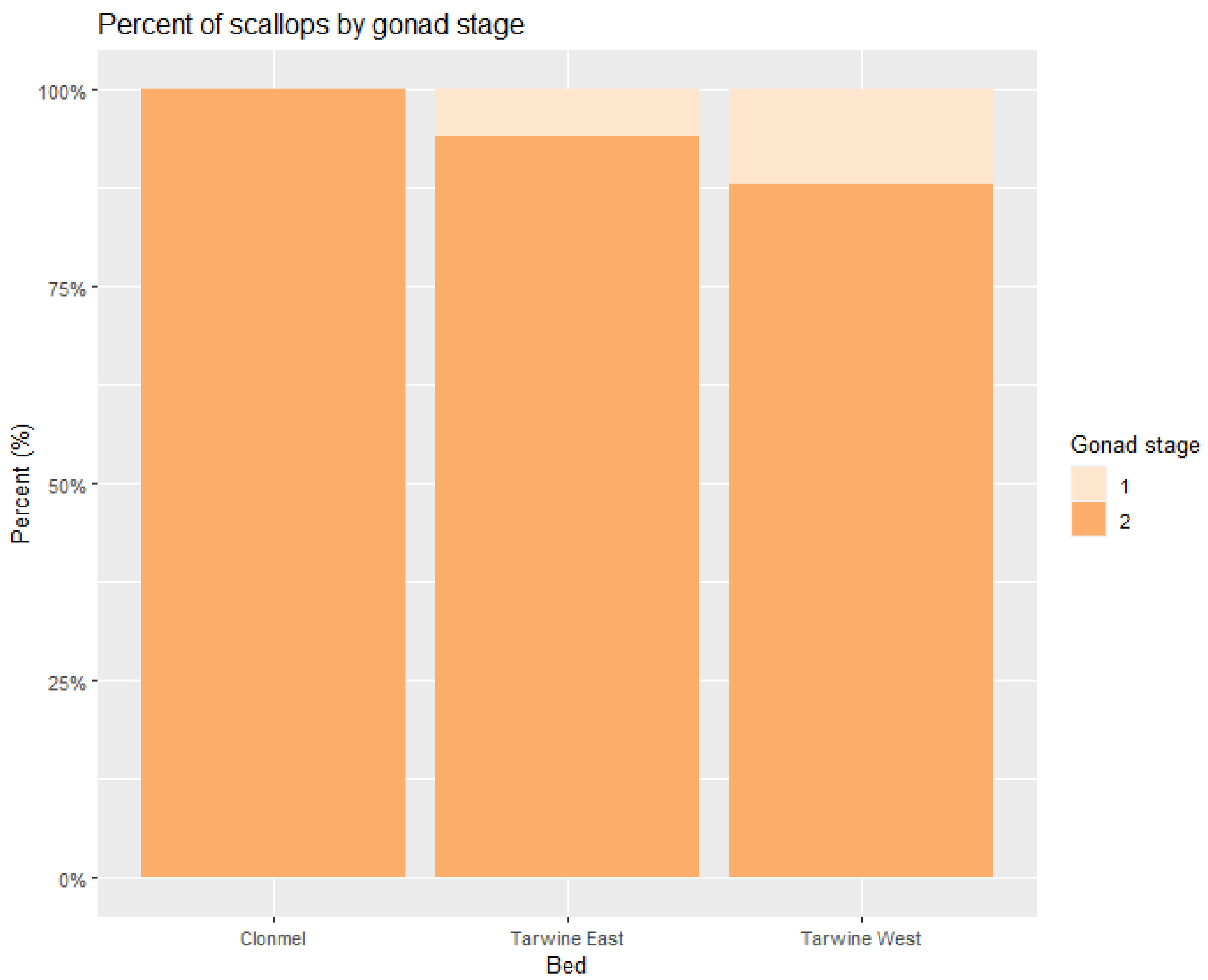

Figure 17. Percent of scallops at each stage from each bed based on macroscopic staging criteria shown in Appendix 2.

Survey catch composition

Species composition of all survey catches is shown in Table 13. Survey catches at Tarwine East and Tarwine West were dominated by Old Single Shell (1,565 kg and 2,177 kg) followed by live Commercial Scallops (1292.6 kg and 1,116.5 kg) and New Single shell (501 kg and 634 kg) (Table 9). Catch composition was very different at Clonmel, dominated by benthos (2,150 kg), sponge (911 kg) and Commercial Scallops (560 kg). Percent composition of scallops and scallop shell also reveals higher proportions of old single shell at the two Tarwine beds than at Clonmel (Figure 18).

The survey caught two species of interest. One Blue-Ringed Octopus was caught at Tarwine West and released alive and one Potbelly Seahorse at Tarwine East and released alive in a weak state.

Table 9. Survey catch (kg) of scallops and other main species by stratum. "U" denotes undifferentiated species. Catch of all species shown in Table 13.

Species	Tarwine East	Tarwine West	Clonmel		Total
Commercial Scallop	1292.6	1116.5	560		2969.1
New Single	501	634	134		1269
Old Single	1565	2177	195		3937
Clappers	2.3	6.6	0.4		9.3
Benthos		285	2150		2435
Sponge (U)	368	520	911		1799
Shell	334	430			764
Ascidian (U)	165	1.1			166.1
Dog Whelk	13	13.4	5.3		31.7
Other species	44.4	70.1	36.5	0	151
Total	**4285.3**	**5253.7**	**3992.2**	**0**	**13531.2**

