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Bass Strait and Central Zone Scallop Fishery — 2018 Survey

Ian Knuckey, Matt Koopman,
and Russell Hudson

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

Executive Summary

At the start of each Bass Strait and Central Zone Scallop Fishery (BSCZSF) fishing season, the Australian Fisheries Management Authority (AFMA) provides a research catch allowance and / or a 150 t total allowable catch (TAC) to enable fishers to search for commercially viable scallop (*Pecten fumatus*) beds. Industry members must then undertake research surveys to determine if the fishery can remain open under a Tier 1 (catches ≤ 2000 t) or Tier 2 (catches > 2000 t) management arrangement. Research surveys must carry an independent observer or electronic monitoring that is able to verify catch quantity, shell size and any other scientific data required to determine biomass estimates. This report provides the results of the 2018 research surveys.

Four commercial fishing vessels were selected by an independent panel to conduct the 2018 scallop surveys: the Dell Richey II, Northern Star, Odete C and the Rachel Maree. During May and June 2018, stratified random surveys were conducted using these vessels on one bed off Flinders Island, six beds off King Island and 2 beds off Apollo Bay. Choice of these beds was suggested by Fishwell following analysis of the 2017 commercial fishing data and approved by the Scallop Resource Assessment Group (ScallopRAG) and the BSCZSF Co-Management Committee. The Flinders Island bed was comprised of the amalgamation of two previously surveyed beds, while four of the King Island beds and the two Apollo Bay beds were carried over from previous years. Two additional King Island Beds were defined set based on commercial catches from previous years. Additional marks provided by industry yielded no beds considered worthwhile surveying. The number of random survey points allocated to each bed was based largely on practical considerations.

The estimated biomass of scallops at the Flinders Island bed was 2,522 t (1,707 t > 85 mm length), with a density of 0.269 individuals per m^2. The estimated biomass at the KI-BDE bed was 14,617 t (14,095 t > 85 mm). Estimated biomass was greater than 2,000 t for four other King Island beds (KI-5S, KI-New, KI-6 and KI-7), and only 16 t at KI-Mid. Total biomass estimated from the two adjacent Apollo beds was 3,696 t (3,694 t > 85 mm). Scallop density in the King Island beds was as high as 2.368 individuals per m^2, and 1.502 individuals per m^2 at the Apollo Bay beds.

Meat weights of scallops >85 mm were 72 meats to the kg at the Flinders Island bed compared to 38–44 meats per kg at the King Island beds other than KI-BDE, KI-6 and KI-7 which had 68, 69 and 55 meats to the kg respectively. Scallops from the Apollo Bay beds similar to those from BDE, KI-6 and KI-7 with meat weights of 67 and 69 meats to the kg. Time series of size frequency, biomass and composition of dead shell indicated significant mortality at the Flinders Island Beds since 2015, and since 2016 at the KI-Mid bed.

Catch composition varied greatly between beds. In general, there was high proportions of old (dead) single shell at the Flinders Island and KI-Mid beds, while other beds were dominated by live Commercial Scallops.

Survey results were presented to ScallopRAG on 20/6/2018 and the Scallop Management Advisory Committee (ScallopMAC) on 21/6/2018 to inform application of the BSCZSF Harvest Strategy.

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Acknowledgements

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Introduction

The main target species in the Bass Strait Central Zone Scallop Fishery (BSCZSF) 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). The species is 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 has to be adaptable to sometimes rapidly changing circumstances, yet still ensure protection of the resource in line with the *Commonwealth Fisheries Harvest Strategy Policy 2007* (HSP).

Under the HSP, the initial harvest strategy for the BSCZSF was developed during 2007. It was revised during the 2012 season and in response to industry concerns about the cost-effectiveness and flexibility, was further reviewed during 2014. The BSCZSF Harvest Strategy has two primary objectives. To:

1. keep stocks within the BSCZSF at ecologically sustainable levels and, within that context, maximise the economic returns to the Australian community; and,
2. pursue efficient and cost-effective management in attaining (1) above.

The Harvest Strategy uses a tiered approach designed to apply different levels of management and research services depending on the state of the resource. Underpinning the tiered approach is the need to balance the risk of over exploitation with obtaining initial knowledge on the status of the stock at the commencement of the season through pre-season surveys.

At the start of each fishing season, the Australian Fisheries Management Authority (AFMA) provides a research catch allowance and / or a 150 t total allowable catch (TAC) to enable fishers to search for commercially viable scallop beds, defined as "*…an area or scallop bed containing no greater than 20 per cent of scallops of a size less than 85 mm"*. To increase the TAC above 150 t, industry members must undertake research surveys to determine if the fishery can remain open under Tier 1 or Tier 2 level management arrangements.

- **Tier 1 management arrangements** require initial closure of an area/s (not more than 2 scallop beds) that contain ≥1500 tonnes in total of high density scallops of a minimum size of 85 mm. The season begins with a 1000 t TAC that can be increased to 2000 t if good catches are achieved.
- **Tier 2 management arrangements** require initial closure of an area/s (not more than 2 scallop beds) that contain ≥3000 tonnes in total of scallops of a minimum size limit of 85 mm of high density. The season begins with a 2000 t TAC that can be increased if good catches are achieved.

Research surveys must carry an independent observer or electronic monitoring that is able to verify catch quantity, shell size and any other scientific data required to determine biomass estimates. This report provides the results of the 2018 stratified random surveys.

Objectives

1. Estimate the scallop biomass and potential commercial catch rates in three different areas of the BSCZSF.
2. Measure the size frequency distribution of scallops in each area to calculate discard rates.
3. Report results to AFMA, ScallopRAG and ScallopRAG.

Methods

Survey Design

Survey methods follow those of Knuckey *et al.* (2015), modified from those described in Harrington *et al.* (2008). Four commercial scallop vessels were used to undertake a stratified random survey of scallop beds with independent observers onboard to collect all of the necessary survey data.

The 2015 survey covered three beds of King Island and one bed off Flinders Island (Figure 1). To provide greater flexibility in management arrangements regarding closures, this was expanded in 2016 with the addition of an extra four sites off King Island and another site off Flinders Island. In addition to the extra sites, the boundaries of some of the 2015 sites were modified (for example northern and southern boundaries of the bed known as KI-Main in Knuckey *et al.* (2015) were brought in slightly, and the eastern and western boundaries moved east slightly to form a bed titled KI-2 in Knuckey *et al.* (2016). The beds surveyed during 2017 were based on advice from the Scallop Research Workshop and input from ScallopRAG and the BSCZSF Co-Management Committee (Knuckey *et al.,* 2017). They comprised previously surveyed beds, modified beds and new exploratory beds.

The beds to be surveyed in 2018 were based on previous surveys, 2017 commercial fishing effort and advice from the ScallopRAG and the BSCZSF Co-Management Committee. These are outlined in Table 1.

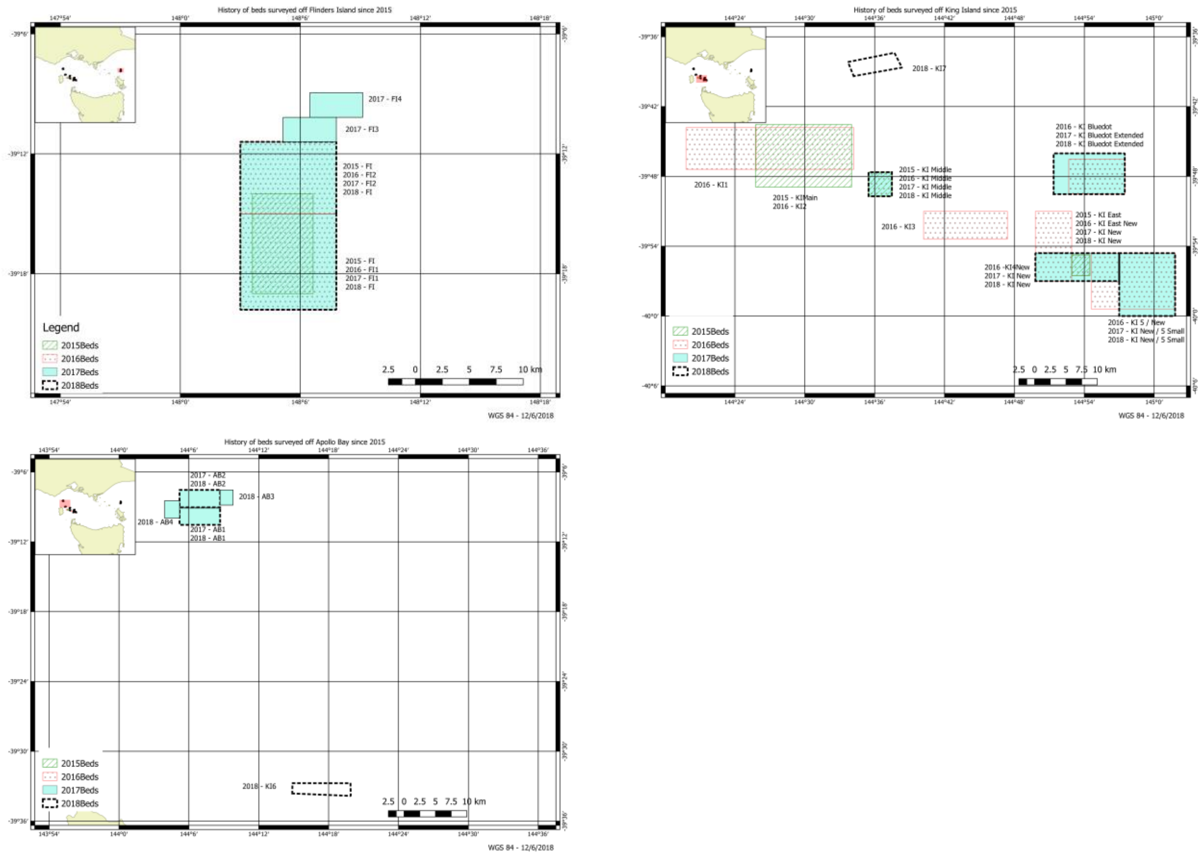

Figure 1. History of beds surveyed off Flinders Island (top left panel), King Island (top right panel) and Apollo Bay (lower panel) since 2015. Beds surveyed during 2018 are shown as heavy dotted polygons.

Table 1. Description of survey beds and changes since 2015. Full names of beds and their boundaries are described in Table 4.

Bed Type	Name	Description
Previously surveyed	KI-Mid	Unchanged from the bed surveyed in 2015, 2016 and 2017. See Table 4 for bed boundaries.
	KI-5S	Originally a larger area that was surveyed in 2016, KI-5S was formed by extending the eastern boundary of KI-New south to S -40˚, and including the area of KI-5 to the east of that. This bed remained unchanged from the 2017 survey.
	KI-New	KI-New was a bed that was defined for management proposes (it formed the initial closure) after the 2016 survey, covering at least parts of three different beds survey in 2016. It is bound by the latitudes and longitudes shown in Table 4. A bed called KIEast was surveyed during 2015, and again in2016, along with two new adjacent beds, KI-4 andKI-5. This bed remained unchanged from the 2017 survey.
	KI-BDE	During the TAC setting MAC for the 2016 season, industry provided information regarding a dense bed of small scallops that would be more suitable for closure than the KI-New bed. This bed titled King Island Blue Dot was mapped out and then surveyed during August of 2016. The area was expanded north and west to form an area closure that replaced the closure of KI-New. The boundaries of this expanded area are shown in Table 4. This bed remained unchanged from the 2017 survey.
	AB-1 and AB-2	Seven exploratory marks off King Island were provided by industry to be explored and considered for additional survey beds in 2016. Only one of those showed enough promise to survey, and the skippers mapped out the area, splitting it into two beds. During 2017, two additional smaller beds were added to each of the western and eastern boundaries, however these contained low densities of scallops, and were dropped from the 2018 survey. The Apollo 1 and 2 bed boundaries remained unchanged from the 2017 survey. The borders of those beds are in Table 4.
Modified Beds	FI	FI-1 was called the “Flinders Island” bed during the 2015 survey. For the 2016 and 2017 surveys, the area was expanded and spilt into the two beds (FI-1 and FI-2). Two additional smaller beds were added to the northern boundary of FI-2 in 2017, however because of low densities, these were dropped for the 2018 survey. For the 2018 survey. FI-1 and FI-2 were combined into a single large bed bound by the latitudes and longitudes shown in Table 4.
Exploratory / New Beds	KI-6	Examination of commercial catch and effort data revealed significant catches in a large area at approximately longitude 144˚ 17’, latitude 39˚ 32’. The vessels mapped out this area to provide a smaller area with high density scallops with the boundaries shown in Table 5.
	KI-7	Examination of commercial catch and effort data revealed significant catches in a large area at approximately longitude 144˚ 36’, latitude 39˚ 38’. The vessels mapped out this area to provide a smaller area with high density scallops with the boundaries shown in Table 5.
	AW1	Exploratory marks were provided from industry observations off Flinders Island. Exploratory fishing did not yield appreciable densities of scallops and no bed was defined.
	AW2	Exploratory marks were provided from industry observations off Flinders Island. Exploratory fishing did not yield appreciable densities of scallops and no bed was defined.
	50-60m bank	Exploratory marks were provided from industry observations along a bank running north west from KI-BDE. Exploratory fishing did not yield appreciable densities of scallops and no bed was defined.

It was decided to re-survey the following 2017 beds (as described in Knuckey *et al.* 2017): KI-Mid, KI-5S, KI-New, KI-BDE, AB-1 and AB-2. Given the decline in scallops at FI-1 and FI-2 in 2017, those beds were combined into a single area called FI.

Exploratory tows around two marks provided off Flinders Island conducted by each vessel revealed very little promise, with the skipper and observer agreeing that there was no value in putting in a survey bed. Exploratory fishing around the 50–60 m bank to the north-west of KI-BDE) also revealed a lack of scallops. However, high densities of scallops were found in the two areas where much of the 2017–18 fishing effort was conducted, and so the extent of these beds were mapped and surveyed.

The number of survey points allocated was largely guided by sampling effort during 2016 and 2017, with consideration given to the maximum number of tows that can be achieved in a 12 hour sampling block[1] and the area of the bed. Primary sampling sites within each bed were randomly allocated using the QGIS Random Points Tool (Figure 2). Additional survey points were allocated to each bed as "backup sites", to be used where "primary sites" were unfishable.

During 2018, surveys were conducted onboard the fishing vessels Dell Richey II (Scientific Permit# 1003884), Northern Star (Scientific Permit# 1003885), Rachael Maree (Scientific Permit# 1003886) and Odete C (Scientific Permit# 1003887). These vessels were selected by an independent panel following an Expression of Interest process in which seven vessels submitted an interest in being involved. To be considered a valid tow, the vessel must dredge within 100 m of the tow location provided (Appendix 1 Figure 20). Lotek LAT1400-64kb temperature-depth loggers were attached to the dredge at the start of the first tow, and set to record an observation every three minutes.

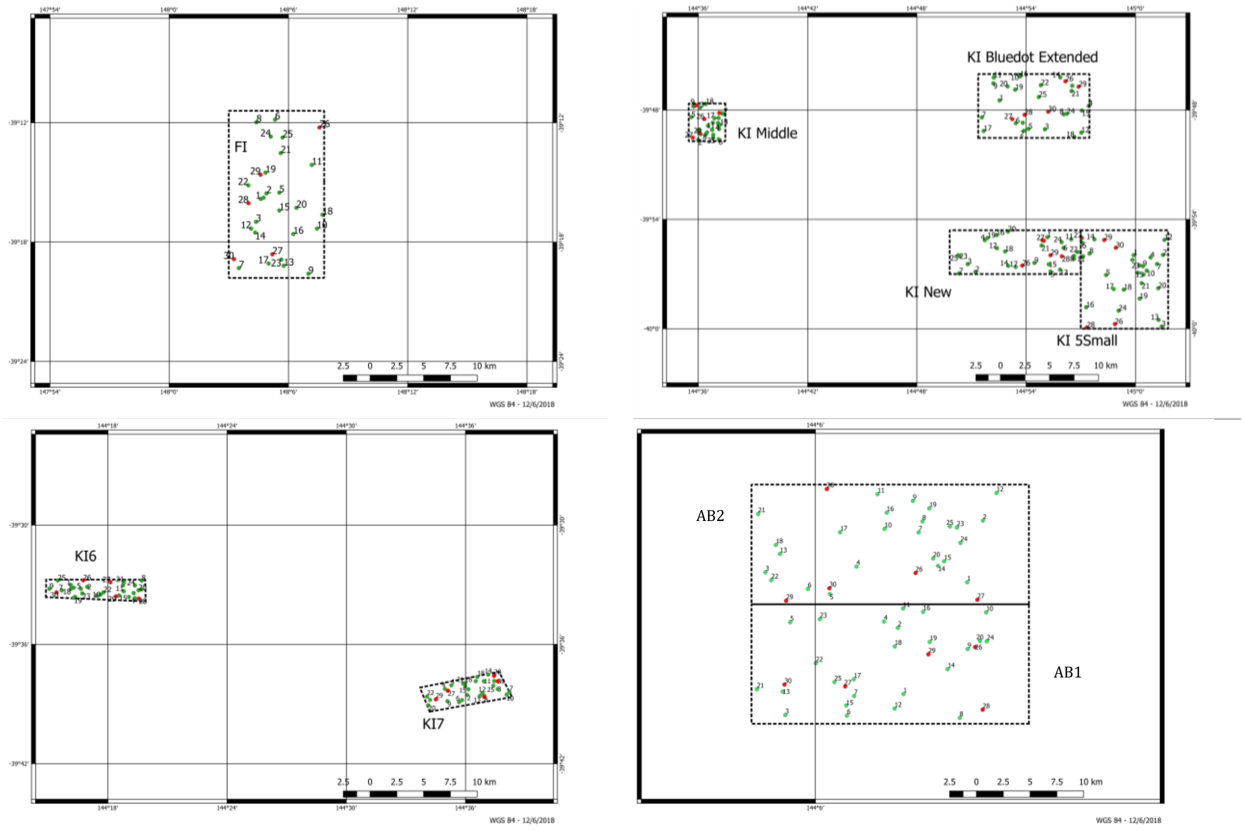

Figure 2. Location of survey marks in beds surveyed off Flinders Island (top left panel) and King Island top right panel), King Island north (lower left panel) and Apollo Bay (lower right penel) during 2018.

