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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 150 t research catch allowance 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 \leq 2,000 t) or Tier 2 (catches $>$ 2,000 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 2022 research surveys.

Four commercial fishing vessels were selected by an independent panel to conduct the 2022 scallop surveys: the Shandara, Northern Star, Odete C and the Rachel Maree. During May 2022, stratified random surveys were conducted using these vessels on three beds in the Flinders Island (FI) region, five beds in the King Island (KI) region and two beds in the Apollo Bay (AB) region. Choice and prioritisation of these beds was based on previous surveys and commercial catches from 2021, and input from the Scallop Resource Assessment Group (ScallopRAG) and the Industry Co-Management Committee. Beds surveyed during 2022 were a combination of new beds and beds that had been previously surveyed. Both of the new beds for 2022 were in the FI region. Biomass estimates were 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 85 mm was estimated to be 13,064 t at the two AB beds, 5,005 t at the three FI beds and 13,824 t at the FI beds (Table 9). Total biomass greater than 85 mm at all sites combined was 31,893 t. The percent of Commercial Scallops greater than 85 mm was more than 80% at most sites, while only 46.9%, 38.2% and 49.4% of Commercial Scallops were greater than 85 mm at KI – 7, KI – 9 and KI – Blue Dot South East (BDSE) respectively. The lower percentage of larger scallops at these sites is attributed to significant recent recruitment. Densities in individuals per m² ranged 0.05 at KI – (Blue Dot Extended) BDE to 2.39 at AB – The Hill (Table 9).

Catch composition varied greatly between beds. Overall, live Commercial Scallops comprised 30% of the catch, while Broken Shell (20%), Old Single Shell (14%). The other 36% of the catch comprised a total of 60 different bycatch species / groups with significant amounts of sponges and ascidians. Several high risk species were recorded. One Southern Blue-Ringed Octopus was recorded from a tow at each at FI – North of Babel (NB) and FI – The Wreck B. Some Black and White Seastars were also recorded. Observers identified King Island Thickshell-Clams at a number of sites but the large number of mollusc species present in catches, lack of obvious identifying features and lack of time inhibits the observers' ability to accurately identify every mollusc species.

These results were presented at the ScallopRAG meeting on 7 June 2022 and at the Scallop Management Advisory Committee (ScallopMAC) meeting on 9 June 2022.

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1 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 must be adaptable to sometimes rapidly changing circumstances, yet still ensure protection of the resource in line with the *Commonwealth Fisheries Harvest Strategy Policy 2018* (HSP).

Under the original 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 (the 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 150 t research catch allowance 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 catch allowance 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 $\geq 1,500$ tonnes in total of high density scallops of a minimum size of 85 mm. The season begins with a 1,000 t total allowable catch (TAC) that can be increased to 2,000 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 $\geq 3,000$ tonnes in total of scallops of a minimum size limit of 85 mm of high density. The season begins with a 2,000 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 2022 stratified random surveys.

1.1 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, the Scallop Resource Assessment Group (ScallopRAG) and the Scallop Management Advisory Committee (ScallopMAC).

2 Methods

2.1 Survey History

The 2015 survey covered three beds in the King Island (KI) region and one bed in the Flinders Island region (Figure 3). To provide greater flexibility in management arrangements regarding closures, this was expanded in 2016 with the addition of an extra four sites in the KI region and another site in the FI region (Figure 3, Table 1). 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 KIMain 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. They comprised previously surveyed beds, modified beds and new exploratory beds. In 2018 two beds were added off King Island, while Apollo Bay (AB)-3, AB-4, FI-3 and FI-4 were not surveyed. In 2019 as well as the FI bed, AB 1 and 2 were surveyed, and two new beds (one stretching south-east of KI Bluedot Extended (BDE) and another called the KI-JH bed comprising high density of juvenile scallops) were added. To protect the juveniles at KI-JH, sampling intensity was reduced, and a fine mesh cover was placed over half of the dredge to better sample small scallops. No survey was undertaken in 2020 because of concerns regarding the Covid-19 outbreak. Twelve beds were surveyed in 2021 when the FI -The Sisters and FI- North of Babel (NB) beds were added in the FI region, the KI-JH site was extended to the southeast, AB-2 was extended to the north and AB-The Hill and AB-Five Hours sites were added in the AB region. The beds surveyed in 2022 were based on previous surveys, analysis of 2021 catch and effort data and advice from the ScallopRAG and the BSCZSF Co-Management Committee.

Changes to the beds surveyed since 2015 are outlined in Table 1.