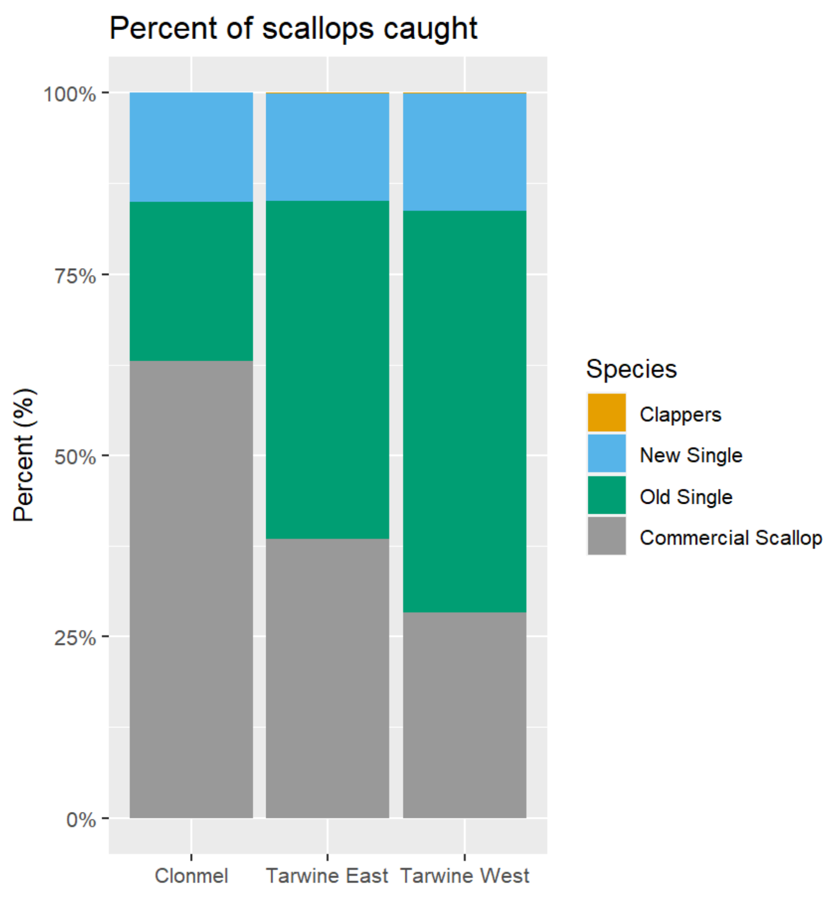

Figure 18. Percent composition of clappers, live scallop, new single and old single shell from each strata from the 2022 pre-season survey.

Comparison of the 2021 2022 pre-season survey results

To aid in the management decisions for the 2022 season, we have provided a comparison of the current 2022 pre-season survey results to those of the previous 2021 pre-season survey results. This information assists in assessing the impact on Tarwine West (where the majority of fishing occurred during 2021), compared to Tarwin East, which was closed to commercial fishing.

Length frequencies from the Tarwine beds from the 2021 pre-season (retrospectively assigned to Tarwine East and Tarwine West) and 2022 pre-season surveys (combined East and West) are shown in Figure 19. The catch composition of live scallop, clappers, new single and old single shell is provided in Figure 20.

A comparison of the biomass estimates and associated uncertainties from the 2021 pre-season (entire Tarwine bed) and 2022 pre-season surveys (combined East and West Tarwine strata) is provided in Table 10.

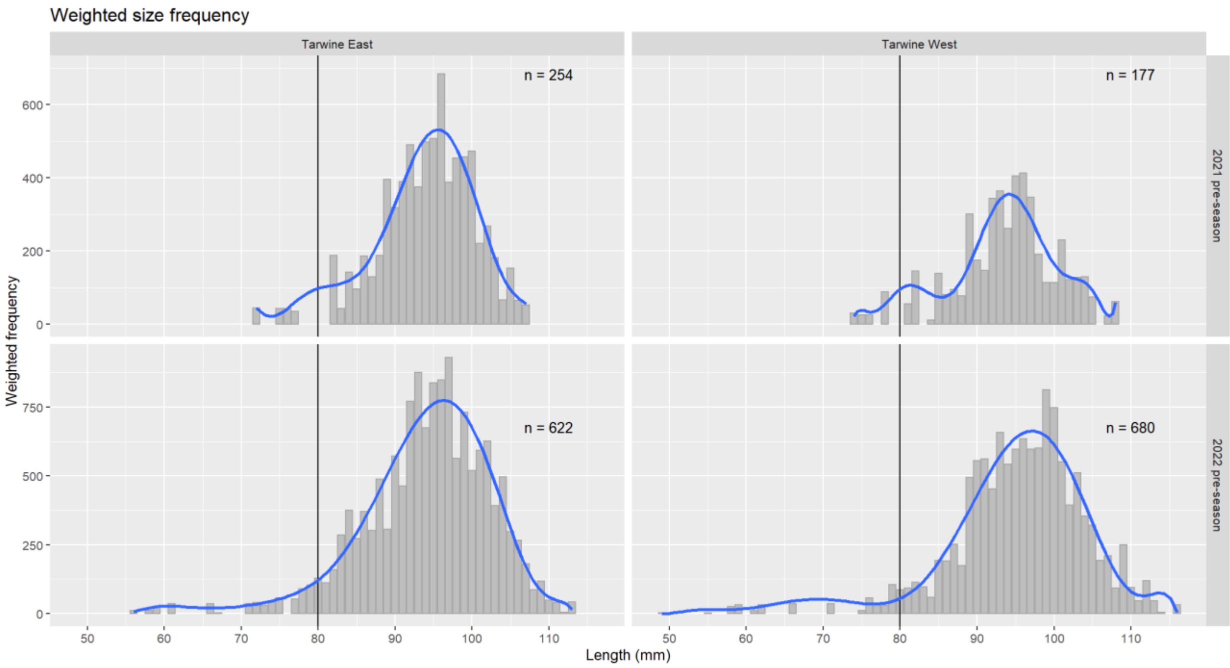

Figure 19. Comparison of the length frequency distributions from the Tarwine East and Tarwine West from the 2021 pre-season survey (top) and the 2022 pre-season survey (bottom). Note that the 2021 pre-survey length frequencies were retrospectively assigned to Tarwine East and Tarwine West, and that data from three tows in the south-west did not fall within the boundaries of the 2022 pre-season survey stratum and were omitted.