[1] For OHS reasons, observers are restricted to a maximum of 12-hour sampling in a 24 hour period.

Sampling methods

For each shot, estimates were made of weight of: total live scallop catch, dead shell and all bycatch by species / species group. Dead shells were 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 shot before they went through the tumbler. The observer measured the length of those scallops using an electronic measuring board. Either the first or last (or both) scallop from each shot measured using the measuring board was also measured by hand using digital callipers or a metal ruler. This was done ensure accuracy and consistency of the measuring board throughout the survey. The sample weight of scallops measured was also recorded.

An additional 10 random scallops were taken from every fifth shot before passing through the tumbler to collect biological information. First, the whole scallop was weighed and the shell length, height and width measured for morphometric analyses. They were then split and the gonad condition staged according to the scale in Table 12 and Table 13 based on Harrington *et al.* (2010) (see Appendix 1). Adductor meat and gonad were removed from the shell and weighed together to calculate number of meats per kg.

Data analysis

All data processing and analysis was undertaken in R (R Core Team, 2018), and density plot created using the package “mapplots” (Gerritsen, 2014). Estimates of biomass and potential commercial catch rates 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), from the outside of the outermost teeth on the tooth bar. Dredge widths used by the Dell Richey 2, Northern Star, Odete C and Racheal Maree were 3.93 m, 3.583 m, 3.905 m and 3.875 m (Table 2). A dredge efficiency of 33% was assumed.

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

$$S = L x W$$

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

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

Where C is the estimated catch in a shot (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} x SE_{meanD})) x A)*3.03 / 1000

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

Were meanD is the mean density (kg) of scallops per m^2 swept, t_{n-1} is the t –value for the number of shots (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 R package "geosphere" (Hijmans et al., 2015).

Biomass and upper and lower 95% CL of scallops greater than 85 mm were calculated as follows:

$B_{>85mm}$ = B * (1-discard rate)

Upper 95% $CL_{>85mm}$ = Upper 95% CL * (1-discard rate)

Lower 95% $CL_{>85mm}$ = 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

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

Were *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.

Potential commercial catch rates

Following Semmens and Jones (2014), potential commercial catch rates were estimated by calculating the weight of scallops that would be caught per hour given the mean density, and assumptions around a "typical scallop tow".

Semmens and Jones (2014) reported that commercial fishers generally conduct four 10-minute tows per hour, with each going approximately 750 m. A scallop density reported in kg/1000 m^2, equates to a distance covered of 250 m (assuming dredge width of 4 m). An estimate of catch of a 10-minute commercial tow (C^{tow}) was calculated as:

$C^{tow} = D_{1000}$ x 3

Where D_{1000} is the mean kg of scallops per 1000 m^2.

To estimate potential catch per hour, C^{tow} is multiplied by 4 (i.e. four 10 minute tows per hour).

$C^{hour} = C^{tow}$ x 4

Because no commercial fishing was conducted during the survey, potential commercial catch rates were calculated only from random survey tows, and so could be considered very conservative.

Biologicals

The length-weight relationship was calculated for each area separately, and the parameters of the relationship are provided in the results. Because of the tight time frame for delivery of results, length-weight relationships calculated from the 2017 were applied to catch-weighted size frequencies to calculate the discard rate at 85 mm. The discard rate was used in calculations of biomass of scallops greater than 85 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 includes quality assurance protocols including automatic data capture (time, date and position), field restrictions, range checks, mandatory fields and lookup tables. All data were manually error checked against data sheets. This database is regularly backed up, and used to extract data for analyses. Data analyses were undertaken using R (R Core Team, 2018), and a subset of outputs were reproduced and compared using an alternative software package. Scallops were measured using electronic measuring boards. The first or last (or both) scallop from each shot 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 AFMA managers. Where required, comments were addressed in preparation of the final report.

Results

Survey summary

The 2018 BSCZSF survey was undertaken during two legs late May and early June respectively. The first leg of the 2018 survey got underway on 25 May with the Del Richey II, skippered by John Richey leaving from Devonport, and the Odete C, skippered by Glen Wisby leaving from Stanley. Russell Hudson and Alex Barber were the observers on the Del Richey II and Michael Davis and Jess Kube on the Odete C. Both vessels were on the grounds by the morning of 26 May — sea conditions were perfect for the entire survey. The Odete C surveyed KI-5S and then KI-New the next day and reported good catches (~50kg/tow) with good clean catches of scallops of good size and condition. The Del Richey II surveyed KI-BDE and then KI-Mid. Reports were that there were very good size and catch rates of scallops on KI-BDE with scallops at 70–75 count with good recovery although no roe developed as yet. Catch rates in Ki-Mid were poor with only a few old scallops and a lot of dead shell. The vessels then joined up to grid and explore the region of 50–60 m bank up to SE corner of KI-7. Despite extensive shots throughout this region, only a smattering of scallops was found — nothing worth commercial fishing or undertaking a formalised survey. The vessels finished the first leg of the survey on 28th May.

The second leg of the survey began on the afternoon of Friday 1 June. The Northern Star with Ian Rule as skipper and Alex Barber as observer left from Lakes Entrance, heading south to first explore around Bream oil rig area (AW2) and south of the horseshoe (AW1), before surveying the FI bed. Once the FI bed was surveyed, they steamed west to KI-7. A number of exploratory shots were conducted before determining a smaller bed within KI-7 to formally survey. Good catches of good size scallops were found. The Rachel Maree with Graham Cull as the skipper and Russell Hudson as observer left Queenscliff and headed south to conduct separate surveys of AB-1 and AB-2. Shells here were about 110 mm, in good condition and good catch rates were observed. They then headed down to KI-6 and ran exploratory shots before defining a more accurate, smaller bed to formally survey. Again, this revealed generally good catch rates of good size scallops. The survey was finished on 4th June and both boats had returned to port early on 5th June.

A total of 25 valid, random, non-targeted tows were undertaken in each of the survey beds Table 6). Mean distances towed were: 533 m (range 447–658 m) at FI, 561 m (range 387–639 m) at KI-BDE, 558 m (range 516–595 m) at KI-Mid, 686 m (range 607–802 m) at KI-5S, 340 m (range 260–561 m) at KI-6, 531 m (range 431–672 m) at KI-7 and 658 m (range 175–706 m) at KI-New. Total area of each stratum is shown in Table 4 and Table 5.

Depth of survey tows ranged 46–91 m and bottom temperatures ranged 11.7–16.1°C.

Biomass, size and potential commercial catch rates

Estimated mean biomass within FI was 2,521.9 t (95%CI 1,674.8 t – 3,369.0 t) (Table 6). Using a discard rate of 32.3% (67.7% > 85 mm), mean biomass for scallops > 85 mm was 1707.1 t (Table 7). Densities were highest in the middle of FI and generally lowest in the very north and south-west corner (Figure 3). Density in individuals per square metre was 0.269 individuals per m^2 (Table 6).

Estimated mean biomasses from the six King Island Beds were: 3,529.4 t (95%CI 2,769.2 t – 4,289.6 t) at KI-5S, 14,617.3 t (95%CI 9,579.7 t – 19,654.8 t) at KI-BDE, 16.3 t (95%CI 6.5 t – 26.1 t) at KI-Mid, 2,780.5 t (95%CI 2,126.5 t – 3,434.4 t) at KI-New, 2,360.5 t (95%CI 1,829.7 t – 2,891.4 t) at KI-6 and 2,036.5 t (95%CI 1,638.6 t – 2,434.5 t) at KI-7 (Table 6).

Mean biomasses estimates for the two Apollo Bay beds were: 1892.3 t (95%CI 1,418 t – 2,366.6 t) for AB-1 and 1803.8 t (95%CI 1,300.3 t – 2,307.3 t) at AB-2 (Table 6). The percentage of scallops >85mm ranged 96.4% to 100% at the King Island Beds, and 99.9% to 100% at the Apollo Bay beds (Table 7 and Figure 15). Consequently, mean biomasses of scallops > 85 mm were either the same, or only slightly lower than total biomass estimates except for at KI-BDE what the estimated mean biomass above 85 mm was 14,095.2 t (Table 7).

Densities within each King Island and Apollo Bay bed are shown in Figure 4 –Figure 11. Scallops were caught at medium densities throughout KI-5S and KI-New, with some lower densities in the south-east and north-east of KI-5S. There were eight zero catches in the southern half of KI-Mid, and while still low, catches increased in the north of the bed. Scallop densities were very high throughout most of KI-BDE apart from a zero catch in the south-west corner and one low catch in the north. The highest density (1,017 kg/1000m^2) was recorded in the north of KI-BDE. Estimated densities in numbers at the King Island beds ranged from 0.014 individuals per m^2 at KI Mid to 2.882 individuals per m^2 at KI-BDE (Table 6).

High densities were also observed at the Apollo Bay beds, with AB-1 being 1.502 individuals per m^2 and AB-2 being 1.408 individuals per m^2 (Table 6). At the Apollo Bay beds, highest densities were in the centre and east of centre.

Comparisons of biomass estimate, percent composition and size distributions of beds that have been repeatedly surveyed are shown in Appendix 2. While the sampling methods have been consistent, the areas of the beds have changed considerably in some cases. Care should be taken when interpreting those results, and consideration of changes in bed areas over time should be made.

Biologicals

Scallops measured from the from the Flinders Island bed were smaller than those from other areas ranging 42 to 119 mm length with a mean of 86 mm (Table 8, Figure 15). Size distribution of scallops from KI-Mid, KI-New and KI-5S with mean lengths of 112 mm, 110 mm and 110 mm respectively (Table 8). At each of those beds, the majority of the scallops were 105–125 mm length (Figure 15). Mean lengths at KI-6 (97 mm) and KI-7 (99 mm) were similar, but the bulk of scallops at KI-6 were 85–100 m with a long tail of larger scallops, while at KI-7 they were mostly 95–105 mm length (Table 8, Figure 15). Length distributions from AB-1 and AB-2 were similar with means of 103 mm and 104 m respectively and most scallops ranging 95–110 m (Table 8, Figure 15).

Comparison of length-weight regressions revealed that the interaction terms was not significant ($p=0.39$), and so there was not enough evidence to conclude that there is a difference in slopes in the length-weight relationship between beds. However the p-value for the indicator variable ($p<0.0001$) suggests that there is a difference in intercepts, and it appears that there are differences in length-weight relationships between areas (Flinders Island, King Island and Apollo beds (Figure 13a). Separate length-weight relationships for each area for calculations of density in individuals per square metre (Table 9).

Reflecting the smaller size of scallops measured there, scallop meats of shells greater than 85 mm length from the Flinders Island beds averaged 72 meats per kg, and individual meat (and gonad) weights were generally less than 15 g (Table 8, Figure 16). Meat weights at KI-5S, KI-Mid and KI-New ranged 38–44 meats per kg, while individual meat weights were generally over 20 g. Scallops from KI-7 had meat weights of 55 meats per kg, and those from KI-6, KI-BDE and AB-1 and AB-2 ranged 67–69 meats per kg.

Scallops from the King Island beds generally (except for KI6) had more advanced staged gonads than other beds with relatively high proportions of stage 5 (5.1, 5.2 and 5.3) gonads (

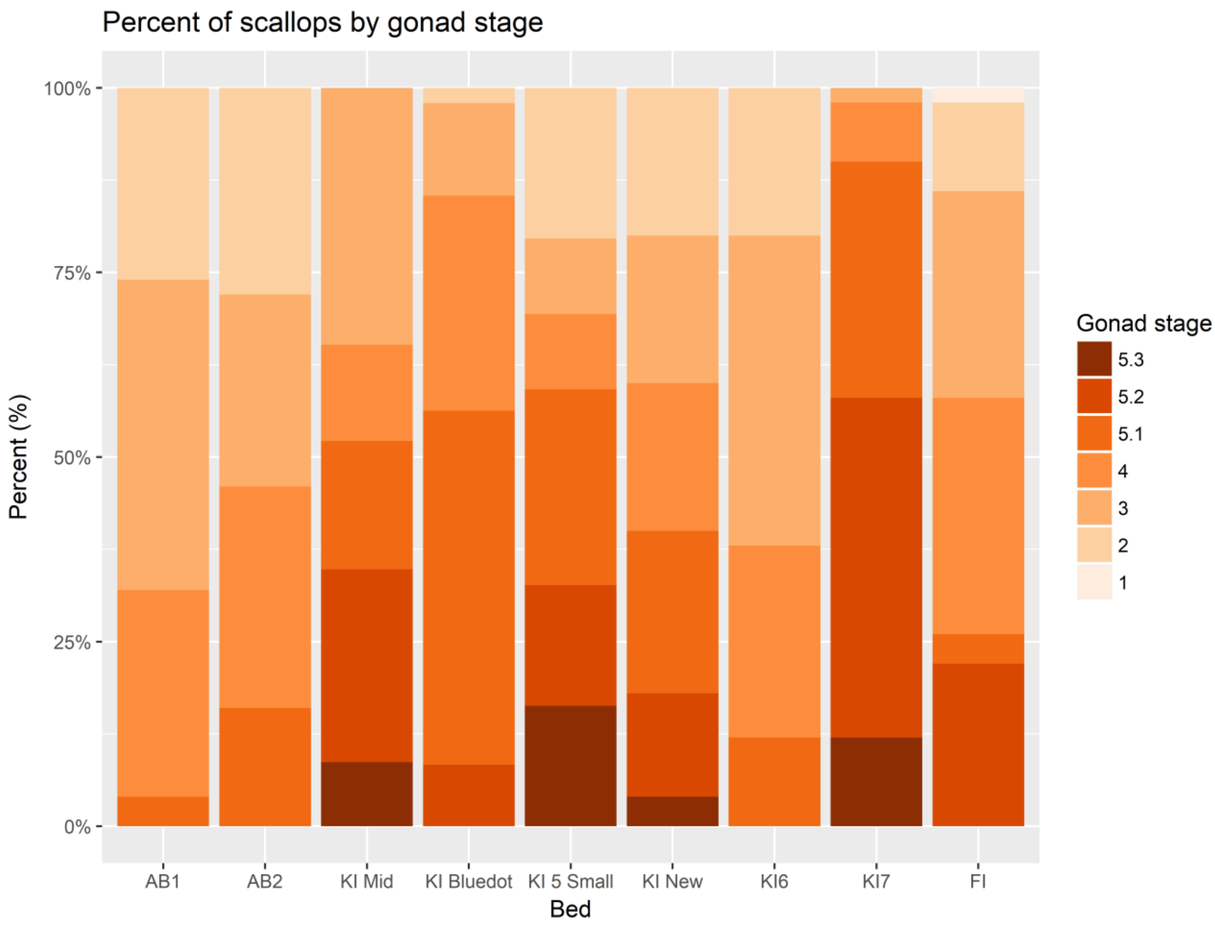

Figure 17). KI-Mid, KI-5S, KI-New and K-I7 were the only beds to have scallops with stage 5.3 gonads. Gonad stages at KI-6, AB-1 and AB-2 were similar with most scallops having stage 3 or 4 gonads.

Scatterplots of each combination of size measurements (including total weight) shown in Figure 12 reveal a linear relationship between measurements (except for those with total weight). The relationship between length and width was different between beds, with scallops from Flinders Island having a greater width for a given length than those from other beds (Figure 13c). This was confirmed by results of an ANCOVA showing significant effects of width ($F=980.05$, $p<0.001$), area ($F=15.73$, $p<0.001$) and the interaction term ($F=7.91$ $p<0.001$) on length. The width for a given height showed a similar difference between areas as the length-width relationships (Figure 13d), revealing significant effects of width ($F=938.75$, $p<0.001$), area ($F=10.36$, $p<0.001$) and the interaction term ($F=13.73$, $p<0.001$) on height. Despite those differences, the height-length relationships appeared similar (Figure 13b), but the effects of length ($F=7563.7$, $p<0.001$), area ($F=5.48$, $p<0.01$) and the interaction term ($F=6.07$, $p<0.01$) on height were significant. Principle Component Analysis reveals that ratios between different measurements of scallops from King Island are very similar to those from Apollo Bay, but somewhat different to those from Flinders Island (Figure 14). This is appears to be largely driven by differences in the ratios of each measurement with weight, which are reflective of PC2.

Bycatch

A total of 80 different bycatch species / groups were identified during the main surveys (Table 10), and catch composition varied greatly between beds. At FI, 39% of the total catch was old single shell, 43% was broken shell (from a range of species) and live Commercial Scallops comprised only 7% of the catch (Figure 18). The catches at KI-5S, KI-New, KI-BDE, KI-6 and to a lesser extent KI-7 were dominated by Commercial Scallop, comprising 35–75% of the total catch. Half of the catch at KI-Mid was old single shell, and 24% new single shell, while 18% of the catch at this bed was 11-arm sea stars. More so than all other beds, the Apollo Bay beds were largely dominated by Commercial Scallop (80–82%).

Considering only the four different scallop "groups" (Commercial Scallops, old single, new single, and clappers), FI and KI-Mid had a much higher percentage of old single shell (greater than 60%) than other beds, while about 35% of the scallop catch from KI-7 was old single shell (Figure 19). KI-Mid (31%) and KI-7 (20%) had the highest percent of new single shells.

Table 2. Inputs used in biomass calculations that are not derived from the surveys.

Inputs	Dell Richey 2	Northern Star	Odete C	Rachael Maree
Dredge width	3.93 m	3.583 m	3.905	3.875
Dredge efficiency	33%	33%	33%	33%

Table 3. Estimated total commercial catch (t) and the number of vessels that fished within each survey bed during 2017 based on logbook data.