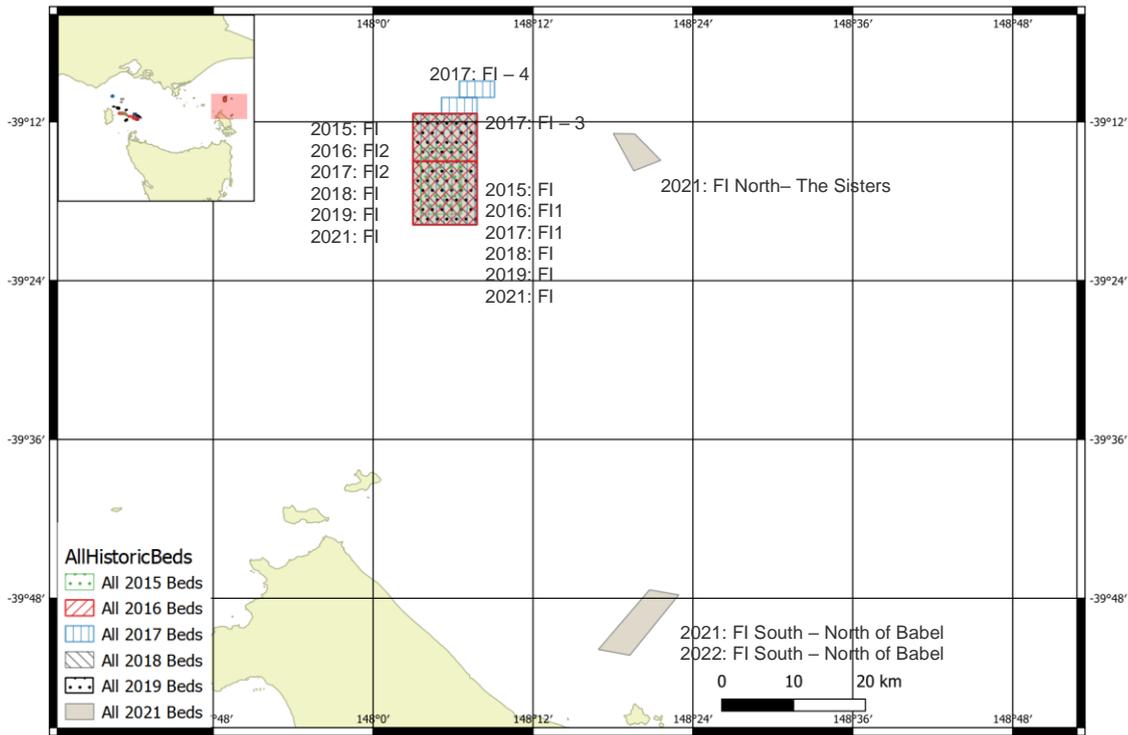


Figure 1. History of beds surveyed off Flinders Island from 2015 to 2021.

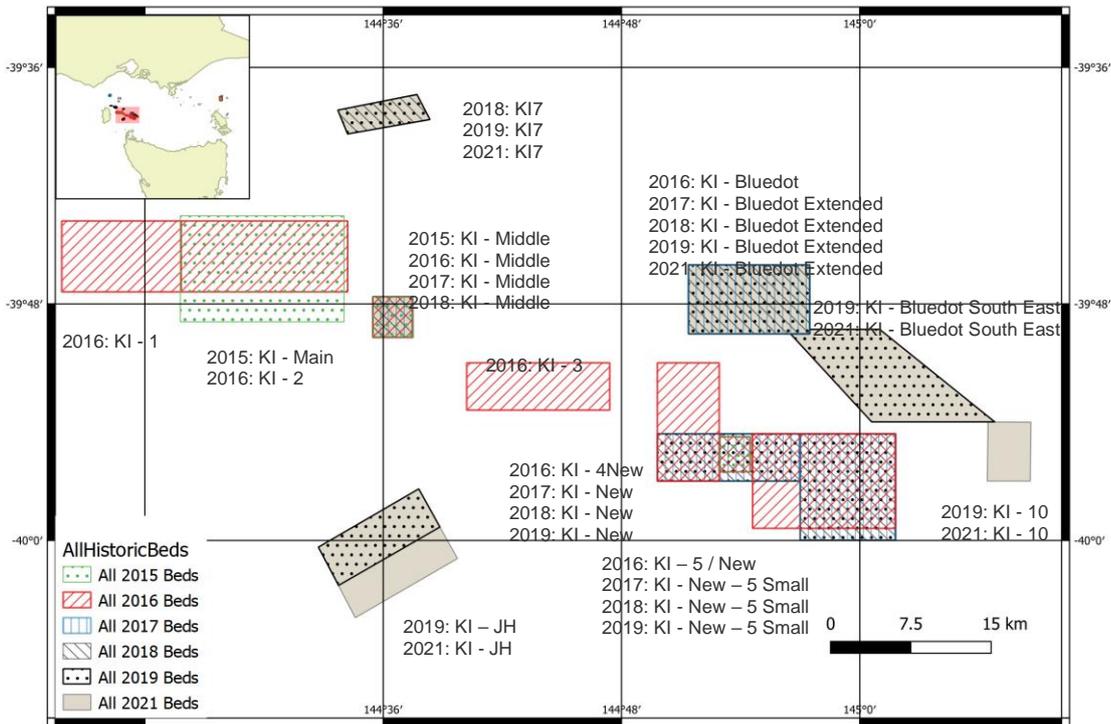


Figure 2. History of beds surveyed off King Island from 2015 to 2021.