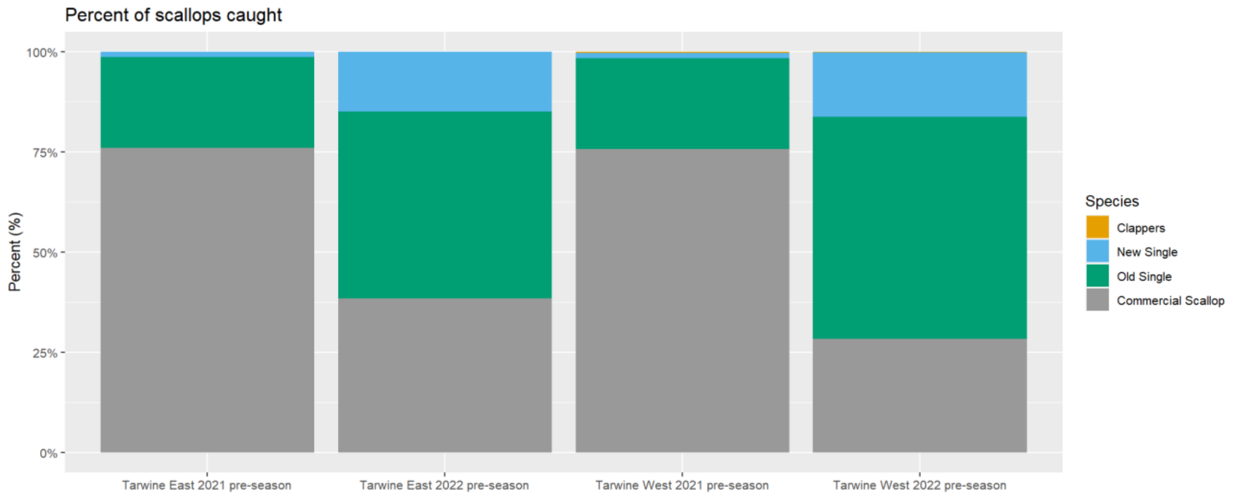

Figure 20. Percent composition of clappers, live scallop, new single and old single shell from Tarwine East and Tarwine West from the 2021 pre-season survey (retrospectively assigned to Tarwine East and Tarwine West – note that data from three tows in the south-west to not fall within the boundaries of the 2022 pre-season survey beds and so are omitted) and the Tarwine East and Tarwine West from the 2022 pre-season.

Table 10. Summary of main results from the 2021 pre-season survey and 2022 pre-season survey with the two Tarwine strata combined. Where results could not be combined, both are shown.

	2022 pre-season survey			2021 pre-season survey
	Clonmel	Tarwine East and West combined		Tarwine
Number of tows	14	39		20
Mean density (kg/1000 m^2)	74.5	123.4 and 105		91.0
Density (ind/m^2)	1.13	1.53 and 1.14		1.2
% weight > 80 mm	72.8	98 and 98.4		98.2
Estimated biomass (t) (95%CI)	200 (136–265)	8921 (5833–12010)		8010 (4706-12020)
Estimated biomass (t) >80 mm (95%CI)	146 (99–193)	8759 (5727–11791)		7876 (4326-11807)

Discussion

Survey beds for 2022 were chosen based on previous surveys, analysis of catch and effort data, information provided by Industry and exploratory fishing. Random stratified surveys were successfully undertaken in three strata across two scallop beds (Tarwine and Clonmel). In total, 53 valid, random survey tows were undertaken across the three strata, allowing biomass to be estimated for each.

The average biomass of Commercial Scallops greater than 80 mm was estimated to be 4,867 t at Tarwine East, 3,892 t at Tarwine West and 146 t Clonmel (Table 6). Total average biomass greater than 80 mm at all sites combined was 8,904 t. The percent of Commercial Scallops greater than 80 mm was 98-98.4% at the two Tarwine strata and 72.8% at Clonmel. Densities (individuals per m^2) ranged 1.13 at Clonmel to 1.53 at Tarwine East (Table 5). Total average biomass greater than 80 mm and the two Tarwine strata from the 2022 pre-season survey was 8,759 t compared to 7,876 at the Tarwine bed from the 2021 pre-season survey (Table 10). Density in individuals per m^2 from the 2021 pre-season survey (1.2) was similar the 2022 pre-season Tarwine West survey (1.12), but at Tarwine East (1.53).

Lengths measured at Clonmel were distributed over a wide size range indicating ongoing recruitment over several years. A tow within this bed was undertaken during the 2017/18 survey revealing a high density of scallops at 70.1 kg/1000 m^2 compared to the mean density of 74.5 kg/1000 m^2 from the Clonmel bed in the current survey.

Compared to the 2021 pre-season survey, the 2022 pre-season survey length distribution shifted to the right in both Tarwine strata, with a higher proportion of large Commercial Scallops caught in the current survey (Figure 19). It appears that there has been some level of recruitment into the fishery with an increase in 80–85 mm scallops, particularly in Tarwine East. There are also signs of larger numbers of smaller recruits <70 mm in the 2022 pre-season survey data. It should be noted that due to the mesh size used on the survey dredge, there is a bias in the size of scallops retained towards larger (>80 mm scallops).

The proportion of old single shell recorded from samples increased by more than 25% at both Tarwine strata since the 2021 pre-season survey (Figure 20), while the increased proportion of new single shell at each bed was similar (Figure 18). Large increases in the proportion of dead shell in the Bass Strait Central Zone Scallop Fishery are usually associated with a decrease in biomass. Examples can be found at the following beds in Appendix 2 of Koopman et al. (2021a):

- FI – biomass decreased from just over 6,000 t in 2015, to about 4,500 t and less than 1,500 t in the following two years. Over those years the percent of dead shell (mostly old single shell) increased from about 40% to 80% to about 95%. Concurrently, the modal length decreased from 94 mm to 91 mm and then 85 mm, and there was a clear decrease in the proportion of scallops greater than 95 mm. This bed was closed to fishing to some extent from 2015–2020.
- KI-BDE – biomass decreased from just under 15,000 t in 2018 to about 8,000 t in 2019. There was no survey in 2020 (at any bed), but biomass further decreased to about 2,000 t in 2021. The proportion of dead shell (mostly old single) increased from about 35% in

2018 to just over 50% the following year and about 90% in 2021. Modal size increased from 95 mm in 2018 to 99 mm in 2019, and the proportion of scallops>100 mm also increased. In 2021 the modal size was 87 mm, with a large reduction in the proportion of scallops>100 mm. This bed was closed to fishing from 2017 to 2020.