Bed	Catch (t)	Number of vessels
FI	0 t	0
KI-5S	0 t	0
KI-New	NA	<5
KI-Mid	NA	<5
KI-BDE	1351 t	11
KI-6	67 t	5
KI-7	756 t	10
All other areas	753 t	NA
Not assigned	NA	<5
Total	2929 t	12

Table 4. Boundaries (decimal degrees) of each scallop bed other than KI-6 and KI-7 surveyed in 2018 and area of polygons (km²).

Bed	Nickname	Latitude		Longitude		Total
		Northern	Southern	Western	Eastern	Area (km²)
Flinders Island	FI	-39.190	-39.33	148.050	148.130	107.32
King Island 5 Small	KI-5S	-39.910	-40.000	144.950	145.030	68.31
King Island New	KI-New	-39.910	-39.950	144.830	144.950	45.56
King Island Middle	KI-Mid	-39.794	-39.8285	144.5912	144.6247	10.99
King Island Bluedot Ext	KI-BDE	-39.7671	-39.8255	144.8561	144.958	56.53
Apollo Bay 1	AB-1	-39.1507	-39.1757	144.0866	144.1447	13.93
Apollo Bay 2	AB-2	-39.1257	-39.1507	144.0866	144.1447	13.95

o

Table 5. Boundaries (decimal degrees) of KI-6 and KI-7 surveyed in 2018 and area of polygons (km²).

Bed	Nickname	Position (latitude / longitude)				Total
		North-west	North-east	South-east	South-west	Area (km²)
King Island 6	KI-6	-39.5457 144.2482	-39.5458 144.3313	-39.5639 144.3317	-39.5604 144.248	13.08
King Island 7	KI-7	-39.6362 144.5618	-39.623 144.6282	-39.6442 144.6391	-39.6564 144.57	14.53

Table 6. Biomass estimates, 95% confidence limits and number of tows included in analyses using the straight-line method. Note that both densities have been adjusted for a 33% assumed dredge efficiency.

Area	Bed	Number of tows	Mean density (kg / 1000m^2)	Standard deviation (kg / 1000 m^2)	Lower 95% CL (t)	Estimated biomass (t)	Upper 95% CL (t)	Potential catch rate (kg / hr)	Density (ind/m^2)
FI	FI	25	23.5	19.1	1674.8	2521.9	3369.0	93	0.269
Sub-total		**25**				**2521.9**			
KI	KI-5S	25	51.7	27.0	2769.2	3529.4	4289.6	205	0.372
KI	KI-BDE	25	258.6	215.9	9579.7	14617.3	19654.8	1024	2.882
KI	KI-Mid	25	1.5	2.2	6.5	16.3	26.1	6	0.014
KI	KI-New	25	61.0	34.8	2126.5	2780.5	3434.4	242	0.406
KI	KI-6	25	180.4	98.3	1829.7	2360.5	2891.4	715	2.368
KI	KI-7	25	140.1	66.3	1638.6	2036.5	2434.5	555	1.293
Sub-total		**150**				**25340.5**			
AB	AB-1	25	135.9	82.5	1418.0	1892.3	2366.6	538	1.502
AB	AB-2	25	129.3	87.4	1300.3	1803.8	2307.3	512	1.408
Sub-total		**50**				**3696.1**			
Total		**225**				**31558.5**			

Table 7. Percent weight of scallops > 85 mm (catch weighted by weight), and biomass estimates 95% confidence limits for scallops greater than 85 mm calculated using the straight-line method.

Bed	% weight > 85 mm	Lower 95% CL (t)	Estimated Biomass (t)	Upper 95% CL (t)
FI-1	67.7	1133.7	1707.1	2280.4
Sub-total			**1707.1**	
KI-5S	99.9	2767.2	3526.9	4286.6
KI-BDE	96.4	9237.5	14095.2	18952.8
KI-Mid	99.7	6.5	16.2	26.0
KI-New	100	2126.5	2780.5	3434.4
KI-6	97.1	1776.3	2291.7	2807.0
KI-7	97.6	1599.3	1987.8	2376.2
Sub-total			**24698.2**	
AB-1	99.9	1416.7	1890.5	2364.4
AB-2	100	1300.3	1803.8	2307.3
Sub-total			**3694.3**	
Total			**30099.6**	

Table 8. Number of length measurements (N), median, mean and standard error (SE) of scallops measured, and % of scallops measured (catch weighted only) less than and greater than 85 mm and mean number of meats per kg of scallops greater than 85 mm from each bed.

		Length (mm)			85 mm		Meats / kg
Bed	N	Median	Mean	SE	%<	%>	Mean
FI	824	85	86	0.4	36.9	63.1	72
KI-5S	790	111	110	0.3	0.7	99.3	41
KI-BDE	933	94	94	0.2	5.1	94.9	68
KI-Mid	174	112	112	0.5	0.3	99.7	44
KI-New	881	111	110	0.3	0.0	100.0	38
KI6	1119	96	97	0.3	2.9	97.1	69
KI7	1010	100	99	0.3	2.3	97.7	55
AB-1	970	103	103	0.2	0.2	99.8	67
AB-2	985	104	104	0.2	0.0	100.0	69

Table 9. Number of scallops retained for biological sampling, and parameter estimates for length weight relationships.

Area	N	a	b	Adjusted R^2
Flinders Island	50	-6.6578	2.4308	0.90
King Island	251	-7.2590	2.5599	0.80
Apollo Bay	99	-6.1992	2.2988	0.71

Table 10. Catch of each species in each bed. (u) refers to undifferentiated species recorded at a higher taxonomic level.

	Catch (kg)								
	Flinders Is	King Island						Apollo Bay	
Species	FI	KI -BDE	KI-Mid	KI-5S	KI-New	KI-6	KI-7	AB1	AB2
Commercial scallop	360.6	4574	26.95	1154.5	1272	1994	2205	2158	2038
Clappers	1.9	2.2			1	1.2		0.5	0.4
New Single	166	1018	153.2	124	88	413	1030	185.5	78.5
Old Single	1987	1633.5	318.7	33.3	69	395	1870	166	123
Algae - Phyllospora								1	
Angel shark					10		1		
Ascidian (u)			0.4	114	174.5		0.4	2	0.2
Banded stingaree				1.1		0.3		0.8	0.8
Bassina spp.								0.1	
Brittlestars (u)	0.1			0.01			0.25		
Brownstriped leatherjacket									0.1
Bug					0.1				
Butterfly gurnard	0.3			0.7	0.6		0.4	0.5	0.6
Carid prawn (u)								0.1	
Cassidae (u)		1.3							
Cockle 1	0.1								
Cocky gurnard	1.1	1.1		0.4	0.5	0.8		0.2	0.8
Common gurnard perch				0.2	0.2			0.7	
Common stargazer					10.2				
Common stinkfish				0.2					
Cowrie (u)						0.4			
Crab (u)		1		0.3	0.11	0.2			0.8
Crassidae (u)						0.6			0.2
Crinoid (u)					0.2				
Cucumberfish, greeneye & flathead lizardfish (u)									0.4
Cuttlefish (u)					0.2		0.1	2	
Deepwater bug		0.2				0.4		0.8	0.8
Doughboy scallop	4.4	80.2		13.2	30	73.7	4.6	1.1	
Draughtboard shark	5		2		1				
Eastern Balmain bug	2.7						1		
Eastern orange perch	0.1								
Eleven-arm seastar		9	115		1		0.2		
False bailer shell								3	
Flounder (u)	0.4		0.5						
Giant cuttlefish							0.7		
Greenback flounder					0.2				
Greenback stingaree				0.4	0.2				
Hard Coral	1.1			0.1		1.5	1		3.2
Hermit crab (u)	46.2	10.5	2.2	3.1	9.7	1.3	11.2	1.5	2.3
Holothurian (u)							0.05		
Leptosynapta dolabrifera	0.7						0.1		

	Catch (kg)								
	Flinders Is	King Island						Apollo Bay	
Species	FI	KI -BDE	KI-Mid	KI-5S	KI-New	KI-6	KI-7	AB1	AB2
Mixed Fish								0.1	
Mollusc (u)				10.9	54.6	0.9			
New Zealand Screw Shell					20				
Nudibranch (u)		0.2							
Octopus (u)	3.95	17.8	0.2	3.4	1.72	6.9	14.3	3.4	6.5
Ornate cowfish	0.6								
Oysters	1.9			0.5		5			
Painted latchet			1						
Peacock skate	1.5	3.5							
Polychaete worm (u)					0.1				0.3
Prickly toadfish				1.2					
Ranellidea (u)	38.7	15.2	2.5			7.6	47.1	1.7	3
Razor Clams	3.5	1		0.2			2.8	1	8.4
Sand crab	1.7						2.4		
Scorpionfish (u)			0.8						
Sea urchin (u)	1.9				0.3		6.7	4	2.2
Seapen (u)	1							0.6	1
Seastar (u)	0.1		0.3	0.4	0.7	0.3	2.5	10.5	9.8
Shark egg (u)	0.4						0.1		
Shaw's cowfish		0.2							0.1
Skate (u)							1		
Soft coral (u)	0.4					1		4.6	2.1
Southern ocean arrow squid								0.5	
Southern sand flathead				0.2	1				
Sparsely-spotted stingaree	1.9	3	4.5	4.2	0.4	1.4	2.2	3.5	0.2
Speckled stargazer									4.1
Spider crab (u)	183.9	146	0.6	40.4	18.3	14.1	126.6		0.1
Sponge (u)	73.1	69	5	27.7	33.3	52.5	330	41.5	64.2
Sponges (Coral)							1.7		
Spotted flounder				1.1					
Stargazer (u)	3.5	1.3	0.5				0.3		
Substrate - Broken Shell	2160	3396	0.7		293.1	407	684	75	99
Substrate - Rock			0.1			22.5		6	11.8
Tasmanian numbfish		0.2	1	0.4		0.9		1	0.7
Tiger flathead			0.3					4.6	2.4
Triggerfish & leatherjacket (u)	0.1						0.2		
Venus shells	6.4		0.4				1.1		
Volute (u)	4.2	0.2		7.1	3.5	4.2	11.1	0.7	5.3
Whitespotted skate				1					

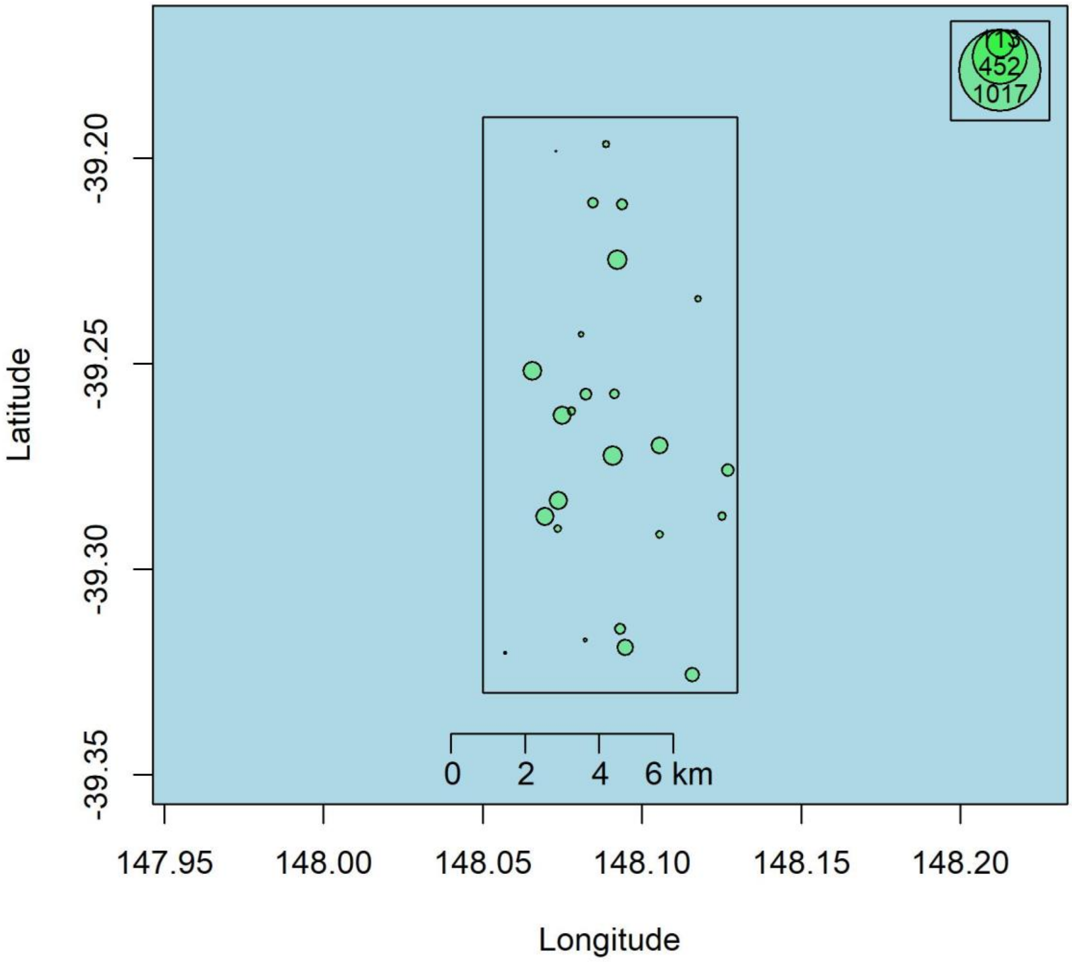

Figure 3. Scallop density (kg / 1000 m^2) within the defined stratum of the FI bed near Flinders Island. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

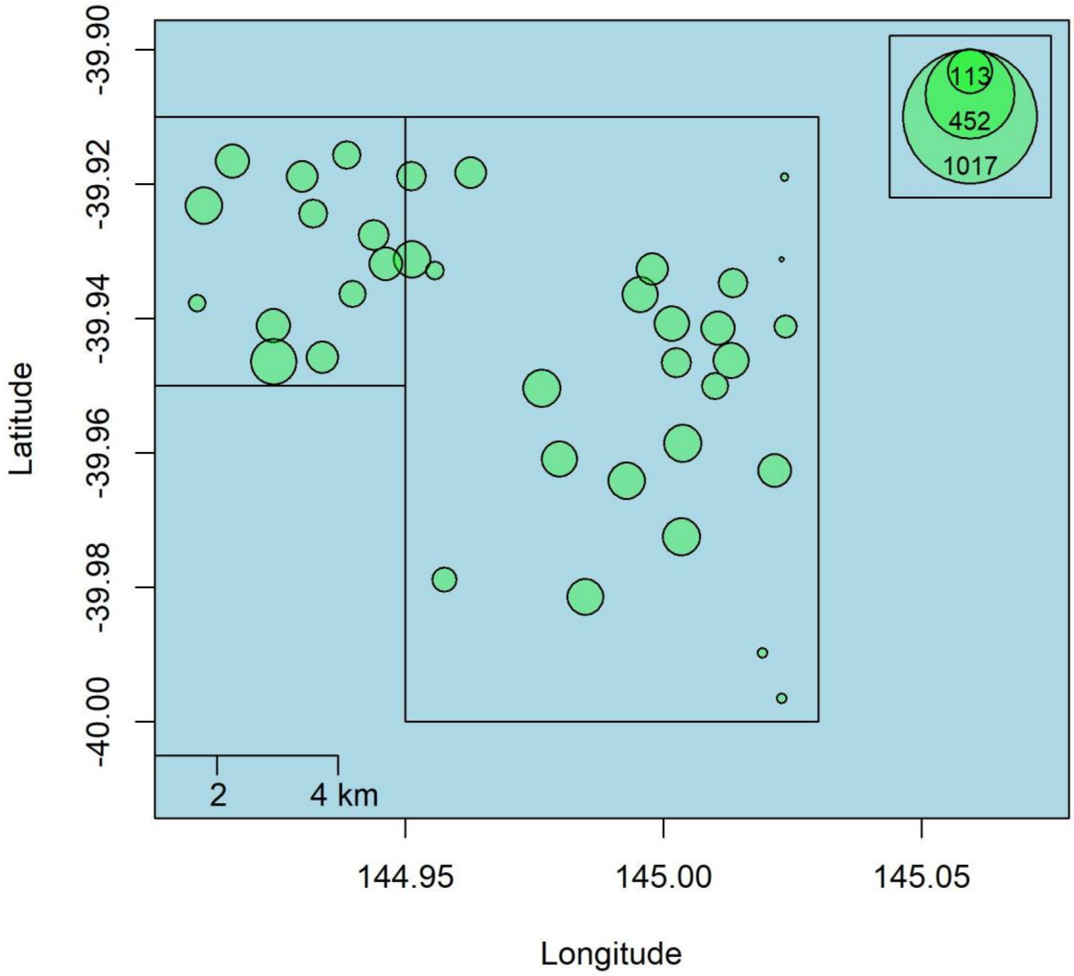

Figure 4. Scallop density (kg / 1000 m^2) within the defined stratum of the KI-5S bed near King Island. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