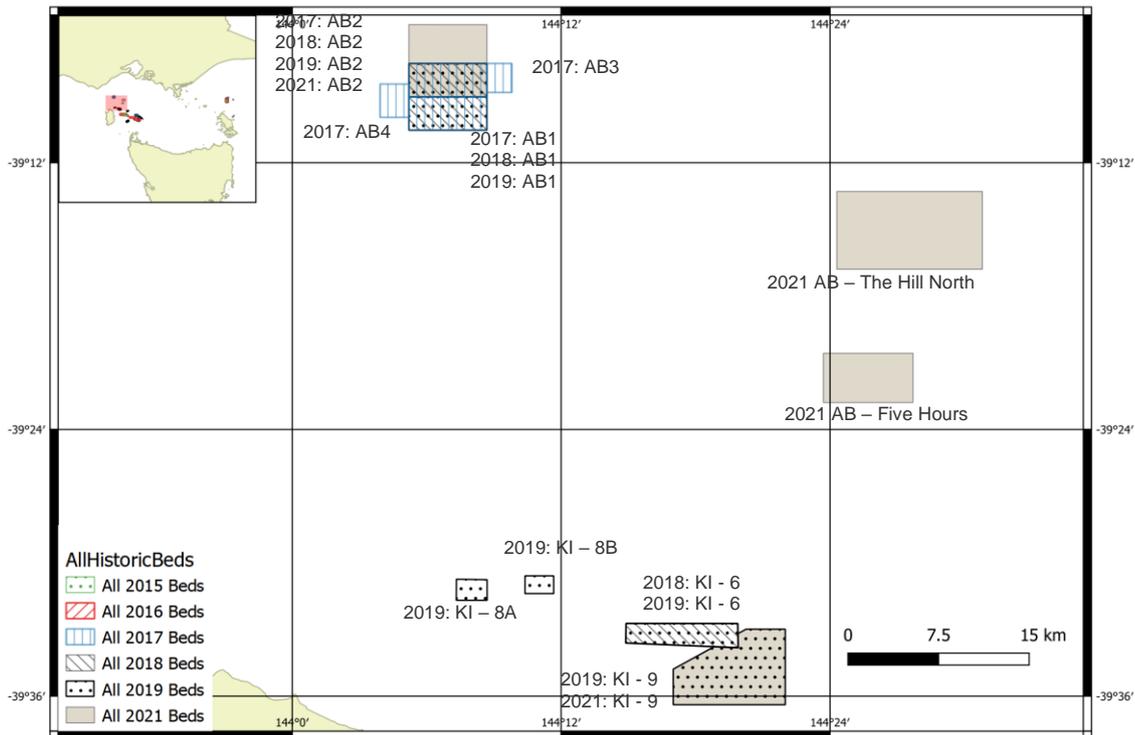


Figure 3 History of beds surveyed off Apollo Bay and King Island from 2015 to 2021.

Table 1. Description of beds surveyed since 2015 and beds new to 2022. See Figure 3 for maps of beds.

Bed Type	Name	Description
Previously surveyed	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 -40°S, and including the area of KI-5 to the east of that. This bed remained unchanged from the 2017 to 2019 when it was last surveyed.
	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 surveyed in 2016. It comprised parts of a bed called KIEast which was surveyed during 2015, and again in 2016, along with two new adjacent beds, KI-4 and KI-5. KI-New remained unchanged from the 2017 to 2019 when it was last surveyed.
	KI-BDE	During the TAC setting by the 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 Figure 3. This bed remained unchanged from the 2017 to 2022 surveys.
	AB-1 and AB-2	Seven exploratory marks in the KI region were provided by industry in 2017 to be explored and considered for additional survey beds. Only one of those showed enough promise to survey, and the skippers mapped out area, splitting it into two beds. 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 and future surveys. The AB-1 and AB-2 bed boundaries remained unchanged during the 2018 and 2019 surveys. For the 2021 survey, only AB-2 was surveyed, and the northern boundary was moved north to cover relatively high levels of commercial effort in that area. Neither were surveyed in 2022
	KI-6	Examination of 2018 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 Figure 3. The bed boundaries remained unchanged from the 2018 survey, was resurveyed in 2019, but dropped for the 2021 survey.
	KI-7	Examination of 2018 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 Figure 3. The bed boundaries remained unchanged from the 2018 survey, was resurveyed in 2019 and was surveyed in 2021 as a replacement for KI-Mid (in accordance with ScallopRAG recommendations) after exploratory revealed low densities there. It was resurveyed in 2022
	Previously surveyed	FI
KI-8a and KI-8b		Examination of 2019 commercial catch and effort data revealed significant catches in a large area at approximately longitude 144° 10', latitude 39° 31'. Within the general area of this effort, there were three main patches of densely populated scallop beds separated by areas of low density and an underwater cable. The two largest of these small areas were selected to survey in that year. They were not surveyed in 2021 or 2022.

Bed Type	Name	Description
Previously surveyed	KI-9	Examination of 2019 commercial catch and effort data revealed significant catches in a large area at approximately longitude 144° 21', latitude 39° 35'. The final boundaries were set based on a combination of fishing effort by the survey vessel in the previous year and exploratory fishing. This bed was resurveyed in 2021 and 2022.
	KI-JH	An industry member provided two marks that bound a line of exploratory tows that contained relatively high densities of juvenile scallops (~50 mm). Being the most recent sign of significant recruitment there was interest in tracking the growth of this bed, however there was some sensitivity around the potential to disturb the bed by surveying it. As a compromise, a relatively small survey area was set with only 20 sampling sites. Based on advice from industry, the bed was extended to the south-east for the 2021 survey. This bed was not surveyed in 2022
	KI-BDSE	Examination of 2019 commercial catch and effort data revealed significant catches in a large area at approximately longitude 145° 00, latitude 39° 49. The final boundaries were set based on a combination of fishing effort by the survey vessel in the previous year and exploratory fishing. This bed was resurveyed in 2021 and 2022.
	KI-Mid	This bed remained unchanged from 2015, 2016, 2017 and 2018. In accordance with RAG recommendations, five exploratory tows were conducted at this bed during 2021 revealing low densities (no scallops were caught), and so KI-7 was surveyed instead. This bed was not surveyed in 2022
	KI – 10	Significant catches were taken from an area to the south-east of the KI-BDSE site during 2020. KI – 10 is that surrounds that catch and was surveyed in 2021 and 2022.
	AB – The Hill North	Industry members provided marks about 17 nm to the south-east of Apollo 2 where significant amounts of scallops were caught in 2020. Based on commercial effort reported from the area, and notes made on a fishing vessel's plotter, a bed was defined and surveyed in 2021 and 2022.
	AB – Five hours	Industry members provided marks about 19 nm to the south-east of AB – Apollo 2 where significant amounts of scallops were caught in 2020. Based on commercial effort reported from the area, and notes made on a fishing vessel's plotter, a bed was defined and surveyed in 2021 and 2022.
	FI – North - The Sisters	Significant catches were taken from an area about 11 nm to the east of the FI site. Based on commercial effort reported from the area, and notes made on a fishing vessel's plotter, a bed was defined. This bed was surveyed in 2021, but not in 2022.
	FI – South – North of Babel	Significant catches were taken from an area about 31 nm to the south-south-east of the FI site. Based on commercial effort reported from the area, and notes made on a fishing vessel's plotter, a bed was defined and surveyed in 2021 and 2022.

Exploratory / New Beds	FI – The Wreck A	Significant catches were taken from an area to the north-west of the FI South – North of Babel site during 2021. FI – The Wreck A is a new bed that together with FI – The Wreck B, surrounds that catch.
	FI – The Wreck B	Significant catches were taken from an area to the north-west of the FI South – North of Babel site during 2021. FI – The Wreck B is a new bed that together with FI – The Wreck A, surrounds that catch.
	FI – (Exploratory mark)	Industry members provided a mark about 8.5 nm to the east of the old Flinders Island bed.