- KI-7 – biomass decreased from about 2,000 t in 2018 to about 800 t in 2019 and back up to nearly 1,500 t in 2021. The proportion of dead shell increased from about 57% in 2018 to about 90% the following year (mostly clappers) but decreased to about 35% in 2021. Modal length increased from 100 mm in 2018 to 102 mm the following year and then decreased to 76 mm in 2021. In 2021, only 14% of the biomass at that site was greater than 85 mm. This bed was closed to fishing in 2020, 2021.
- KI-9 – biomass decreased from just under 10,000 t in 2019 to 6,000 t in 2021. The proportion of dead shell increased from about 27% in 2019 to nearly 60% (mostly old single) in 2021. The modal length was 95 mm in 2019, and of the scallops greater than 85 mm in 2021 (there was a large number of 55–75 mm scallops), the modal length was 98 mm and there was a relatively large proportion of scallops greater than 105 mm. This bed was closed to fishing in 2021.

The above examples and preliminary analyses (unpublished) looking at patterns in proportion of scallops over different sizes to predict decreased biomass in the following year do not reveal any indicators that could be used to predict mass mortality. It is clear however, that an increase in dead shell is usually associated with a decline in biomass, but that a large decline in biomass does not necessarily lead to a large increase in the proportion of dead shell (e.g. the AB2-E bed in Koopman et al. (2021a)). Further, like the Tarwine bed, in between years where a biomass increase was found, at the KI-BDE bed in Koopman et al. (2021a) the proportion of dead shell also increased between 2017 and 2018.

Scallop densities on the Tarwine bed have increased over the past year in terms of both weight (kg per $1000m^2$) and number (individuals per m^2) (Table 10), likely reflecting somatic growth and recruitment to be bed respectively. The combination of these two factors appears to have resulted in an overall increase of the biomass of scallops on the Tarwine Bed, although there is high uncertainty surrounding the biomass estimates in both years.

Application of survey results to harvest strategy

The Victorian Ocean Scallop Fishery Harvest Strategy guides annual TACC-setting based on whether or not a fishery independent biomass survey is conducted, and the biomass and density of scallops in surveyed beds. Applying the results from this survey to the harvest strategy, the TACC can be set above the 135 t default TACC because a biomass survey was undertaken and a “viable scallop bed” was located. Each of the east and west strata of the Tarwine Bed could be considered a “viable scallop bed” under the harvest strategy with each “containing at least 1500 tonnes biomass (assuming 33% dredge efficiency) of high-density scallops above the minimum legal size”. This report provides information to assist managers in setting: fisheries closures to protect a portion of high-density scallops; and, a precautionary TACC for the 2022 season.

SAFS assessment

The Status of Australian Fish Stocks Reports (SAFS, https://www.fish.gov.au/) brings together available biological, catch and effort information to determine the status of Australia's key wild catch fish stocks. As of July 2018, SAFS summary information has been used to inform Australia's progress against UN Sustainable Development Goal 14.4.1 [1], proportion of fish stocks within biologically sustainable levels. The SAFS criteria against which Australian fish stocks are assessed are provided in Table 11.

We provide the following comments with regard to the results of the 2022 pre-season survey and the SAFS criteria.

- Historical catch and CPUE information would suggest the scallop stocks in coastal eastern Victorian waters (off Lakes Entrance) were heavily depleted during the 1970s – 2000s.
- A formal quantitative stock assessment was not undertaken at that time, so no quantitative depletion estimate is available for the population of Commercial Scallops along the Victorian coast.
- Exploratory, broad area fishery-independent surveys were conducted during 2009, 2012 and again in 2017, revealing only very low densities of scallops, negligible recruitment and no commercially viable scallop beds. This suggested that there had been virtually no recovery of the stock at that stage.
- Evidence of some recent recruitment and a potentially viable scallop bed prompted a survey of the "Tarwine Bed" south east of Lakes Entrance during 2020. At that time, this bed had commercially viable densities of large (>80mm) scallops and an estimated biomass of about 8,000 t of legal-sized scallops.
- Half of this bed (the 2022 pre-season survey Tarwine east stratum) was closed to commercial fishing and the other half (Tarwine west stratum) supported a commercial catch of ~630 t during the 2021 season (Jeavons, pers. comm.).
- The current 2022 pre-season survey supports that the Tarwine Bed (east and west strata combined) remains commercially viable, with about 9,000 t of legal-sized scallops.
- Other than the Tarwine Bed, there is little evidence of recovery of historical beds. The Clonmel bed shows only a low biomass.
- Thus, the stock appears to remain significantly depleted compared to historical levels, but there is some evidence of recovery in small and isolated patches.

The development of the SAFS process has been useful in providing a generic framework under which different fisheries jurisdictions can report the status of their fish stocks. There remain some difficulties, however, in its application to spatially and temporally patchy species (e.g. scallops and abalone). There is no doubt that scallop stocks off the Victorian coast are heavily depleted compared to historic levels, yet the SAFS "Depleted" description states "Current management is not adequate to recover the stock, or adequate management measures have been put in place but have not yet resulted in measurable improvement". The first part does not apply because the fishery has previously had a zero TACCs and is currently controlling catch through a TACC that is adequate to allow improvement. The second part is also not entirely

[1] https://www.sdgdata.gov.au/goals/life-below-water/14.4.1

applicable either, because recent surveys have shown a "measurable improvement" in the fishery.

In contrast to the "Depleted" classification, the SAFS "Recovering" classification states "Biomass (or proxy) is depleted and recruitment is impaired, but management measures are in place to promote stock recovery and recovery is occurring". There is no aspect of this description that is actually incorrect for the Victorian scallop stocks.