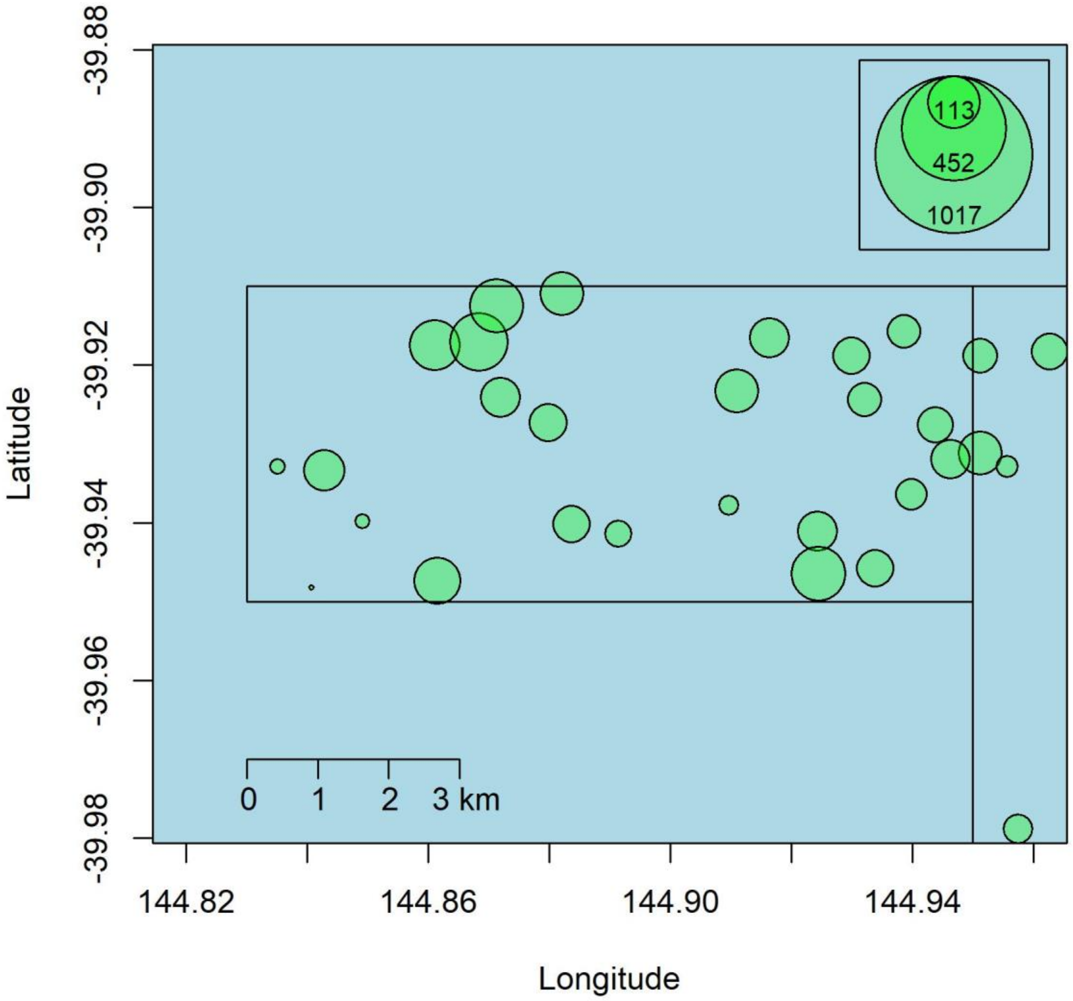

Figure 5. Scallop density (kg / 1000 m2) within the defined stratum of the KI-New bed near King Island. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

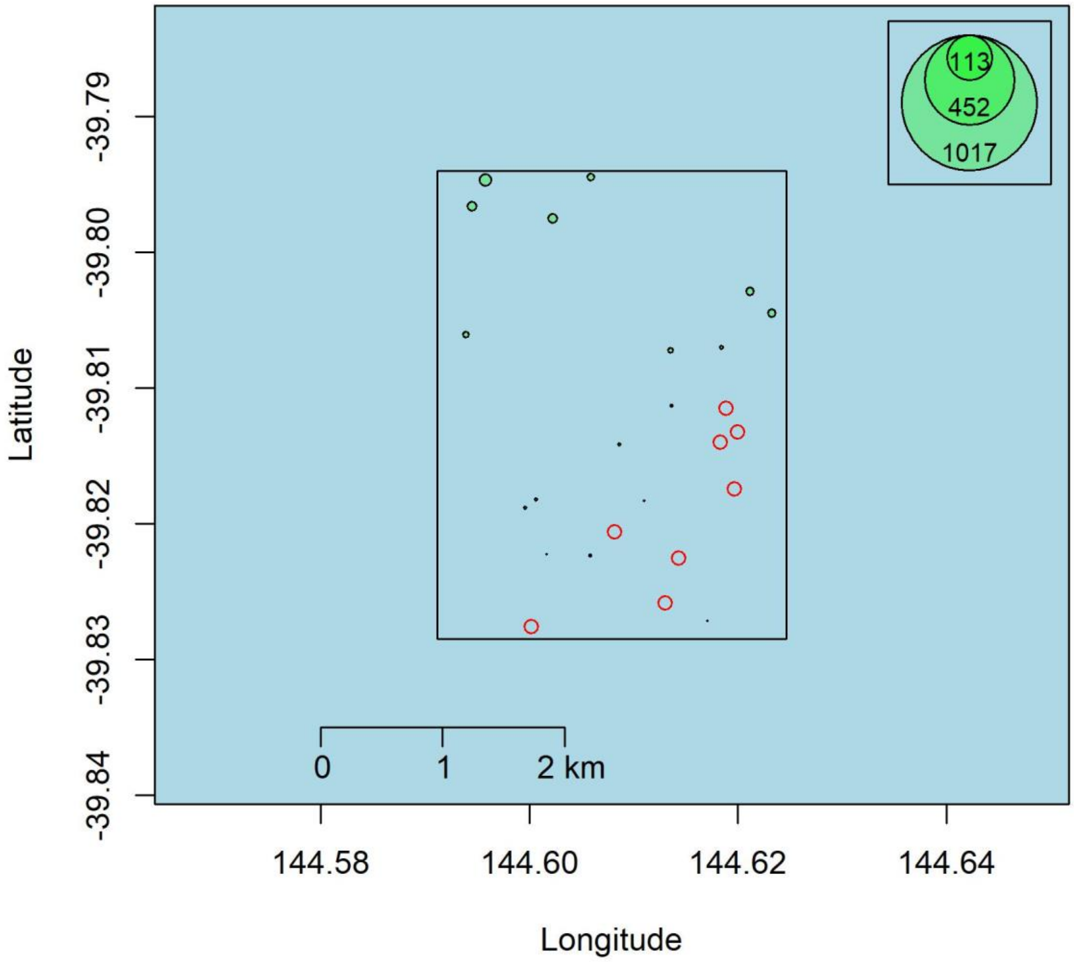

Figure 6. Scallop density (kg / 1000 m^2) within the defined stratum of the KI-Mid bed near King Island. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

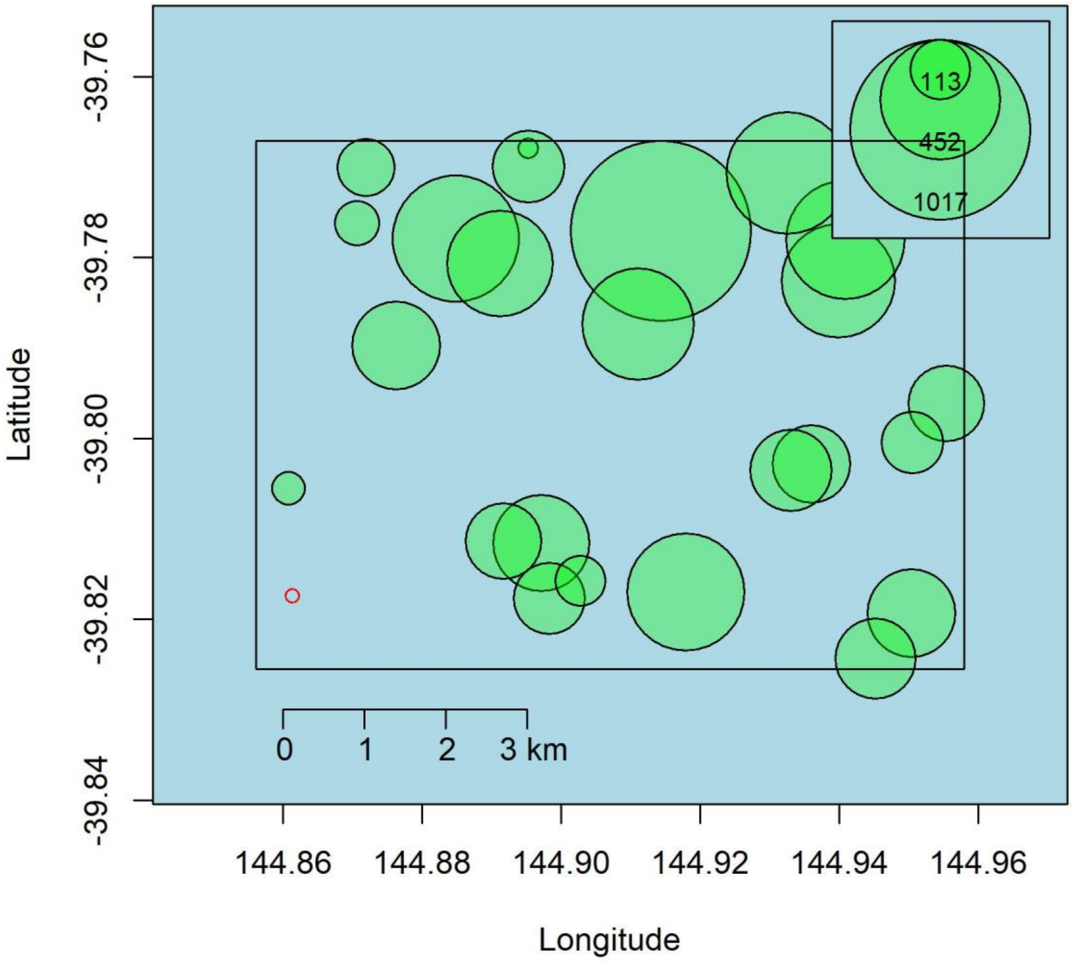

Figure 7. Scallop density (kg / 1000 m^2) within the defined stratum of the King Island Bluedot Extended bed near King Island. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

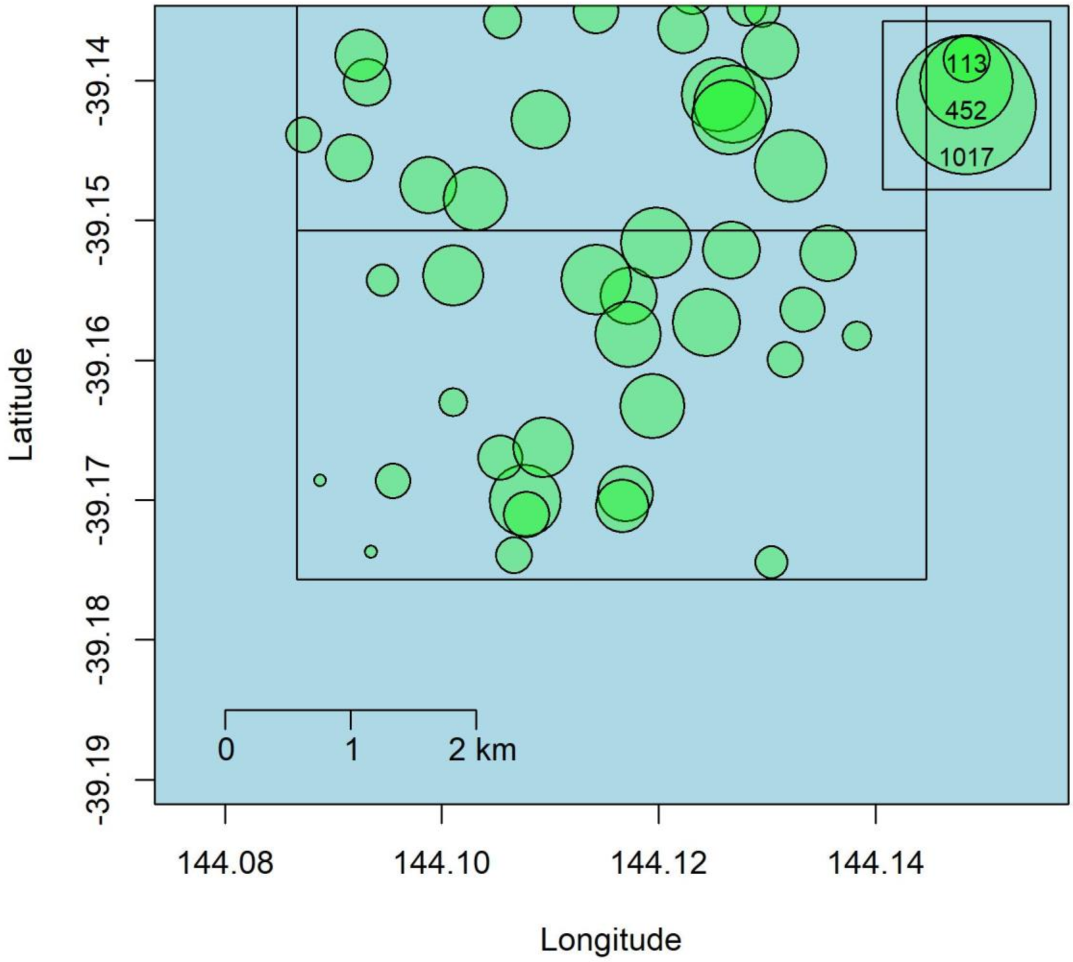

Figure 8. Scallop density (kg / 1000 m^2) within the defined stratum of the AB-1 bed near Apollo Bay. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

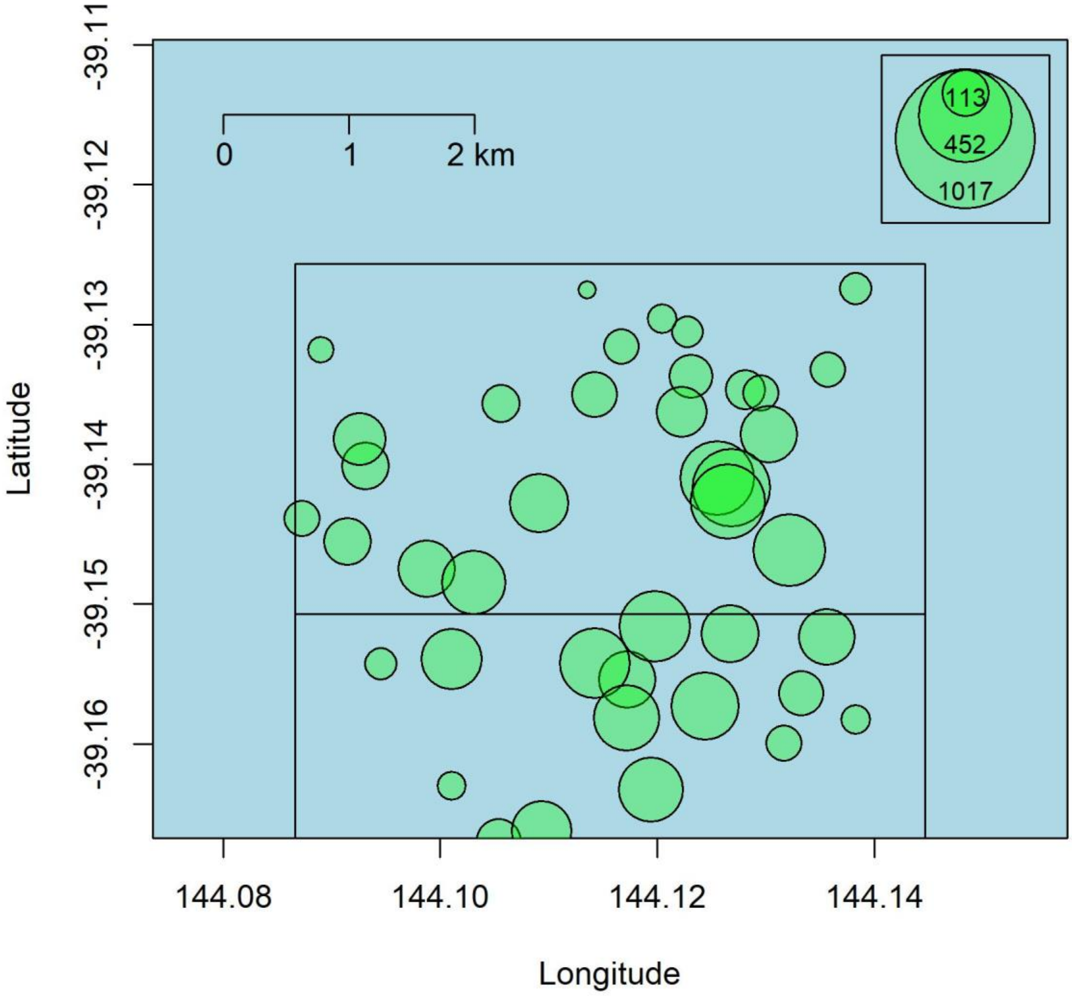

Figure 9. Scallop density (kg / 1000 m^2) within the defined stratum of the AB-2 bed near Apollo Bay. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