For the 2022 survey, ScallopRAG recommended including the following beds:

1. Apollo Bay Five Hours
2. Apollo Bay The Hill North
3. King Island Blue Dot Extended
4. King Island Blue Dot South East
5. King Island 10
6. King Island 9
7. King Island 7
8. Flinders Island South/ North of Babel
9. Flinders Island The Wreck A
10. Flinders Island The Wreck B
11. Flinders Island (Exploratory mark)

Survey bed names were given nick names to simplify for tables and figures. These are shown in Table 2 and are used throughout this report.

2.2 Survey Design

Survey methods follow those of Knuckey *et al.* (2015, 2016, 2017, 2018), Koopman *et al.* (2019, 2021), modified from those described in Harrington *et al.* (2008). Four vessels were selected to undertake the survey.

The number of survey points allocated to each bed was largely guided by sampling effort during past surveys, with consideration given to the maximum number of tows that can be achieved in a 12-hour sampling block¹. Primary sampling sites within each bed were randomly allocated using the QGIS Random Points in Polygons Tool. Additional survey points were allocated to each bed as “backup sites”, to be used where “primary sites” were unfishable.

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

During 2022, surveys were conducted onboard the fishing vessels Rachel Maree (Scientific Permit# 1005312), Shandara (Scientific Permit# 1005313), Odete C (Scientific Permit# 1005309) and the Northern Star (Scientific Permit# 1005308), which were selected by an independent panel. To be considered a valid tow, the vessel must dredge within 100 m of the tow location provided. Lotek LAT1400-64kb temperature-depth loggers were attached to the dredge at the start of the first tow for each trip. They were set to record an observation at regular intervals so that multiple records would be obtained for each trip.

2.2.1 Sampling methods

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. The observer measured the length of those scallops using an 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 in based on Semmens, *et al.* (2018) (Table 10). 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.

2.2.2 Data analysis

All data processing and analysis was undertaken in R (R Core Team, 2022). Estimates of biomass and potential commercial catch rates followed the methods of Semmens and Jones (2014).

2.2.3 Biomass estimates

The internal widths of the dredges used during the survey were measured in accordance with Semmens and Jones (2014). Dredge widths used by the Shandara, Odete C, Northern Star and Rachel Maree were 4.87 m, 3.905 m, 3.583 m and 3.930 m (Table 2). A dredge efficiency of 33% was assumed.

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.

Scallop catch in each tow ($C^{\text{standardised}}$ in kg/1000 m²) was calculated as follows:

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

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

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

$$B = \text{meanD} * A * 3.03 / 1000$$

$$\text{Upper 95\% CI} = ((\text{meanD} + (t_{n-1} \times \text{SE}_{\text{meanD}})) \times A) * 3.03 / 1000$$

$$\text{Lower 95\% CI} = ((\text{meanD} - (t_{n-1} \times \text{SE}_{\text{meanD}})) \times A) * 3.03 / 1000$$

Where meanD is the mean density (kg) of scallops per m² 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 (m²). The area of each bed was calculated using the R package “Simple Features” (Pebesma, 2018).

Biomass and upper and lower 95% confidence intervals (CI) of scallops greater than 85 mm were calculated as follows:

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

$$\text{Upper 95\% CI}_{>85 \text{ mm}} = \text{Upper 95\% CI} * (1 - \text{discard rate})$$

$$\text{Lower 95\% CI}_{>85 \text{ mm}} = \text{Lower 95\% CI} * (1 - \text{discard rate})$$

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

$$I = \sum_{\text{len}} W L f / S$$

Where WLf is the weighted length frequency for each length class len, and S is the swept area (m²).

All densities (kg / m² and individuals per m²) reported have been adjusted for the 33% assumed dredge efficiency (see Harrington *et al.* (2008) for origin of the 33%).

2.2.4 Biologicals

The length-weight relationship was calculated for each area separately, and the parameters of the relationship are provided in the results. Length-weight relationship was 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.

2.2.5 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, 2022), and a subset of outputs were reproduced and compared using an alternative software package. Scallops were measured using 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 AFMA managers. Where required, comments were addressed in preparation of the final report.

3 Results

3.1 Survey order

The 2022 BSCZSF survey was undertaken over four legs during May. During the first leg, the Rachel Maree surveyed the AB – The Hill, AB – Five Hours and KI – 9 (see Table 2 for bed nicknames) beds between 1st May 2022 and the 3rd May 2022. The Odete C surveyed KI – 7, KI – BDE and KI – 10 between the 9th May 2022 and 11th May 2022. The Shandara surveyed KI – BDSE and FI – NB between the 20th May 2022 and 22nd May 2022. The Northern Star surveyed FI – The Wreck A and FI – The Wreck B between 23th May 2022 and 24th May 2022, and undertook one exploratory tow at the Flinders Island Exploratory mark, however hydraulic issues caused the vessel to cease fishing and return to port. The total area of each bed is shown in Table 2.

3.2 Biomass, size and potential commercial catch rates

Mean biomass estimates for AB – Five Hours and AB – The Hill were 1,037 t (95%CI 553 t – 1,521 t) and 14,601 t (95%CI 11,343 t – 17,859 t) respectively (Table 4). The percentage of scallops >85mm at each of those beds were 97.8% and 82.5% (Table 5), and consequently the mean biomasses of scallops > 85 mm were 1,014 t and 12,050 t respectively (Table 5).

Mean biomass estimates for FI – The Wreck A, FI – The Wreck B and FI – NB were 1,578 t (95%CI 1,138 t – 2,018 t), 1,856 t (95%CI 1,335 t – 2,337 t) and 1,632 t (95%CI 1,135 t – 2,130 t) respectively (Table 4). The percentage of scallops <85mm was greater than 5% at all three FI beds (Table 5), and consequently mean biomasses of scallops > 85 mm were only slightly lower than total biomass estimates: 1,544 t, 1,839 t and 1,622 t respectively (Table 5).