Based on the above, when assessed against the SAFS criteria, the Victorian coastal stock of scallops could be classified as "Recovering", albeit from a heavily depleted state.

Certainly, recent survey results of the Commonwealth BSCZSF scallop resource (effectively the same stock as that in coastal Victoria but outside state jurisdiction) show many (19) commercially viable beds spread over a wide spatial extent of Bass Strait (Koopman et al. 2021a). Commercially viable beds are developing and being discovered further north-east from Flinders Is, towards the historical Victorian beds.

Nevertheless, we would recommend highly precautionary management of the Tarwine Bed (including continued closure of Tarwine east) is essential until more widespread evidence of recovery across the spatial extent of the Victorian fishery is observed.

Table 11. SAFS assessment criteria.

	Stock status	Description	Potential implications for management of the stock
	Sustainable	Biomass (or proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (recruitment is not impaired) and for which fishing mortality (or proxy) is adequately controlled to avoid the stock becoming recruitment impaired (overfishing is not occurring).	Appropriate management is in place.
	Depleting	Biomass (or proxy) is not yet depleted and recruitment is not yet impaired, but fishing mortality (or proxy) is too high (overfishing is occurring) and moving the stock in the direction of becoming recruitment impaired.	Management is needed to reduce fishing mortality and ensure that the biomass does not become depleted.
	Recovering	Biomass (or proxy) is depleted and recruitment is impaired, but management measures are in place to promote stock recovery, and recovery is occurring.	Appropriate management is in place, and there is evidence that the biomass is recovering.
	Depleted	Biomass (or proxy) has been reduced through catch and/or non-fishing effects, such that recruitment is impaired. Current management is not adequate to recover the stock, or adequate management measures have been put in place but have not yet resulted in measurable improvements.	Management is needed to recover this stock; if adequate management measures are already in place, more time may be required for them to take effect.
	Undefined	Not enough information exists to determine stock status.	Data required to assess stock status are needed.
	Negligible	Catches are so low as to be considered negligible and inadequate information exists to determine stock status.	Assessment will not be conducted unless catches and information increase.

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Appendix 1 – Valid survey tow

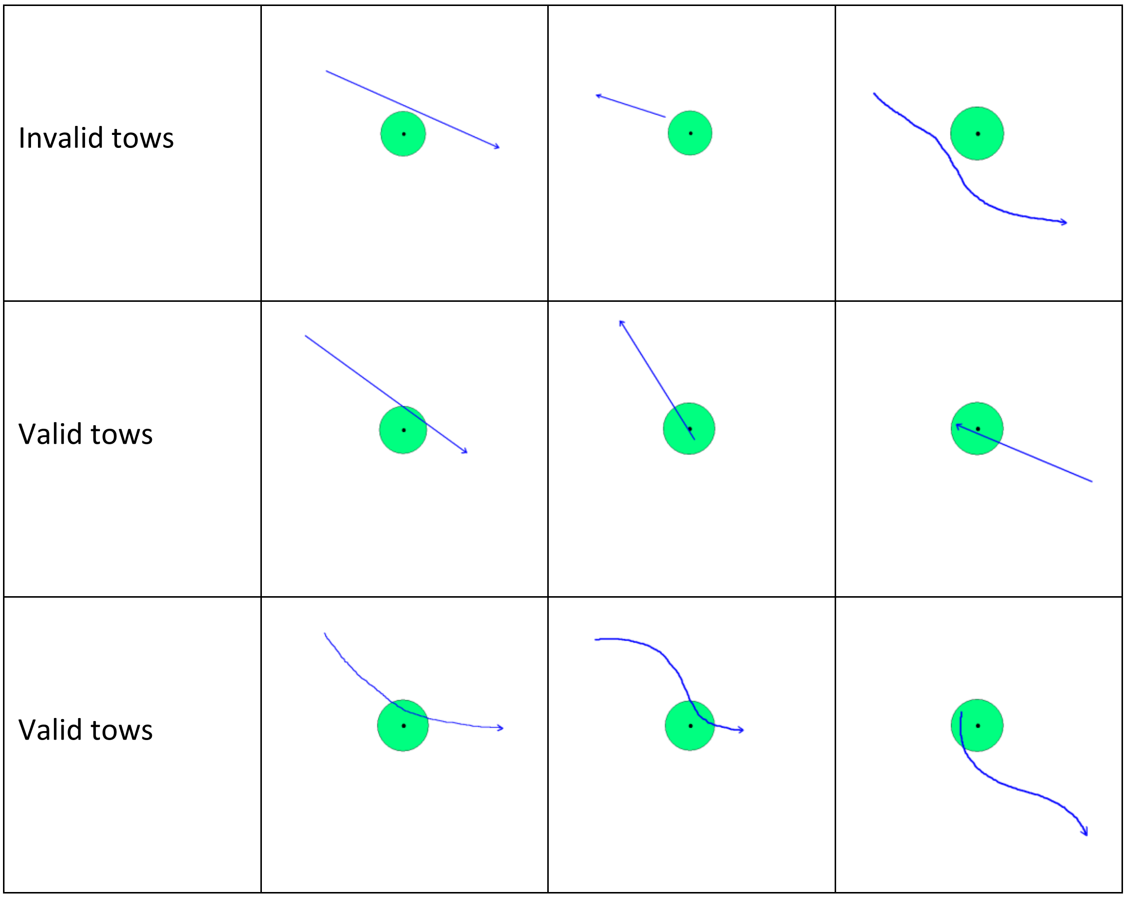
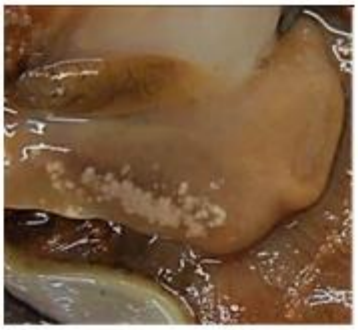


Figure 21. How to conduct a valid survey tow. Green circle is 100 m radius.