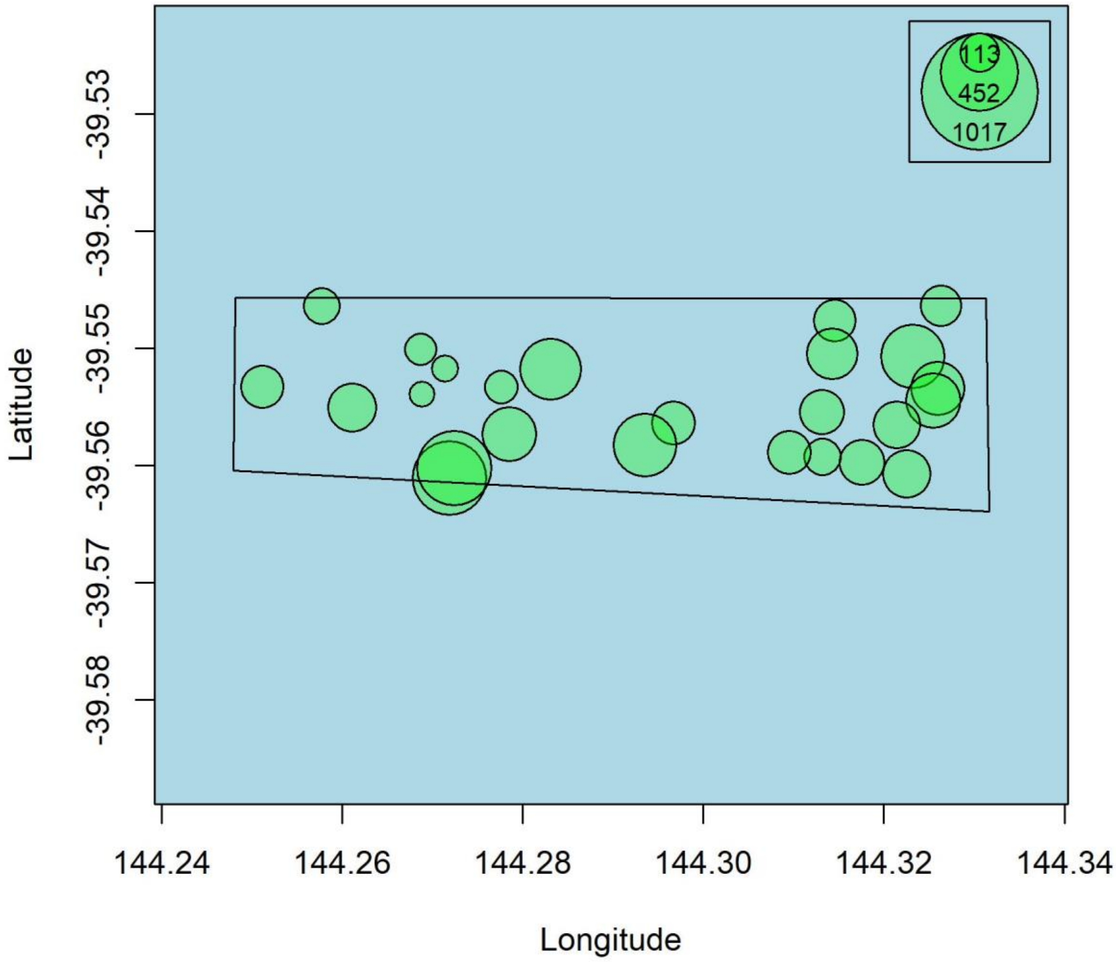

Figure 10. Scallop density (kg / 1000 m^2) within the defined stratum of the KI-6 bed near King Island. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

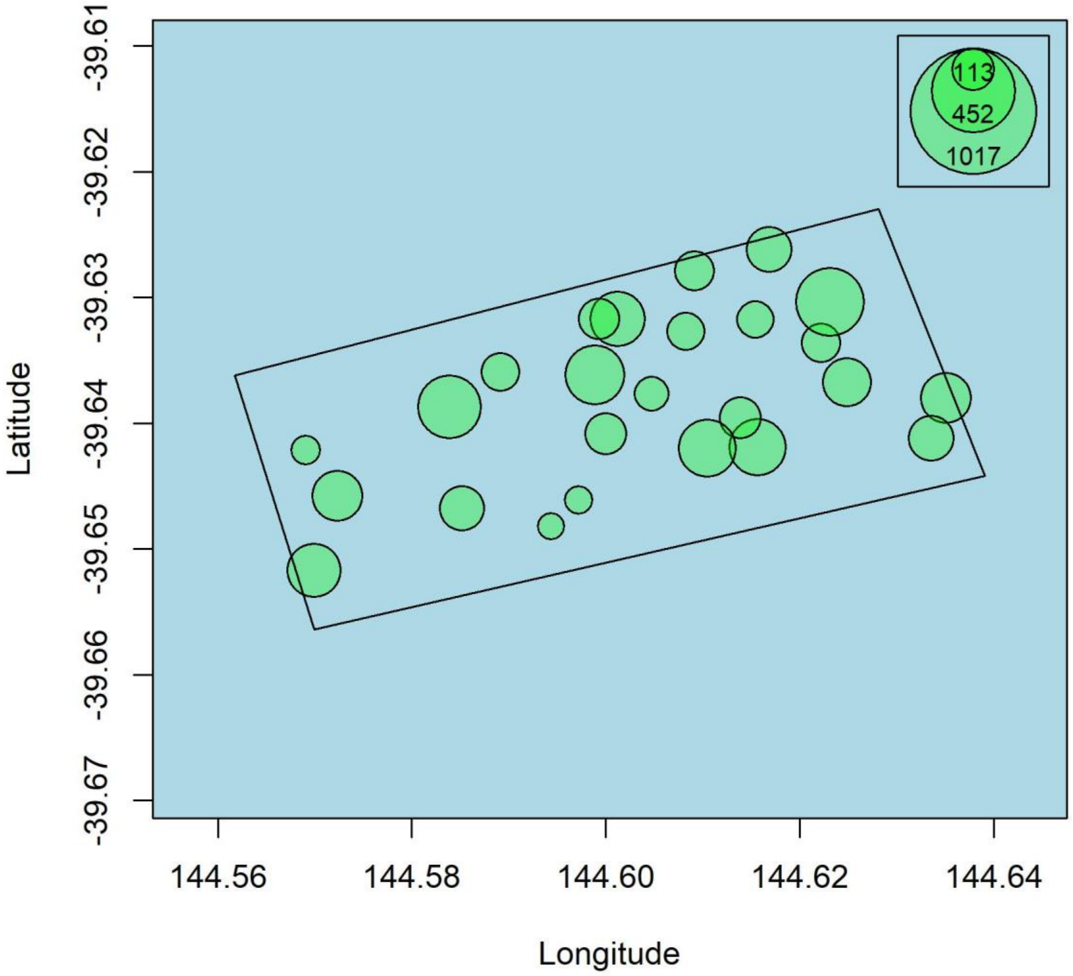

Figure 11. Scallop density (kg / 1000 m^2) within the defined stratum of the KI-7 bed near King Island. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

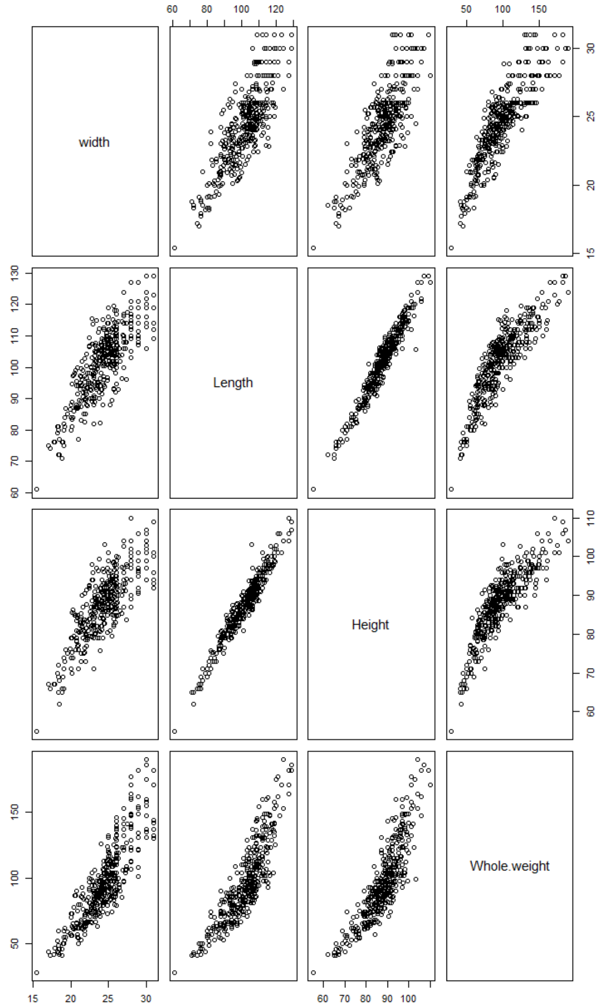

Figure 12. Scatterplot matrix of size measurements and total weight for all samples combined.

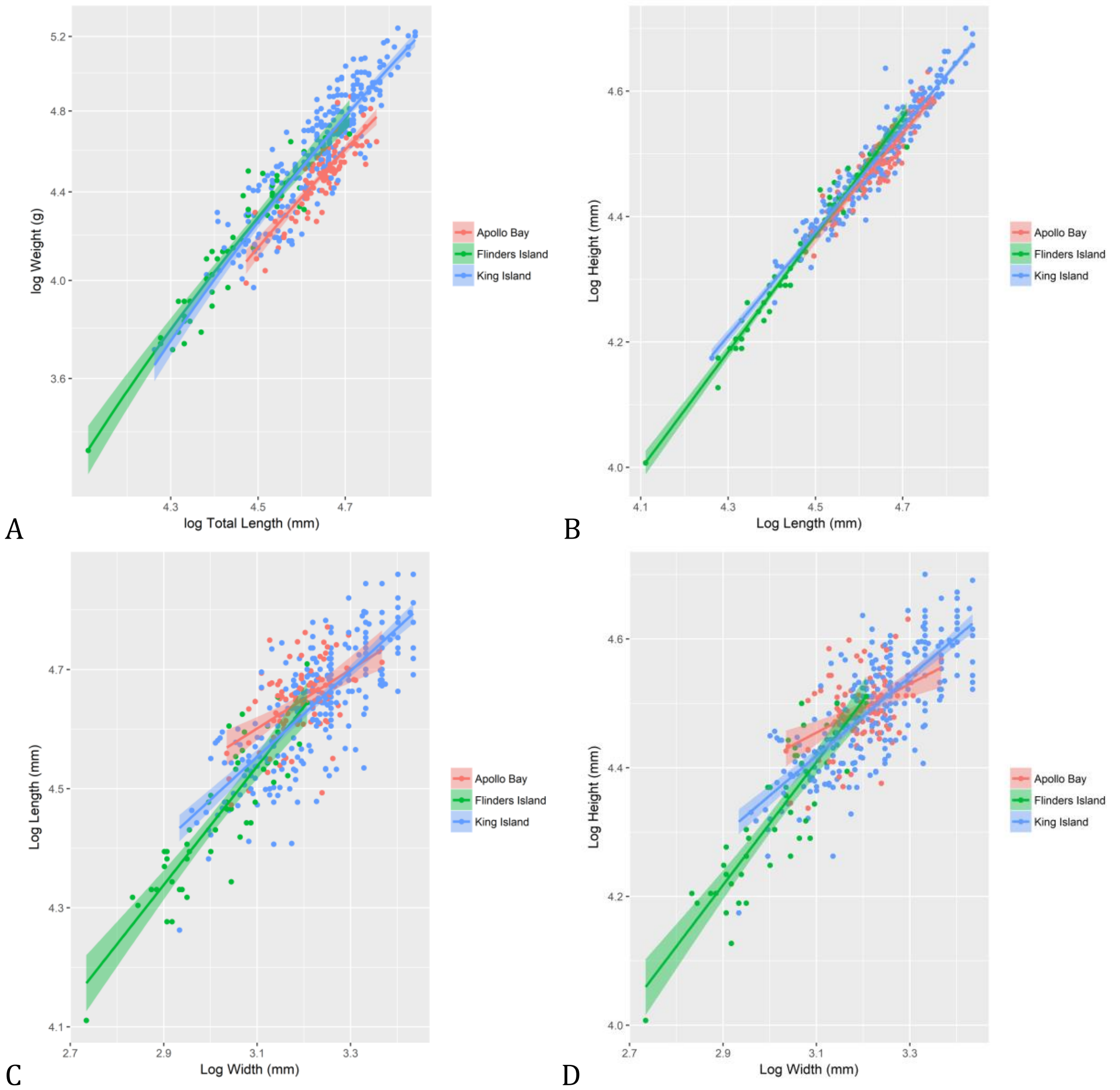

Figure 13. Log transformed A) length and weight, B) length and height, C) length and width and D) height and width from each bed.

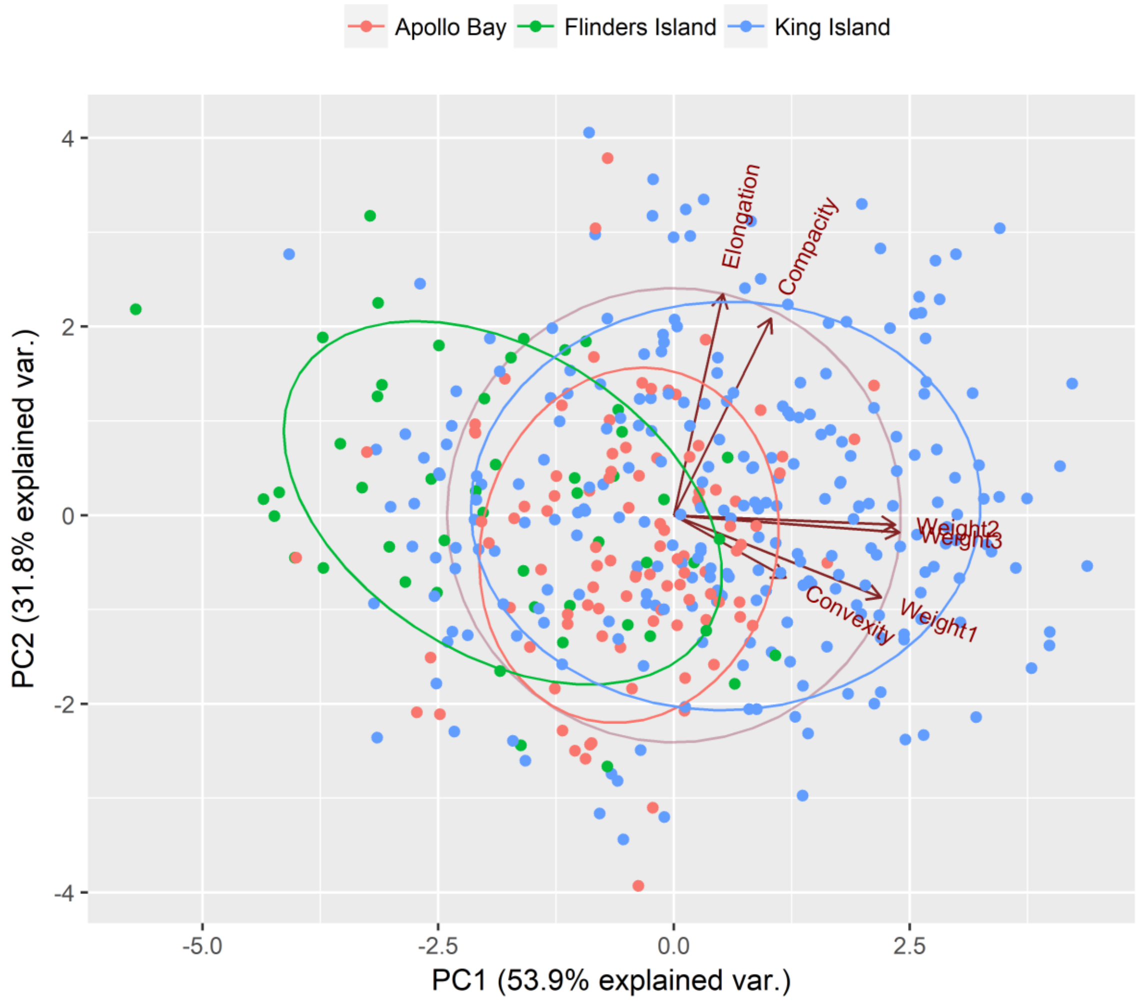

Figure 14. Principle component analysis on ratios of different shell measurements and weight: Elongation – length/width; Convexity – height/ width; Compacity - length / width; Weight1 – weight/ length, Weight2 – weight/ height, Weight1 – weight/ width.

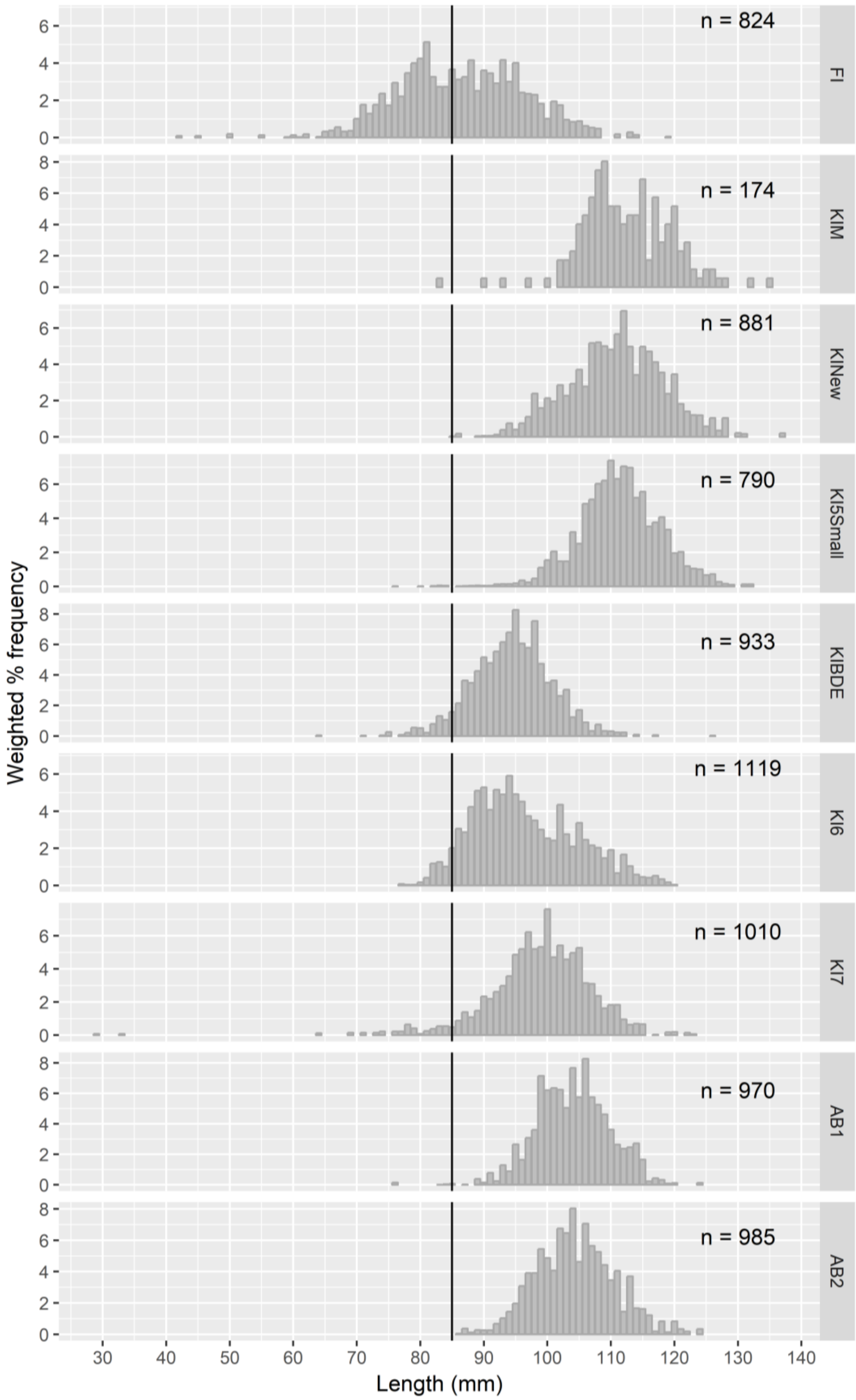

Figure 15. Catch weighted size frequency from shots included in biomass estimates from each bed. The vertical line is at 85 mm.