Mean biomass estimates for KI – 10, KI – 7, KI – 9, KI-BDSE and KI-BDE were 3,860 t (95%CI 2,920 t – 4,799 t), 313 t (95%CI 134 t – 492 t), 10,482 t (95%CI 7,412 t – 13,552 t), 12,707 t (95%CI 7,264 t – 18,150 t) and 234 t (95%CI 75 t – 393 t) respectively (Table 4). The percentage of scallops <85mm at KI – 10, KI – 7, KI – 9, KI-BDSE and KI-BDE were about 17.7%, 53.1%, 61.8%, 50.6% and 8.6% (Table 6), resulting in mean biomasses of scallops > 85 mm of 3,178 t, 147 t, 4,007 t, 6,278 t and 214 t respectively (Table 5).

Densities in kg/1000m² for the FI beds are shown in Figure 4. At all three beds, medium densities were relatively consistent throughout, with some low density catches, particularly in the south of the FI – North of Babel bed and the west of the FI – The Wreck A and FI – The Wreck B. KI – BDE and KI – 7 were the only beds at which zero catches were recorded (Figure 5). Continuing on from the low density catches in the south-east of KI – BDE, densities in the north of KI – BDSE were also low, but very high in the south. Densities were consistently medium throughout KI – 10. At KI – 9 there were medium to high density tows recorded in the south. Medium to high density tows were also recorded throughout AB – The Hill, while medium density tows were recorded in the north of AB – Five Hours, but low densities in the south (Figure 6).

Estimated densities in numbers of Commercial Scallops >85 mm ranged 0.05 individuals per m² at KI – BDE to 2.39 individuals per m² (Table 4). Densities were relatively low at all three FI beds.

Comparisons of biomass estimates, percent catch composition and size distributions of beds that have been repeatedly surveyed and surveyed in 2021 are shown in Appendix 2. While the sampling methods have been consistent, the areas of the beds have changed considerably. Care should be taken when interpreting those results, and consideration of changes in bed areas over time should be made.

3.3 Biologicals

Mean length of scallops measured from beds ranged 83 mm at KI – 7 to 105 mm at FI – NB (Table 6). Length frequency distributions from all sites are shown in Figure 8. Significant recruitment was observed at KI-7, KI – 10, KI-9 and KI-BDSE, while small signs of recruitment were observed at AB – The Hill, AB – Five Hours and FI – The Wreck. Scallop meats were much smaller at the KI and AB beds compared to FI (Table 6, Figure 9). Overall, most meats were less than 20 g, and meats per kg ranged 48 at FI – NB to 158 at The Hill (Table 6). The larger meat weights at the Flinders beds are reflected in the maturity stages (Table 10), with the highest proportion of stage 2 gonads at FI – The Wreck A, FI – The Wreck B and FI – NB-TS. No stage 3 gonads were observed.

Comparison of length-weight regressions between beds revealed that the interaction term was significant ($p < 0.0001$), suggesting that there is a difference in slopes in the length-weight relationship between beds. The p -value for the indicator variable was also significant ($p < 0.0001$) suggesting that there is also a difference in intercepts, and it appears that there are differences in length-weight relationships between beds. A similar result was obtained when beds were grouped into the areas FI, KI and AB ($p < 0.0001$). Within the FI region, there was no significant difference in the length-weight relationship between beds and so data were pooled in calculation of parameters. There was a difference between the AB beds and so those data were kept separate. There was a significant difference between length-weight relationships for the three connected Bluedot beds, however, there was no difference between KI – BDE and KI – BDSE, and KI – BDE and KI – 10. For simplicity, data from the Bluedot beds were combined. There was no evidence of a difference in length-weight relationships between KI-7 and KI-9 and so those data were combined. Separate length-weight relationships were calculated for each sub area (Table 7). Scatterplots of each combination of size measurements (including total weight) shown in Figure 7.

3.4 Bycatch

A total of 60 different species / groups were identified during the survey (Table 8), and catch composition varied greatly between beds (Figure 11). Overall, live Commercial Scallops comprised 30% of the catch, while Broken Shell (20%), Old Single Shell (14%), and Sponge (12%) comprised the largest other components of the catch. Ascidians comprised relatively high proportions of the catch at FI – The Wreck A and FI – The Wreck B (Figure 11).

Several high risk species were recorded. One Southern Blue-Ringed Octopus was recorded from a tow at each at FI – NB and FI – The Wreck B. At least one Black and White Seastar was recorded from FI – The Wreck B, and several others may have been caught at KI – 7, however these were small animals and while coloration and number of legs was consistent with Black and White Seastars, the shape of the disc and leg was different and it is unclear if this reflects a change in shape with size, or that they were a different species. Suspected King Island Thickshell-Clams were caught at AB – Five Hours, AB – The Hill, FI – NB, FI – The Wreck A and FI – The Wreck B. The large number of mollusc species present in catches, lack of obvious identifying features and lack of time inhibits the observers ability to accurately identify that species.

Considering only the four different scallop “groups” (Commercial Scallops, old single, new single, and clappers), KI – 7 and KI-BDE had a much higher percentage of old single shell (more than 75%) than other beds (Figure 12). KI – 10, KI – 9 and KI – BDSE had the highest proportion of live Commercial Scallop (>70%). Only Small amounts of clappers were recorded from some beds.

Table 2 Names, nicknames (used in this report) surveyed in 2021 and area of polygons (km2).