Appendix 2 – Gonad staging

Table 12. Gonad maturation scheme for macroscopic field staging of scallops (modified from Semmens *et al*., 2019).[2]

Stages	Description
1 Developing or spent	Gonad is small, thin, translucent, brownish colour. Intestinal loop usually visible. Ovarian and testicular tissues difficult to differentiate.  
2 Maturing or atretic (reabsorbing eggs as spawning is delayed)	Separate acini clearly visible, male (white) and female (orange) part of gonad distinguishable. Gonad increases in turgor (rigidity) and becomes less granular in appearance as acini begin to fill until ovarian tissue appears uniform in colour.  
3 Partially spawned	Gonad reduced in size compared to previous stage. Ovary appears mottled, presumably due to some acini being voided. Intestinal loop usually visible, ovarian tissue uniform in colour, but interspersed with isolated specs of translucent (void) acini. Testicular tissues turn paler in colour.  

[2] Semmens, J.M., Mendo, Jones, Keane, Leon, Ewing, Hartmann., Institute for Marine and Antarctic Studies, 2019, Determining when and where to fish: Linking scallop spawning, settlement, size and condition to collaborative spatial harvest and industry in-season management strategies, University of Tasmania, Hobart, June. CC BY 3.0

Appendix 3 – Shell measurements

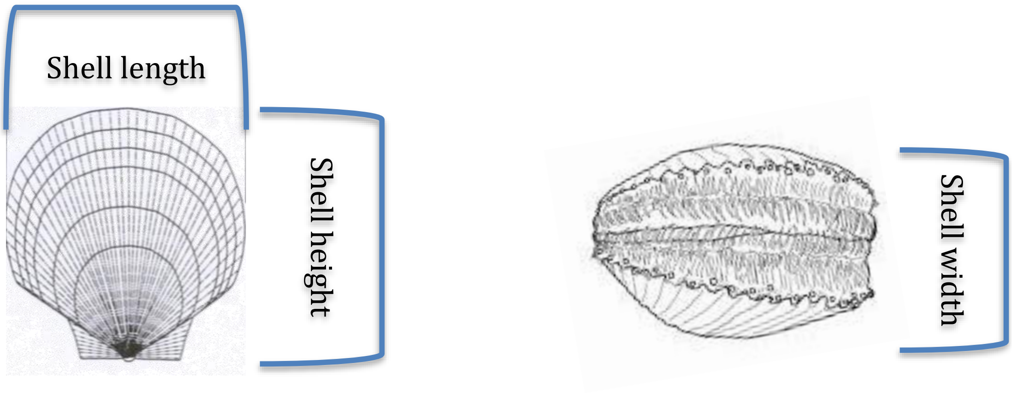


Figure 22. Shell diagram showing measurement of length, height and width used in this report.

Appendix 4 – Catch composition

Table 13. Catch (kg) of each species by stratum. "U" denoted undifferentiated species.

Species	Tarwine East	Tarwine West	Clonmel		Total
Commercial Scallop	1292.6	1116.5	560		2969.1
New Single	501	634	134		1269
Old Single	1565	2177	195		3937
Clappers	2.3	6.6	0.4		9.3
Benthos		285	2150		2435
Sponge (U)	368	520	911		1799
Shell	334	430			764
Ascidian (U)	165	1.1			166.1
Dog Whelk	13	13.4	5.3		31.7
Razor Clams	15.7	11.4	4.1		31.2
Oysters	3.5	10.7	6		20.2
Hard Coral	1	13	2		16
Sea Urchin (U)	1.7	13.1	0.1		14.9
Maori Octopus	1.1	7.3	4.9		13.3
Hermit Crabs (U)	8.7	3.5			12.2
Eleven-Arm Seastar	2		5.5		7.5
Doughboy Scallop	2.2	2.2	2		6.4
Spider Crab (U)	1.5		4.5		6
Octopus (U)	1.7	0.4	0.8		2.9
Seastar (U)	0.5	1	1.3		2.8
Seapen (U)		2.2			2.2
Venus Shells	0.3	0.8	0.7		1.8
Cockle 1	0.5	1.15			1.65
Spotted Flounder			1.6		1.6
Sparsely-Spotted Stingaree	0.7		0.5		1.2
Speckled Stargazer	1.2				1.2
Shark Egg (U)	0.1	0.2	0.8		1.1
Southern Calamari		1			1
False Bailer Shell	0.7				0.7
Red Gurnard	0.7				0.7
Mussel	0.1	0.55			0.65
Cuttlefish (U)			0.5		0.5
Banded Stingaree		0.2	0.3		0.5
Pale Octopus		0.4			0.4
Bug			0.3		0.3
Common Gurnard Perch			0.3		0.3
Southern Sand Flathead	0.3				0.3
Southern Bluespotted Flathead		0.3			0.3
Snipe Eel (U)		0.2			0.2
Velvet Leatherjacket			0.2		0.2
Flounder (U)		0.2			0.2
Bassina Spp.	0.1				0.1
Blue-Ringed Octopus		0.1			0.1
Cassidae (U)	0.1				0.1
Brittlestars (U)			0.1		0.1
Potbelly Seahorse		0.1			0.1
Soldier (Cobbler)		0.1			0.1
Total	**4285.3**	**5253.7**	**3992.2**	**0**	**13531.2**

Appendix 5 – Tarwine bed and Clonmel bed tow locations

Table 14. Survey marks for the Tarwine beds (also see Figure 6)