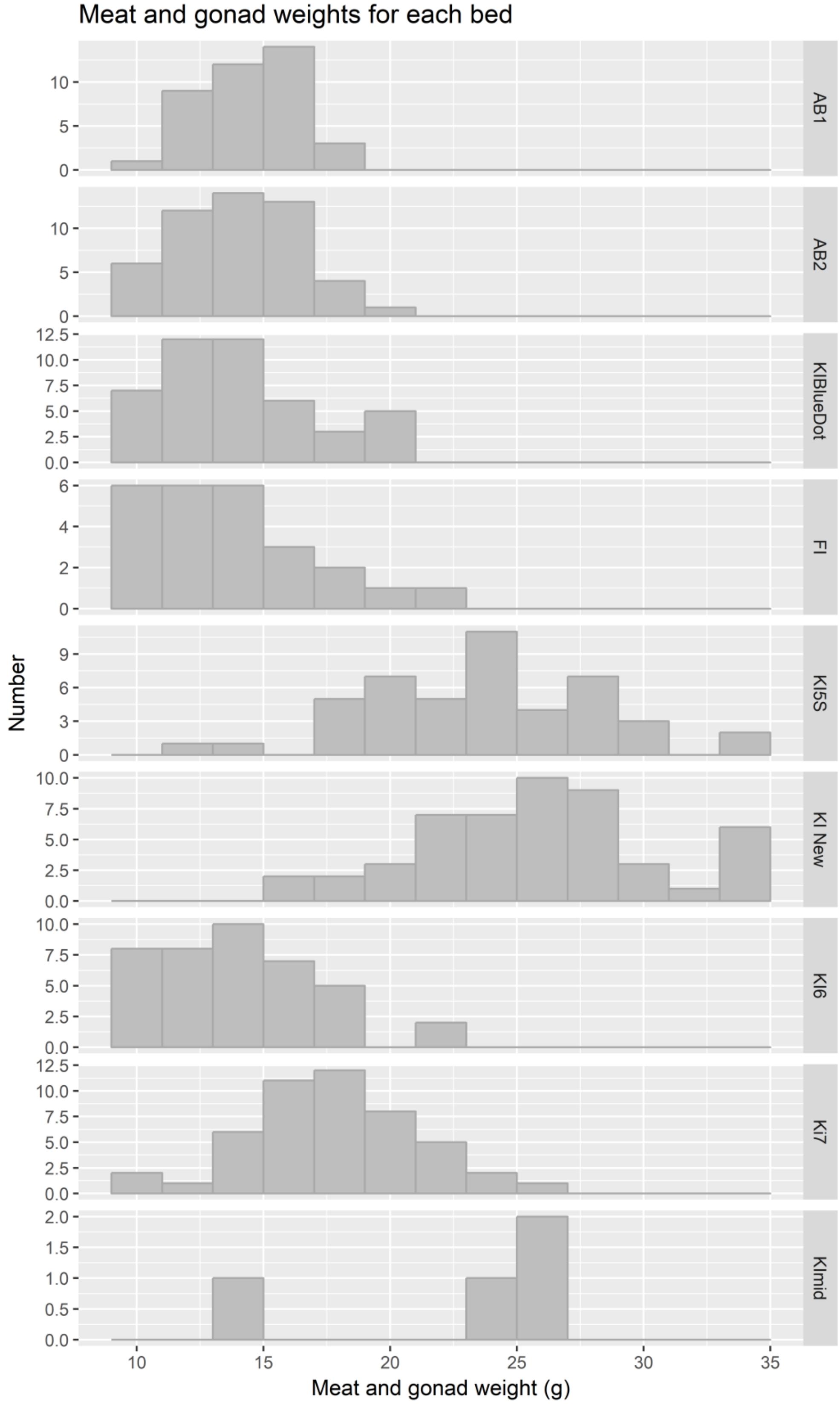

Figure 16. Frequency of combined meat and gonad weights of scallops >85 mm measured from each bed binned into 2 g weight categories.

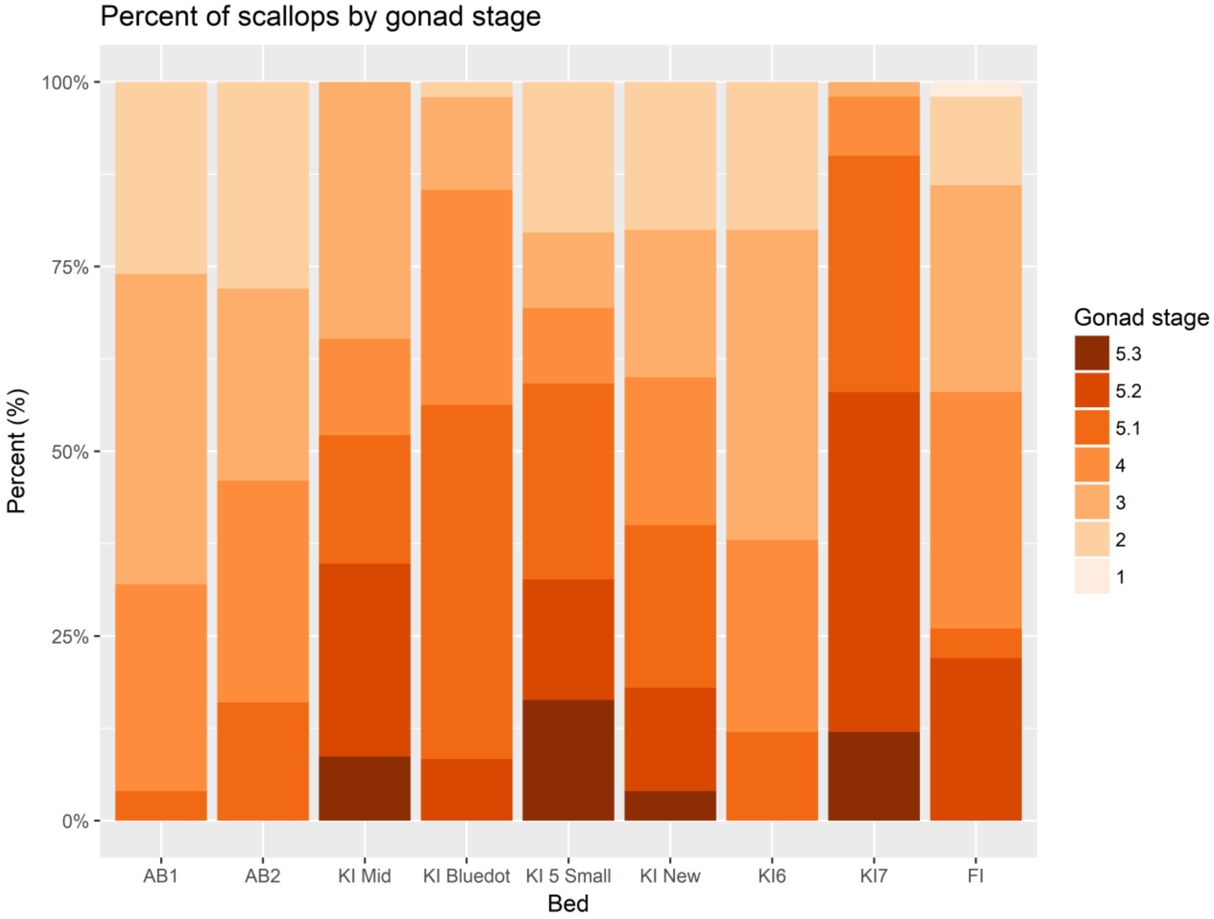

Figure 17. Percent of scallops at each stage from each bed based on macroscopic staging criteria.

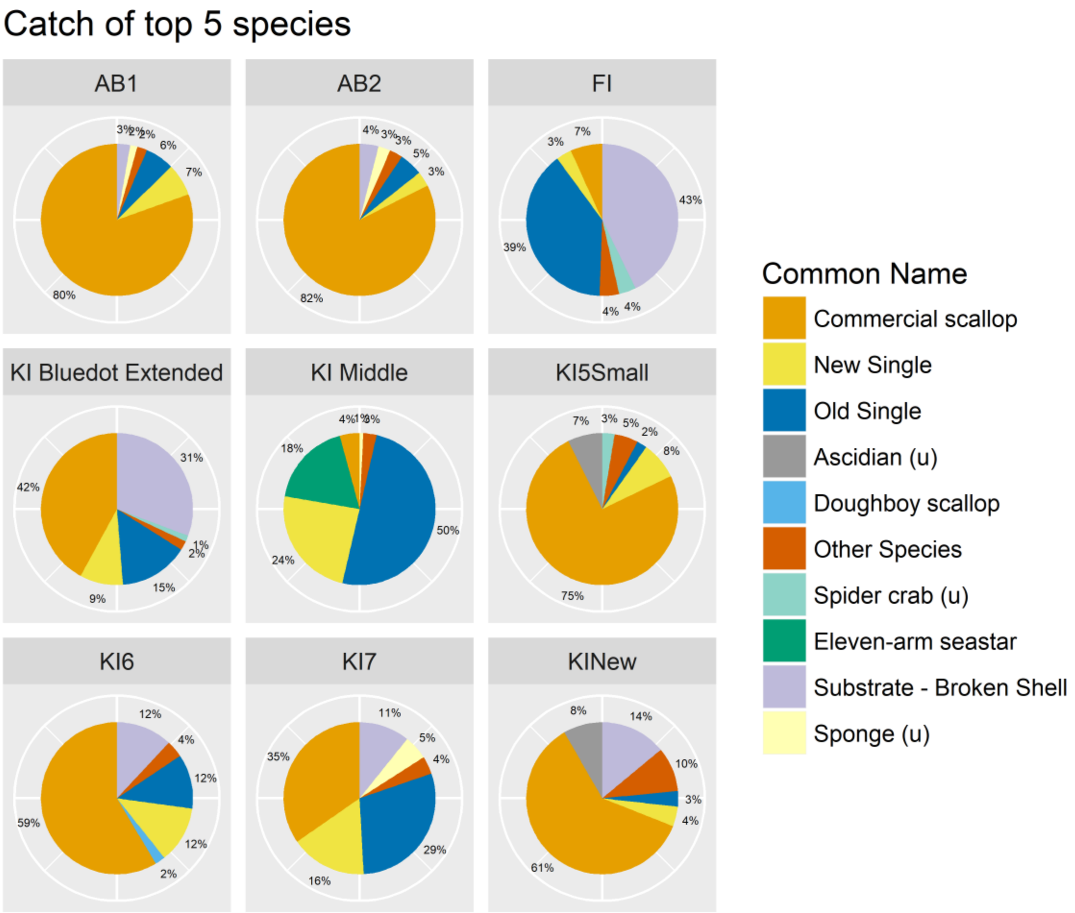

Figure 18. Percent catch composition in each bed sampled by weight from all beds.

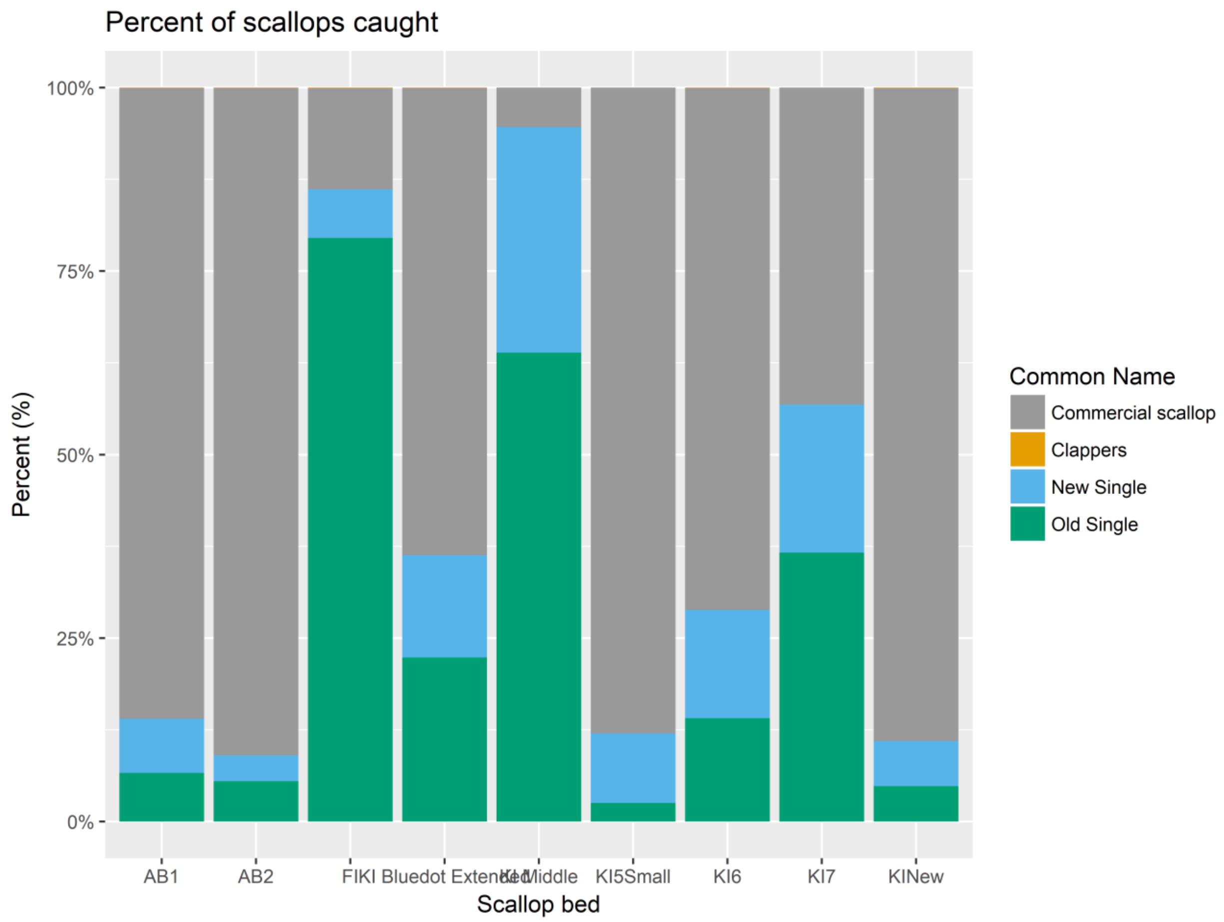

Figure 19. Percent composition of clappers, live scallop, new single and old single shell from each Bed.

Discussion

Main survey

Random stratified surveys were successfully undertaken on four scallop beds off each of Flinders Island, King Island and Apollo Bay (Figure 1, Figure 2, Table 4 and Table 5). Beds were selected based on a combination of previous surveys, fishing effort from the 2017 season, advice from ScallopRAG and the BSCZSF Co-management Committee and marks provided by industry. In total, 225 valid, random survey tows were undertaken. 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 (from the outside of the outermost tooth-bar).

Biomass had increased at the Flinders Island bed from the 2017 survey, totalling 2521.9 t, of which only 1,707.1 t was above 85 mm (Table 11), while the % weight of shell >85mm (determining the discard rate) was 68% (Table 11). Densities at Flinders Island were all below 0.269 individuals per m^2 (Table 11). No commercial catch was recorded from the Flinders Island bed during 2017 (Table 3). Like previous years, there was a significant amount of dead scallop shell in the catch (Figure 19).

Biomass in KI-BDE, the bed from which nearly half of the 2017 season commercial catch was taken (see Table 3), increased from a total of 11,809.2 t in 2017 (see Appendix 2) to 14,617.3 t in 2018, with 14,095.2 t > 85 mm (Table 11). This increase in biomass is in line with the progressively increasing length frequency distribution in that bed (see Appendix 2). Density at this site was 2.882 individuals per m^2 (Table 11). Significant biomasses were also observed at KI-5S, KI-New, KI-6 and KI-7, ranging 1,987.8 t (> 85 mm) at KI-7 to 3,526.9 t (> 85 mm) at KI-5S (Table 11). Densities at those beds ranged 0.372 individuals per m^2 at KI-5S to 2.4 individuals per m^2 at KI-6. KI-Mid continues to show signs of significant natural mortality since 2016, and nor any sign of recent recruitment.

The Apollo Bay beds were closed during the 2017 season. These beds had similar biomass estimates of 1,890.5 t >85 mm and 1,803.8 t >85 mm in AB-1 and AB-2 respectively, with densities of 1.5 individuals per m^2 and 1.4 individuals per m^2 (Table 11). The lengths of nearly all scallops measured from those 2 sites were greater than 85 mm.

Table 11. Summary of data used to inform the ScallopRAG and ScallopMAC recommendation for 2018 harvest strategy requirements and TAC.