Bed	Nickname	Total Area (km2)
Flinders Island – The Wreck A	FI – The Wreck A	37.51
Flinders Island– The Wreck B	FI – The Wreck B	36.41
Flinders Island South - North of Babel	FI - NB	31.43
Apollo Bay - The Hill North	AB - The Hill	60.47
Apollo Bay - Five Hours	AB - Five Hours	23.59
King Island - 10	KI - 10	17.11
King Island - Blue Dot Extended	KI - BDE	56.47
King Island - Blue Dot South East	KI - BDSE	66.88
King Island - 9	KI-9	36.36
King Island - 7	KI - 7	14.52

Table 3. Total commercial catch (t) and the number of vessels that fished within each 2022 survey bed during the 2021 fishing season based on logbook data. Records coloured red are confidential – they were used in the analyses but removed for final report.

Bed	Catch (t)	Number of vessels
FI – The Wreck A	370	7
FI – The Wreck B	501	8
FI-NB	256	6
AB - The Hill	Confidential	<5
AB - Five Hours	268	6
KI - 10	Confidential	<5
KI - BDE	0	0
KI - BDSE	Confidential	<5
KI-9	0	0
KI - 7	0	0
Outside of beds	796	10
Total	2312	10

Table 4. Biomass estimates, 95% confidence intervals and number of tows included in analyses. Note that both densities have been adjusted for a 33% assumed dredge efficiency.

Area	Bed	Number of tows	Mean density (kg/1000 m ²)	Standard deviation (kg/1000 m ²)	Lower 95% CI (t)	Estimated biomass (t)	Upper 95% CI (t)	Potential catch rate (kg/hr)	Density (ind/m ² >85mm)
Apollo	AB-5 Hours	25	44	49.7	553	1,037	1,521	174	0.43
	AB-The Hill	25	241.5	130.5	11,343	14,601	17,859	956	2.39
Sub-total		50				15,638			
Flinders	FI – The Wreck A	25	42.1	28.4	1,138	1,578	2,019	167	0.34
	FI – The Wreck B	25	51	34.7	1,335	1,856	2,377	202	0.43
	FI-NB	25	51.9	38.3	1,135	1,632	2,130	206	0.36
Sub-total		75				5,066			
King	KI - 10	25	225.6	133	2,920	3,860	4,799	893	2.06
	KI - 7	25	21.6	29.9	134	313	492	85	0.14
	KI - 9	25	288.3	204.6	7,412	10,482	13,552	1,142	1.17
	KI-BDSE	25	190	197.2	7,264	12,707	18,150	752	0.97
	KI - BDE	25	4.1	6.8	75	234	393	16	0.05
Sub-total		125				27,596			
Total		250	250			48,300			

Table 5. Percent weight of scallops > 85 mm (catch weighted by weight), and biomass estimates 95% confidence intervals for scallops greater than 85 mm.

Area	Bed	% weight > 85 mm	Lower 95% CI (t)	Estimated Biomass (t)	Upper 95% CI (t)
Apollo	AB-5 Hours	97.8	541	1,014	1,488
	AB-The Hill	82.5	9,361	12,050	14,739
Sub-total				13,064	
Flinders	FI – The Wreck A	97.8	1,113	1,544	1,975
	FI – The Wreck B	99.1	1,323	1,839	2,355
	FI-NB	99.4	1,128	1,622	2,117
Sub-total				5,005	
King	KI - 10	82.3	2,404	3,178	3,951
	KI - 7	46.9	63	147	231
	KI - 9	38.2	2,833	4,007	5,180
	KI-BDSE	49.4	3,589	6,278	8,966
	KI - BDE	91.4	69	214	359
Sub-total				13,824	
Total				31,893	

Table 6. 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 85 mm and mean number of meats per kg of scallops greater than 85 mm from each bed.

Bed	N	Length (mm)			85 mm		Meats / kg
		Median	Mean	SE	%<	%>	Mean
AB - Five Hours	599	98	97	0.3	97.8	2.2	98
AB - The Hill North	875	94	93	0.3	82.5	17.5	158
FI – The Wreck A	875	101	101	0.3	97.8	2.2	54
FI – The Wreck B	791	100	100	0.3	99.1	0.9	52
FI-NB	831	105	105	0.3	99.4	0.6	48
KI - 10	875	96	95	0.3	82.3	17.7	70
KI - 7	512	83	83	0.2	46.9	53.1	91
KI - 9	911	84	87	0.4	38.2	61.8	108
KI - BDSE	787	88	88	0.3	49.4	50.6	80
KI - BDE	303	91	91	0.4	91.4	8.6	70

Table 7. Number of scallops retained for biological sampling, and parameter estimates for length weight relationships. The Blue Dot Beds sub area included KI-BDE, KI-BDSE and KI-10.

Sub Area	N	a	b	Adjusted R ²
Flinders Island	136	-6.7037	2.4483	0.72
KI - Blue Dot Beds	110	-8.07122	2.73304	0.89
KI-7 and KI-9	100	-6.8211	2.4465	0.83
AB – The Hill	49	-3.5422	1.7009	0.54
AB – Five Hours	48	-4.5781	1.9595	0.87

Table 8. Catch of each species in each bed. (u) refers to undifferentiated species recorded at a higher taxonomic level.