Latitude	Longitude	Tow Number	Bed	Priority
-38 25.187	147 33.253	1	East	Primary
-38 26.318	147 32.463	2	East	Primary
-38 25.375	147 32.339	3	East	Primary
-38 25.946	147 32.324	4	East	Primary
-38 27.683	147 30.732	5	East	Primary
-38 27.896	147 30.574	6	East	Primary
-38 25.183	147 32.709	7	East	Primary
-38 26.099	147 30.527	8	East	Primary
-38 23.180	147 36.805	9	East	Primary
-38 23.432	147 36.032	10	East	Primary
-38 25.515	147 30.352	11	East	Primary
-38 26.052	147 33.134	12	East	Primary
-38 28.377	147 30.234	13	East	Primary
-38 26.235	147 32.599	14	East	Primary
-38 24.384	147 34.307	15	East	Primary
-38 25.182	147 32.122	16	East	Primary
-38 26.664	147 31.935	17	East	Primary
-38 24.816	147 32.509	18	East	Primary
-38 27.227	147 30.500	19	East	Primary
-38 25.415	147 33.934	20	East	Primary
-38 26.817	147 31.121	21	East	Secondary
-38 24.764	147 34.000	22	East	Secondary
-38 25.439	147 32.495	23	East	Secondary
-38 24.832	147 34.864	24	East	Secondary
-38 25.765	147 30.355	25	East	Secondary
-38 27.416	147 27.508	1	West	Primary
-38 29.446	147 28.294	2	West	Primary
-38 27.127	147 29.598	3	West	Primary
-38 30.452	147 27.403	4	West	Primary
-38 29.586	147 28.378	5	West	Primary
-38 30.197	147 26.860	6	West	Primary
-38 29.740	147 26.562	7	West	Primary
-38 27.309	147 28.472	8	West	Primary
-38 29.812	147 28.380	9	West	Primary
-38 28.102	147 29.514	10	West	Primary
-38 27.959	147 28.956	11	West	Primary
-38 28.715	147 27.585	12	West	Primary
-38 28.265	147 27.972	13	West	Primary
-38 29.253	147 26.913	14	West	Primary
-38 28.855	147 29.177	15	West	Primary
-38 29.163	147 29.164	16	West	Primary
-38 29.116	147 27.866	17	West	Primary

Latitude	Longitude	Tow Number	Bed	Priority
-38 30.006	147 27.886	18	West	Primary
-38 28.730	147 28.442	19	West	Primary
-38 27.289	147 27.829	20	West	Primary
-38 28.241	147 26.687	21	West	Secondary
-38 27.650	147 28.525	22	West	Secondary
-38 29.752	147 26.074	23	West	Secondary
-38 27.080	147 29.478	24	West	Secondary
-38 26.857	147 27.686	25	West	Secondary

Table 15. Survey marks for the Clonmel bed (also see Figure 12)

Latitude	Longitude	Tow Number	Bed	Priority
-38 50.009	146 50.056	1	Clonmel	Primary
-38 49.984	146 49.045	2	Clonmel	Primary
-38 50.029	146 49.197	3	Clonmel	Primary
-38 50.056	146 48.990	4	Clonmel	Primary
-38 50.292	146 48.923	5	Clonmel	Primary
-38 49.871	146 49.866	6	Clonmel	Primary
-38 50.647	146 49.177	7	Clonmel	Primary
-38 50.266	146 49.954	8	Clonmel	Primary
-38 49.998	146 49.644	9	Clonmel	Primary
-38 50.271	146 49.951	10	Clonmel	Primary
-38 50.581	146 49.171	11	Clonmel	Primary
-38 50.014	146 49.380	12	Clonmel	Primary
-38 50.327	146 49.806	13	Clonmel	Primary
-38 50.378	146 49.356	14	Clonmel	Primary
-38 50.189	146 48.963	15	Clonmel	Primary
-38 50.383	146 49.255	16	Clonmel	Backup
-38 50.113	146 49.596	17	Clonmel	Backup
-38 50.473	146 49.039	18	Clonmel	Backup
-38 49.872	146 49.318	19	Clonmel	Backup
-38 50.443	146 49.527	20	Clonmel	Backup

Appendix 6 – Tow details

Table 16. Exploratory tow details.

Date	Start Time	Start Lat	Start Long
18-Dec-21	07:11:08	-39.0303	146.5153
18-Dec-21	07:58:58	-38.9556	146.5198
18-Dec-21	08:26:28	-38.9375	146.5609
18-Dec-21	08:50:54	-38.9483	146.5961
18-Dec-21	09:27:54	-38.964	146.6593
18-Dec-21	11:09:24	-38.8356	146.8293
18-Dec-21	11:25:21	-38.8357	146.8301
18-Dec-21	11:47:33	-38.8378	146.8201
18-Dec-21	12:10:19	-38.8282	146.8246
18-Dec-21	12:19:46	-38.8319	146.8363
18-Dec-21	12:25:32	-38.8369	146.838
18-Dec-21	12:34:13	-38.8425	146.8296
18-Dec-21	12:44:33	-38.847	146.8262
18-Dec-21	12:56:01	-38.8468	146.8149
18-Dec-21	13:05:44	-38.8362	146.81
18-Dec-21	19:05:14	-38.7896	147.0317
19-Dec-21	09:00:31	-38.4705	147.4143
19-Dec-21	09:31:46	-38.473	147.4082
20-Dec-21	07:33:10	-37.9091	148.1999
20-Dec-21	07:59:05	-37.8874	148.2503
20-Dec-21	08:20:04	-37.8692	148.2685
20-Dec-21	08:42:10	-37.8587	148.3175
20-Dec-21	09:45:31	-37.839	148.4151
20-Dec-21	10:47:09	-37.8689	148.5654
20-Dec-21	11:16:09	-37.8717	148.6292
20-Dec-21	11:53:01	-37.8796	148.7237
20-Dec-21	12:10:24	-37.8867	148.7383
20-Dec-21	13:11:20	-37.8083	148.8513
20-Dec-21	13:25:18	-37.8076	148.869
20-Dec-21	13:45:08	-37.8067	148.9167
20-Dec-21	14:01:30	-37.8109	148.9497
20-Dec-21	14:15:38	-37.812	148.9706
20-Dec-21	14:33:25	-37.8134	148.983
20-Dec-21	14:51:42	-37.809	148.9721
20-Dec-21	15:40:04	-37.8099	149.0787
20-Dec-21	16:01:00	-37.811	149.0525
20-Dec-21	16:32:15	-37.8151	149.0075
21-Dec-21	12:31:16	-38.2307	147.628

Table 17. Catch of Commercial Scallop in survey tows, tow details and stratum.