Area	Bed	Estimated biomass (t)	% weight > 85 mm	Estimated biomass (t)>85 mm	Density (ind/m^2)	Mean size	Meats / kg
FI	FI-1	2521.9	67.7	1707.1	0.269	86	72
	Sub-total	**2521.9**		**1707.1**			
KI	KI-5S	3529.4	99.9	3526.9	0.372	110	41
KI	KI-BDE	14617.3	96.4	14095.2	2.882	94	68
KI	KI-Mid	16.3	99.7	16.2	0.014	112	44
	KI-New	2780.5	100	2780.5	0.406	110	38
	KI-6	2360.5	97.1	2291.7	2.368	97	69
KI	KI-7	2036.5	97.6	1987.8	1.293	99	55
	Sub-total	**25340.5**		**24698.2**			
AB	AB-1	1892.3	99.9	1890.5	1.502	103	67
AB	AB-2	1803.8	100	1803.8	1.408	104	69
	Sub-total	**3696.1**		**3694.3**			
	Total	**31558.5**		**30099.6**			

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Appendix 1 –methods

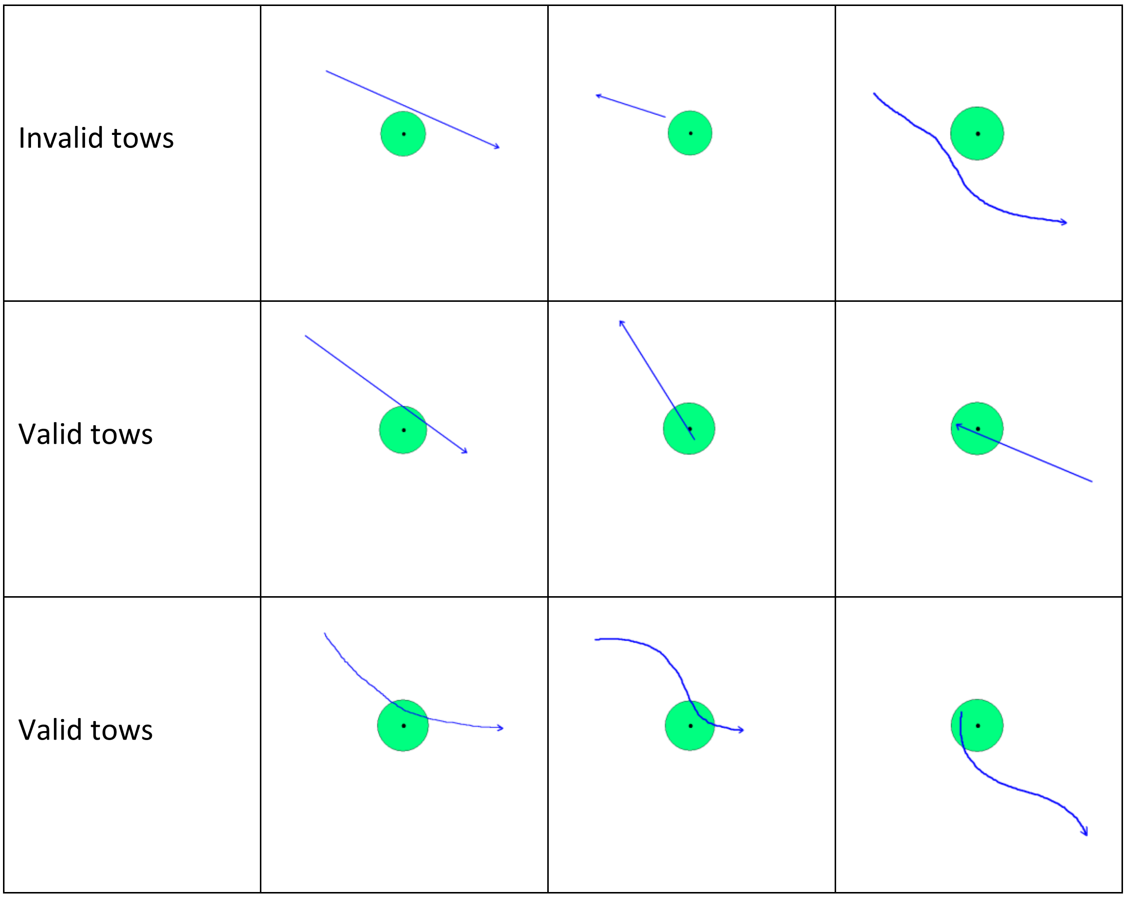


Figure 20. How to conduct a valid survey tows. Green circle is 100 m radius.

Table 12. Gonad maturation scheme for macroscopic field staging of scallops (taken from Harrington *et al*., 2010).

Stages	Description
1	Immature. Small strap-like organ, transparent and with the intestine seen looping through it.
2	Similar to stage-1, but gonad larger. Completely spawned scallops may revert to this stage.
3	Early developing. Gonad larger with male and female components distinguishable, but with the intestine visible through the wall of the testis and ovary. Ovary becoming orange.
4	Gonad larger than stage-3. Intestine only in the male part of the gonad. Ovary becoming orange.
5	Gonad larger than stage-4, intestine not visible. Ovary orange. Will be sub-categorised as stage 5.1 – 5.3 (see Table 1b)
6	Ripe. Gonad very large and full, ovary bright orange. Difficult to differentiate from stage-5.
7	Running ripe. Expresses when light pressure applied.
8	Spent

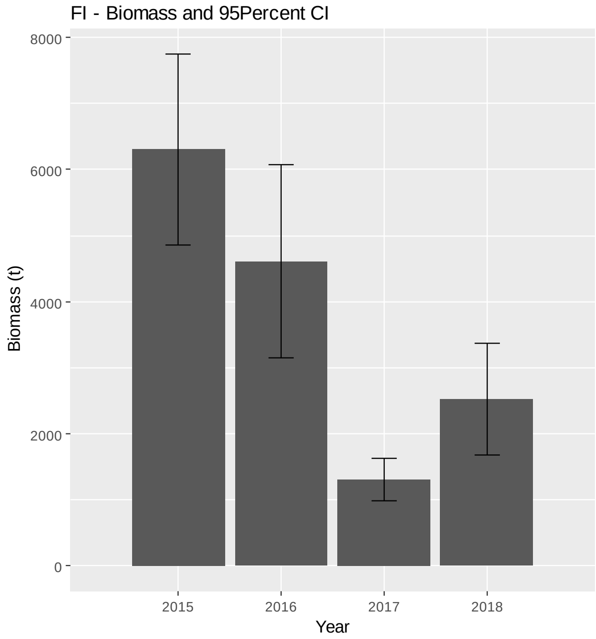
Table 13. Gonad maturation scheme for macroscopic field staging of scallops (taken from Harrington *et al.*, 2010).

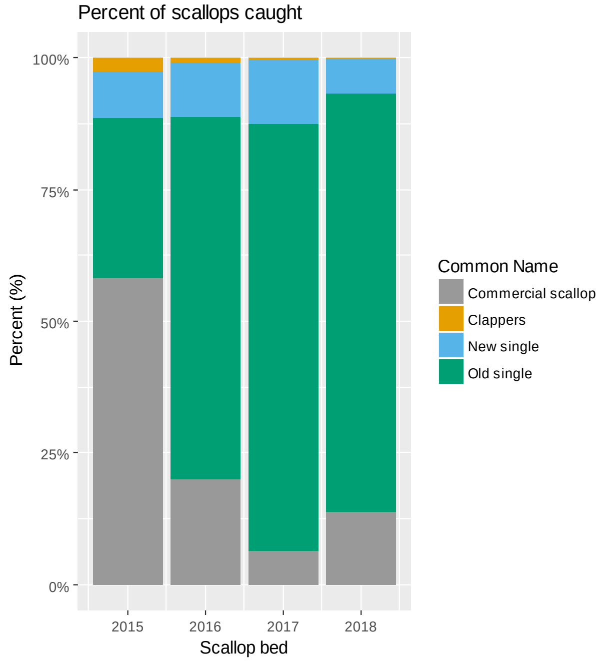
Stages	Description
5.1	Ovary orange. Intestine not visible. Gonad smaller than size of meat.
5.2	Ovary orange. Intestine not visible. Gonad approximately equal to size of meat.
5.3	Ovary orange. Intestine not visible. Gonad larger than size of meat.

Appendix 2 – Time series data

Flinders Island (FI)

2017commercial catch	0 t
2018 biomass	2521.9 t
Change since 2015	-3787 t





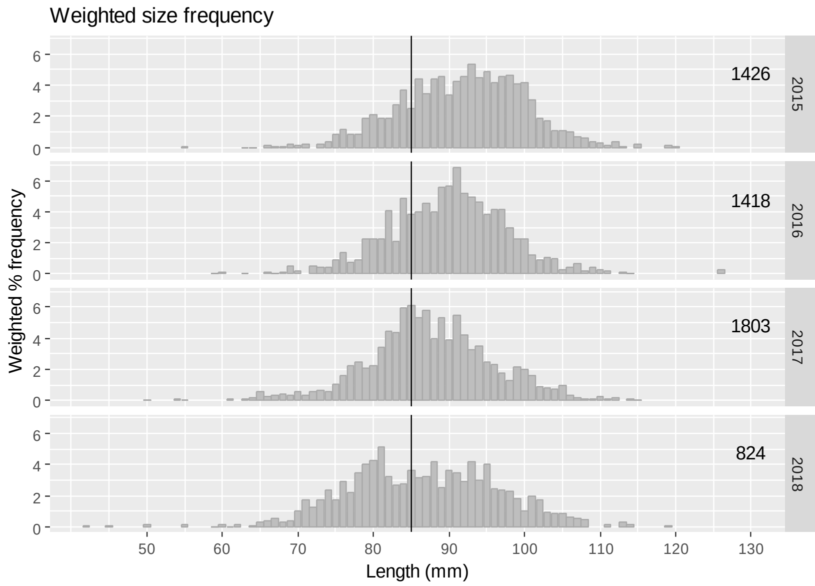
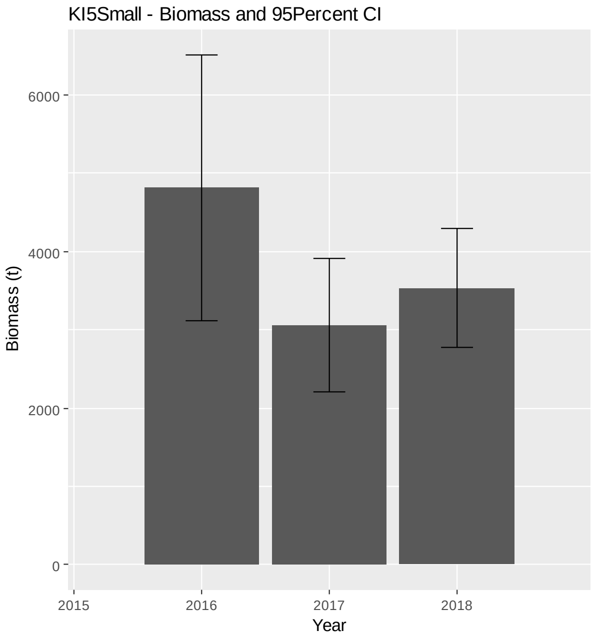
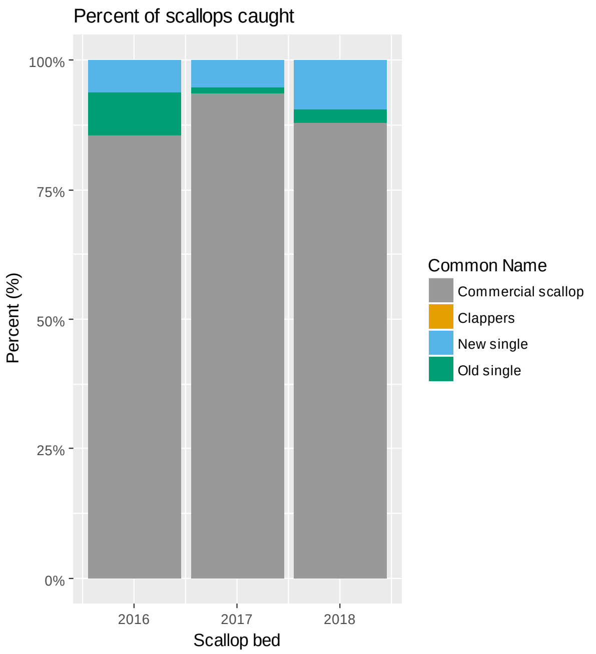


Figure 21. Summary of commercial catch, biomass, change in biomass, percent composition of live scallops and dead scallop shell and size frequency distribution from 2015 to 2018 from within the FI bed boundaries used during the 2018 survey. Note that while data included in these results are from tows conducted within the FI bed boundaries used during the 2018 survey, the previous surveys were designed based on different areas (Figure 1, Table 1).

King Island 5 Small (KI-5S)

2017 commercial catch	0 t
2018 biomass	3529.4 t
Change since 2016	-1289 t





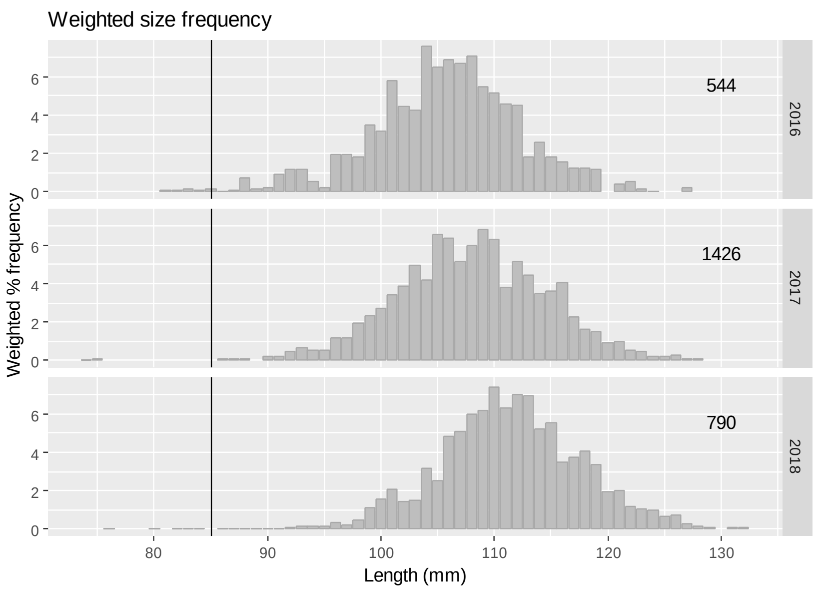


Figure 22. Summary of commercial catch, biomass, change in biomass, percent composition of live scallops and dead scallop shell and size frequency distribution from 2016 to 2018 from within the KI 5 Small bed boundaries used during the 2018 survey. Note that while data included in these results are from tows conducted within the KI-5S bed boundaries used during the 2018 survey, previous surveys were designed based on different areas (Figure 1, Table 1).

King Island Bluedot Extended (KI-BDE)

2017 commercial catch	1351 t
2018 biomass	14617.3 t
Change since 2016	5230 t

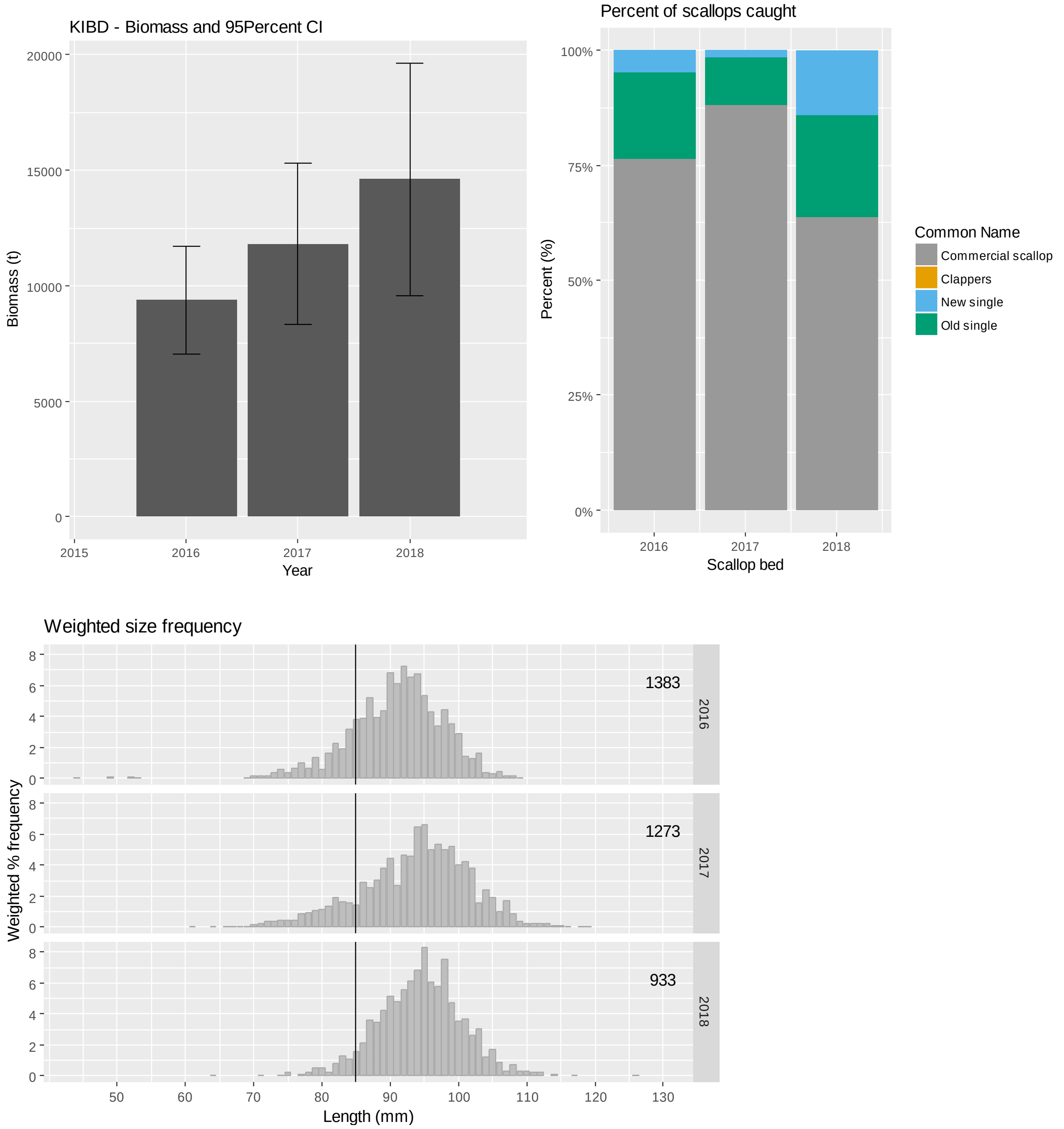


Figure 23. Summary of commercial catch, biomass, change in biomass, percent composition of live scallops and dead scallop shell and size frequency distribution from 2016 to 2018 from within the KI-BDE bed boundaries used during the 2018 survey. Note that while data included in these results are from tows conducted within the KI-BDE bed boundaries used during the 2017 survey, previous surveys were designed based on different areas (Figure 1, Table 1).