Species	Catch (kg)									
	AB - Five Hours	AB - The Hill North	FI-NB	FI – The Wreck A	FI – The Wreck B	KI - 10	KI - 7	KI - 9	KI - BDE	KI - BDSE
Commercial Scallop	753.94	4297.2	1059.91	641.58	855	4341.61	398.18	4763.7	80.51	3896.92
Clappers	2.55	222.33	15.19	1.73	5.82	53.6	5.03	58.82	6.9	180.38
New Single	180.96	2153.5	192.76	80.34	182.87	530.42	65.54	383.61	117.7	705.66
Old Single	664.94	755.16	776.86	509.76	690.74	770.24	1565.82	1321.24	1959.22	1139.3
Ascidian (U)	130.3	36.7		1635.36	1468.69	69.36	72.7	17.9	78.29	26
Banded Stingaree				1.15			1.07	3.6	0.45	0
Barracouta								0.05		
Bassina Spp.			1.7							
Black And White Seastar					0.22		0.08			
Bluefin Leatherjacket			0.25							
Brittlestars (U)					0.76	0.01	1.57			
Cockle	2.75		0.1					8.15		
Cocky Gurnard	0.9	0.4	0.4			13.97	0.4	2.5	0.75	1
Common Gurnard Perch	0.8		0.4			0.35	0.4	0.6	0.5	
Common Stargazer			2.1	1.85						
Cowrie (U)								0.6		
Crab (U)			0.06				0.01	0.42		
Cuttlefish (U)				0.7						
Dog Whelk			1.6				3			
Doughboy Scallop				5.6	3.78			126.05	0.44	8
Eleven-Arm Seastar										321
False Bailer Shell	6.3	4.7		87.45	102.92	118.18	42.93			
Greenback Stingaree			2.05	0.25	0.2	0.35	0.15		0.2	0
Hard Coral					0.35					
Hermit Crab (U)	1.9	3.2	49.34	17.94	19.54	6.5	20.9	1.1	8.24	13
Holothurian (U)					6.8					
King Island Thickshell-Clam	1.45	2	68.18	3.06	4.44					
Longnose Skate	1.8		4.1	0.34	1		2.8			0
Maori Octopus			0.4				0.4			
Mollusc (U)		0.2	2.16	0.96						
Octopus (U)	3.3	3.65	6.09	4.1	2.7	4.2	3.6	1.35	1.15	2
Oysters		14.3	548.72	590.94	711.08			22		
Pale Octopus		2.4				1	1.3	1.4		
Polychaete Worm (U)			0.01							
Razorfish (U)			12.1	0.9	5.52					
Roundsnout Gurnard							0.15			
Sea Urchin (U)			0.15		1.9					
Seapen (U)	20	5.65	1.38		1.38	0.8			4.58	15
Seastar (U)				1.12	0.48					
Shark Egg (U)		0.3	0.28	0.35		1.1	0.15	0.2		
Shaw Cowfish			0.15		0.1		0.45			
Silverbelly								0.05		
Skate (U)			5			2.99			0.46	
Soft Coral (U)		22.8	46.4	83.64	353.63	1.1	443.75			
Sole (U)				0.12						7
Solitary Ascidians (U)		11.4	0.7		0.4	1.25	0.25	1.65	0.1	2
Southern Blue-Ringed Octopus			0.2		0.3					
Southern Red Scorpionfish					0.06					
Southern Sand Flathead				0.2		0.5				
Sparsely-Spotted Stingaree	0.5	0.85	0.85	0.5			0.2	0.5	0.2	6
Speckled Stargazer	1.7	2.3	0.45	0.35						
Spider Crab (U)	108.2	673.5	51.8	33.05	15.1	139.2	79.78	109.1	624.11	473.3
Sponge (U)	160.15	614.8	1819	215.05	514.81	906.35	2087.99	907.22	1320.1	209.9
Substrate - Broken Shell	315.3	1766.1	2390.5	834.21	1005.91	1060.51	786.8	1418.63	2339.8	1900.3
Substrate - Rock	216.95	52.8	382.6	11.2	56.9	13.5	259.2	28.1		
Tasmanian Numbfish			0.35	0.45	0.8	0.5		0.65	0.25	0
Tiger Flathead		2.2		0.8						
Venus Shells		2.4	47.83	4.16	7.44	0.05				
Volute (U)	17.2	0.3	0.85	0.66		0.5	2.32	4.3	1	
Whelk	15.4	2.65	91.29	45.08	42.18	54	255.96	40.27	40.73	86

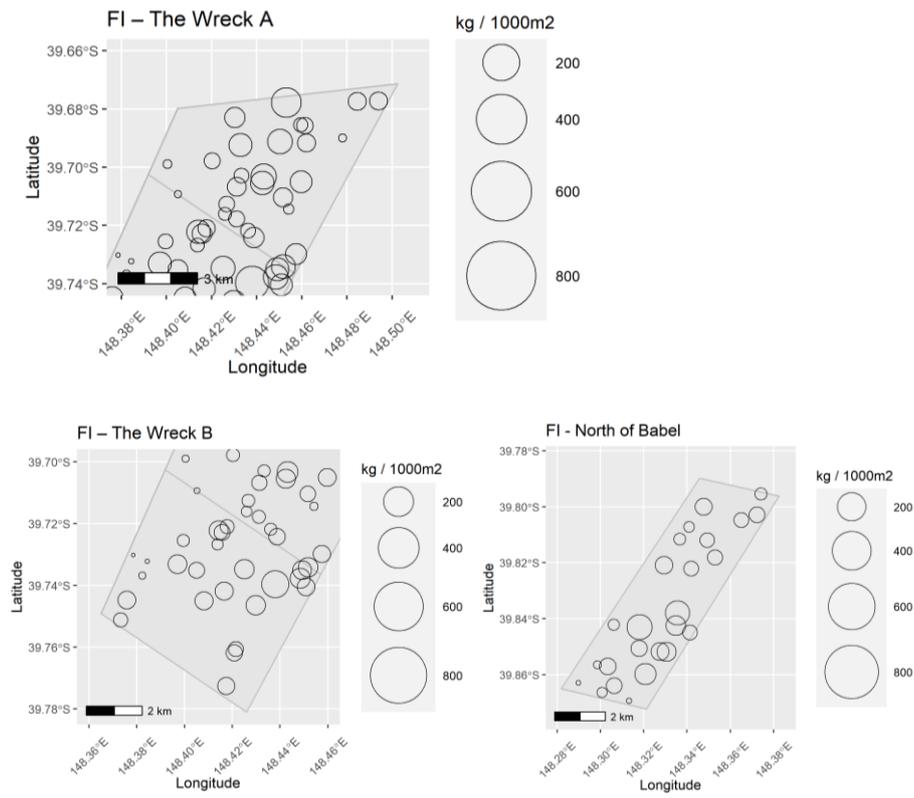


Figure 4. Scallop density (kg / 1000 m²) within the FI – The Wreck A, FI – The Wreck B and FI – North of Babel beds near Flinders Island. The scale bubbles on the right reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