Date	Start Time	Start Lat	Start Long	Tow Speed (kts)	Distance Towed (m)	Area Swept (m^2)	Catch Weight (kg)	Stratum
18-Dec-21	14:32:57	-38.844	146.8198	3	391.0	1524.9	34	Clonmel
18-Dec-21	14:51:38	-38.8435	146.8188	3	425.6	1660.0	8	Clonmel
18-Dec-21	15:07:20	-38.8401	146.8216	3	452.9	1766.5	25	Clonmel
18-Dec-21	15:25:07	-38.838	146.8133	3	432.7	1687.5	55	Clonmel
18-Dec-21	15:40:11	-38.8386	146.8146	3	430.6	1679.2	40	Clonmel
18-Dec-21	15:52:50	-38.8341	146.8165	3	460.2	1794.9	27	Clonmel
18-Dec-21	16:05:33	-38.8322	146.8185	3	281.0	1095.8	13	Clonmel
18-Dec-21	16:15:05	-38.8338	146.8195	3	486.2	1896.2	63	Clonmel
18-Dec-21	16:28:40	-38.8331	146.8234	3	344.9	1345.1	35	Clonmel
18-Dec-21	16:43:00	-38.8328	146.8276	3	370.6	1445.2	65	Clonmel
18-Dec-21	16:56:43	-38.8309	146.8312	3	347.6	1355.8	4	Clonmel
18-Dec-21	17:09:22	-38.8334	146.8343	3	384.7	1500.5	67	Clonmel
18-Dec-21	17:31:38	-38.839	146.83		424.2	1654.5	44	Clonmel
18-Dec-21	17:43:17	-38.838	146.8324		498.8	1945.4	80	Clonmel
19-Dec-21	5:50:32	-38.5052	147.4601	3	427.8	1668.6	1.5	Tarwine West
19-Dec-21	6:05:15	-38.5036	147.447	3	403.5	1573.8	12	Tarwine West
19-Dec-21	6:17:26	-38.5003	147.4644	3	440.7	1718.8	16	Tarwine West
19-Dec-21	6:29:41	-38.4975	147.4729		396.0	1544.2	13	Tarwine West
19-Dec-21	6:41:35	-38.4924	147.4731		445.5	1737.5	43	Tarwine West
19-Dec-21	6:52:02	-38.49	147.4724		412.5	1608.7	72	Tarwine West
19-Dec-21	7:06:59	-38.4866	147.4855	3	371.4	1448.3	62	Tarwine West
19-Dec-21	7:17:20	-38.4816	147.4862	3	505.8	1972.5	84	Tarwine West
19-Dec-21	7:30:40	-38.4779	147.4753		395.9	1544.1	112	Tarwine West
19-Dec-21	7:40:37	-38.4843	147.4659		441.6	1722.2	79	Tarwine West
19-Dec-21	7:58:37	-38.4705	147.467	3	355.9	1388.0	120	Tarwine West
19-Dec-21	8:08:54	-38.4782	147.4603	3	390.3	1522.0	59	Tarwine West
19-Dec-21	8:20:10	-38.4871	147.4491	3	515.2	2009.5	48	Tarwine West
19-Dec-21	8:31:39	-38.4948	147.4437	3	390.5	1522.9	72	Tarwine West
19-Dec-21	10:16:52	-38.456	147.458	2.8	409.3	1596.3	3	Tarwine West
19-Dec-21	10:31:32	-38.4544	147.4635	3	424.8	1656.7	32	Tarwine West
19-Dec-21	10:45:25	-38.4545	147.4743	3	466.9	1820.9	18	Tarwine West
19-Dec-21	10:57:05	-38.4655	147.4823	3	477.1	1860.6	72	Tarwine West
19-Dec-21	11:10:49	-38.4692	147.4919		422.1	1646.4	108	Tarwine West
19-Dec-21	11:28:31	-38.4513	147.4923	3	373.1	1455.0	90	Tarwine West
21-Dec-21	6:22:07	-38.4757	147.5046		489.1	1907.3	55	Tarwine East
21-Dec-21	6:32:42	-38.4686	147.5091	3	390.4	1522.7	86	Tarwine East
21-Dec-21	6:44:54	-38.4645	147.5118		408.1	1591.6	115	Tarwine East
21-Dec-21	6:59:40	-38.4549	147.5073		440.6	1718.4	98	Tarwine East
21-Dec-21	7:16:12	-38.4354	147.5079	3	484.7	1890.2	120	Tarwine East
21-Dec-21	7:32:23	-38.4255	147.505	3	399.7	1559.0	0	Tarwine East
21-Dec-21	7:54:27	-38.4444	147.5319	3	388.6	1515.4	71	Tarwine East
21-Dec-21	8:04:56	-38.4389	147.5404	3	378.8	1477.3	40	Tarwine East
21-Dec-21	8:15:32	-38.4379	147.5445	3	466.1	1817.9	52	Tarwine East

Date	Start Time	Start Lat	Start Long	Tow Speed (kts)	Distance Towed (m)	Area Swept (m^2)	Catch Weight (kg)	Stratum
21-Dec-21	8:27:04	-38.4326	147.5384	3	464.0	1809.6	38.6	Tarwine East
21-Dec-21	8:53:21	-38.4241	147.565	3	434.9	1696.3	46	Tarwine East
21-Dec-21	9:08:23	-38.4189	147.555	3	385.9	1504.9	37	Tarwine East
21-Dec-21	9:37:20	-38.4188	147.546	3	414.6	1617.0	156	Tarwine East
21-Dec-21	10:03:56	-38.4188	147.5363	3	321.7	1254.6	96	Tarwine East
21-Dec-21	10:40:31	-38.4071	147.5709	3	454.3	1771.7	0	Tarwine East
21-Dec-21	10:58:39	-38.3916	147.599	3	365.0	1423.4	130	Tarwine East
21-Dec-21	11:11:07	-38.3871	147.6136	3	441.4	1721.4	11	Tarwine East
7-Jan-22	8:40:17	-38.4362	147.5503	3	633.9	2472.4	9	Tarwine East
7-Jan-22	9:46:46	-38.4212	147.5415		736.1	2870.8	132	Tarwine East