King Island Middle (KI-Mid)

2017 commercial catch	NA
2018 biomass	16.3 t
Change since 2015	-561 t

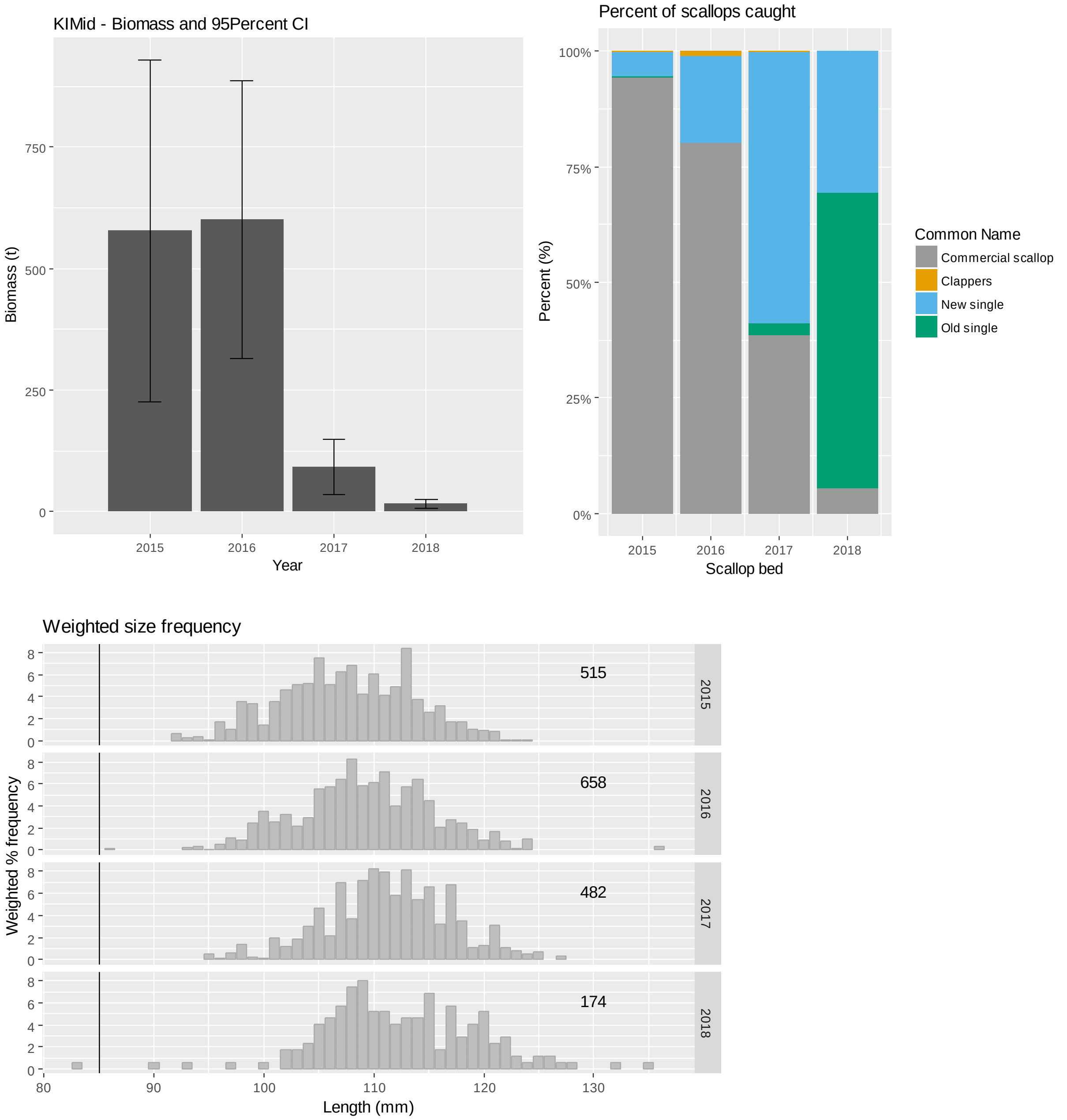


Figure 24. Summary of commercial catch, biomass, change in biomass, percent composition of live scallops and dead scallop shell and size frequency distribution from 2015 to 2018 from within the KI Middle bed boundaries used during the 2018 survey.

King Island New (KI-New)

2017 commercial catch	NA
2018 biomass	2780.5 t
Change since 2015	121 t

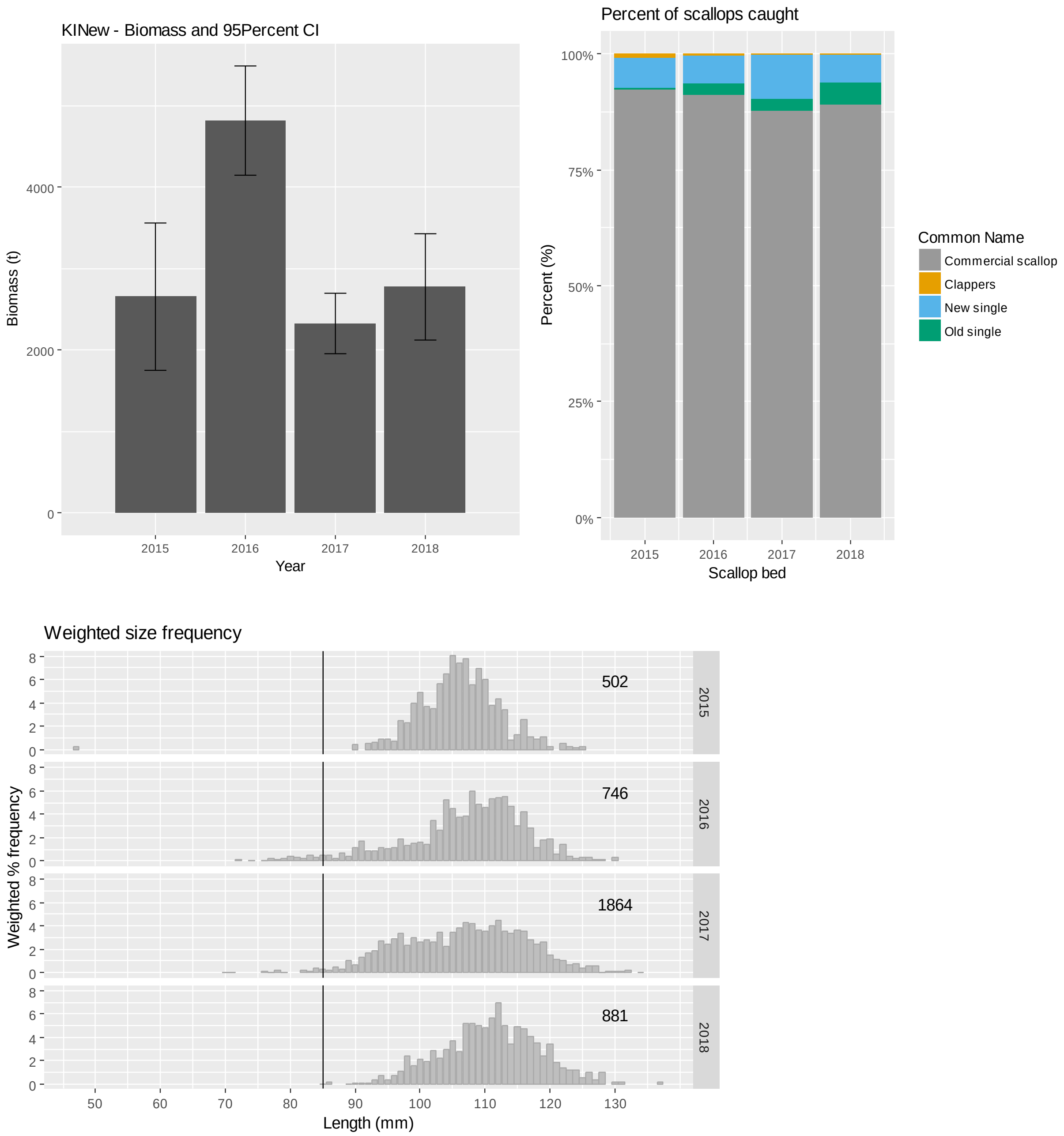


Figure 25. Summary of commercial catch, biomass, change in biomass, percent composition of live scallops and dead scallop shell and size frequency distribution from 2015 to 2018 from within the KI New bed boundaries used during the 2018 survey. Note that while data included in these results are from tows conducted within the KI New bed boundaries used during the 2018 survey, previous surveys were designed based on different areas (Figure 1, Table 1).

Apollo Bay 1 (AB1)

2017 commercial catch	0 t
2018 biomass	1892.3 t
Change since 2017	-286 t

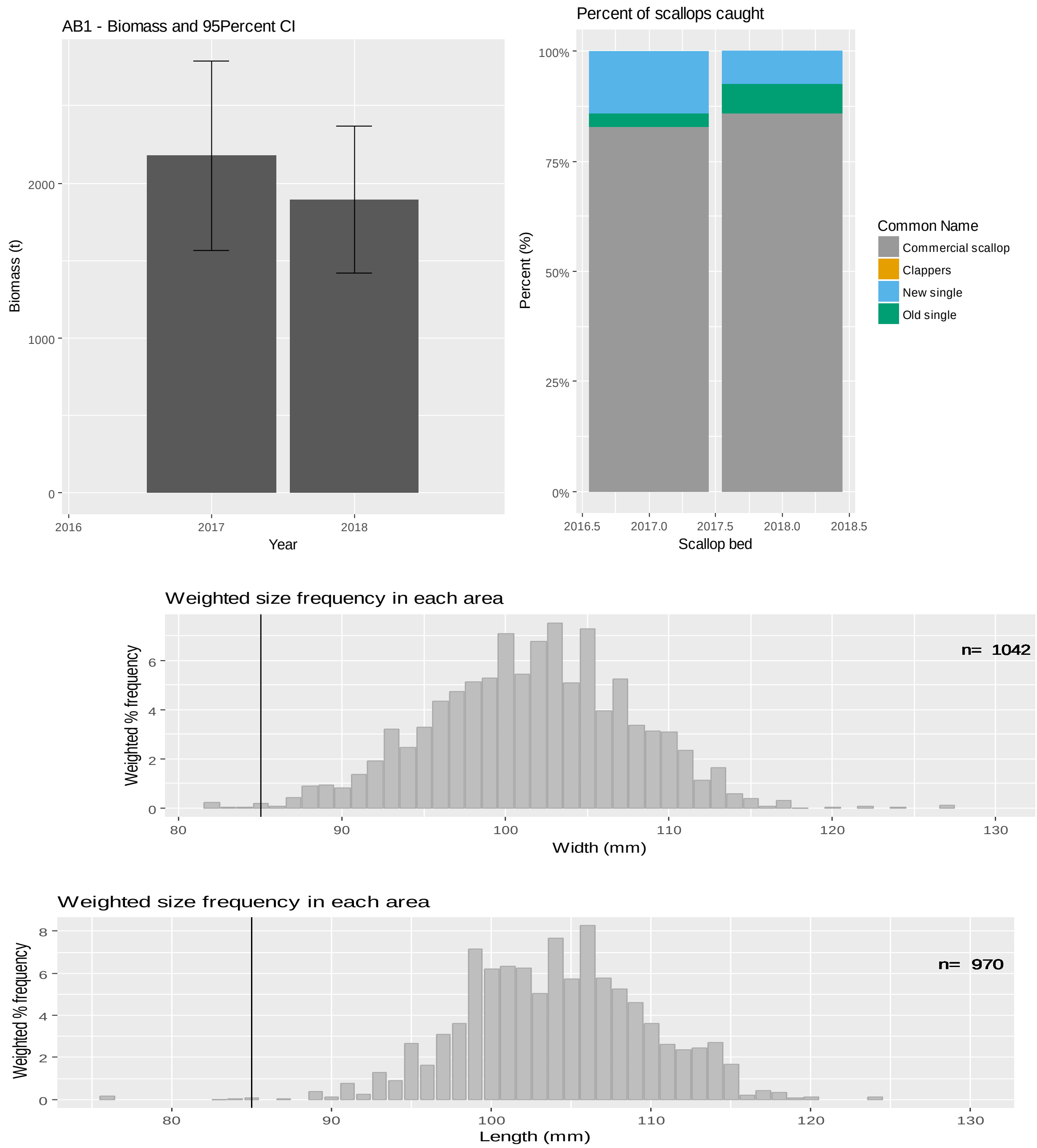


Figure 26. Summary of commercial catch, biomass, change in biomass, percent composition of live scallops and dead scallop shell and size frequency distribution from 2017 to 2018 from within the AB-1 bed boundaries used during the 2018 survey.

Apollo Bay 2 (AB2)

2017 commercial catch	0 t
2018 biomass	1803.8 t
Change since 2017	-1057 t

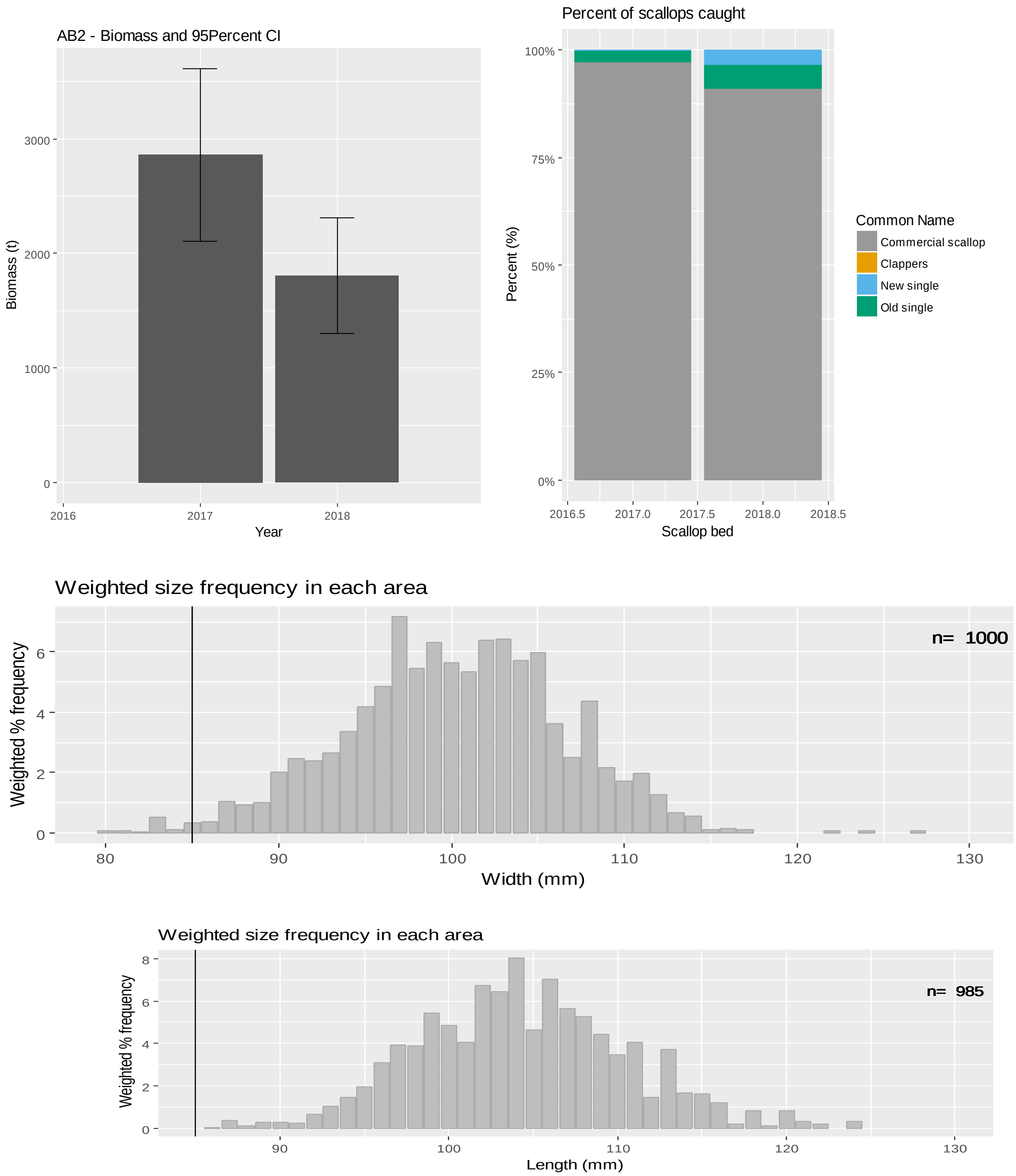


Figure 27. Summary of commercial catch, biomass, change in biomass, percent composition of live scallops and dead scallop shell and size frequency distribution from 2017 to 2018 from within the AB-2 bed boundaries used during the 2018 survey.