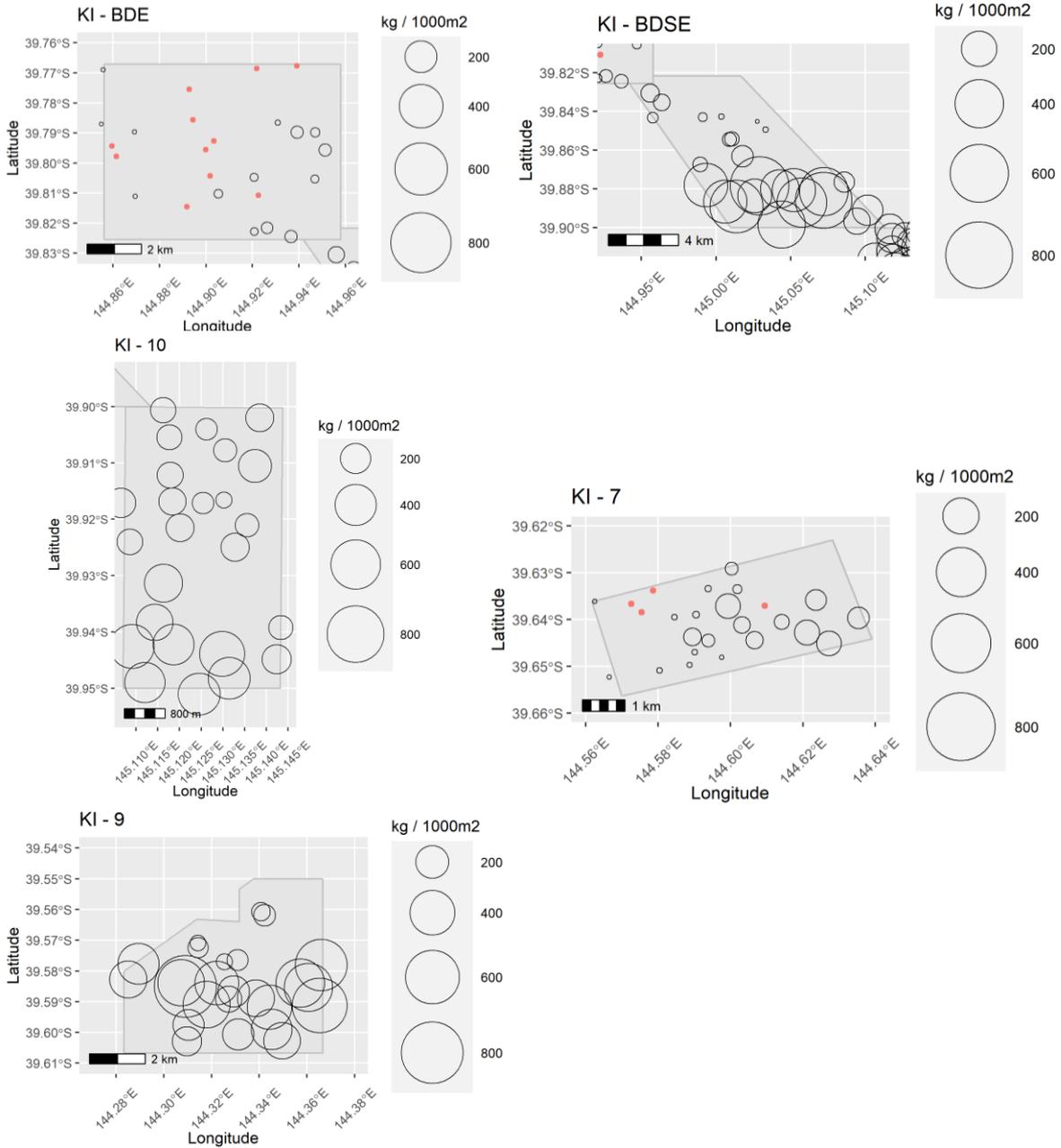


Figure 5. Scallop density (kg / 1000 m²) within the KI - BDE, KI – BDSE, KI - 10, KI – 7 and KI - 9 beds. The scale bubbles on the right reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

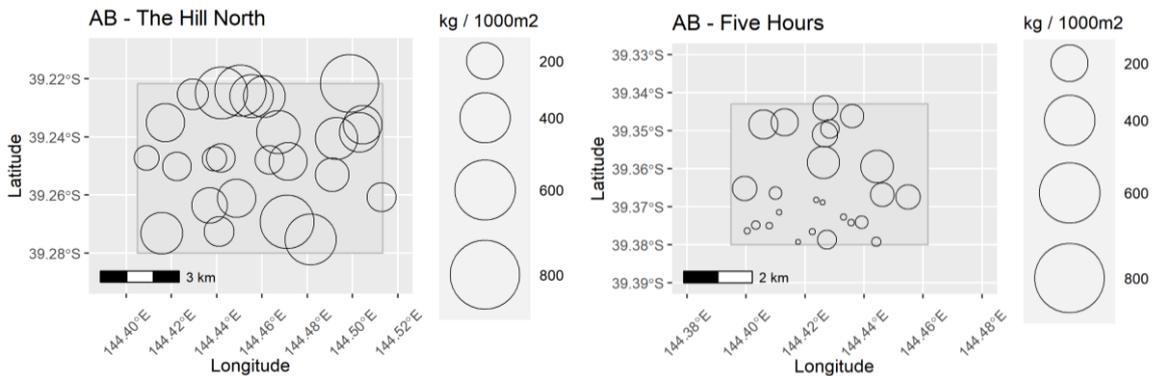


Figure 6. Scallop density (kg / 1000 m²) within the AB – The Hill and AB – Five Hours beds. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

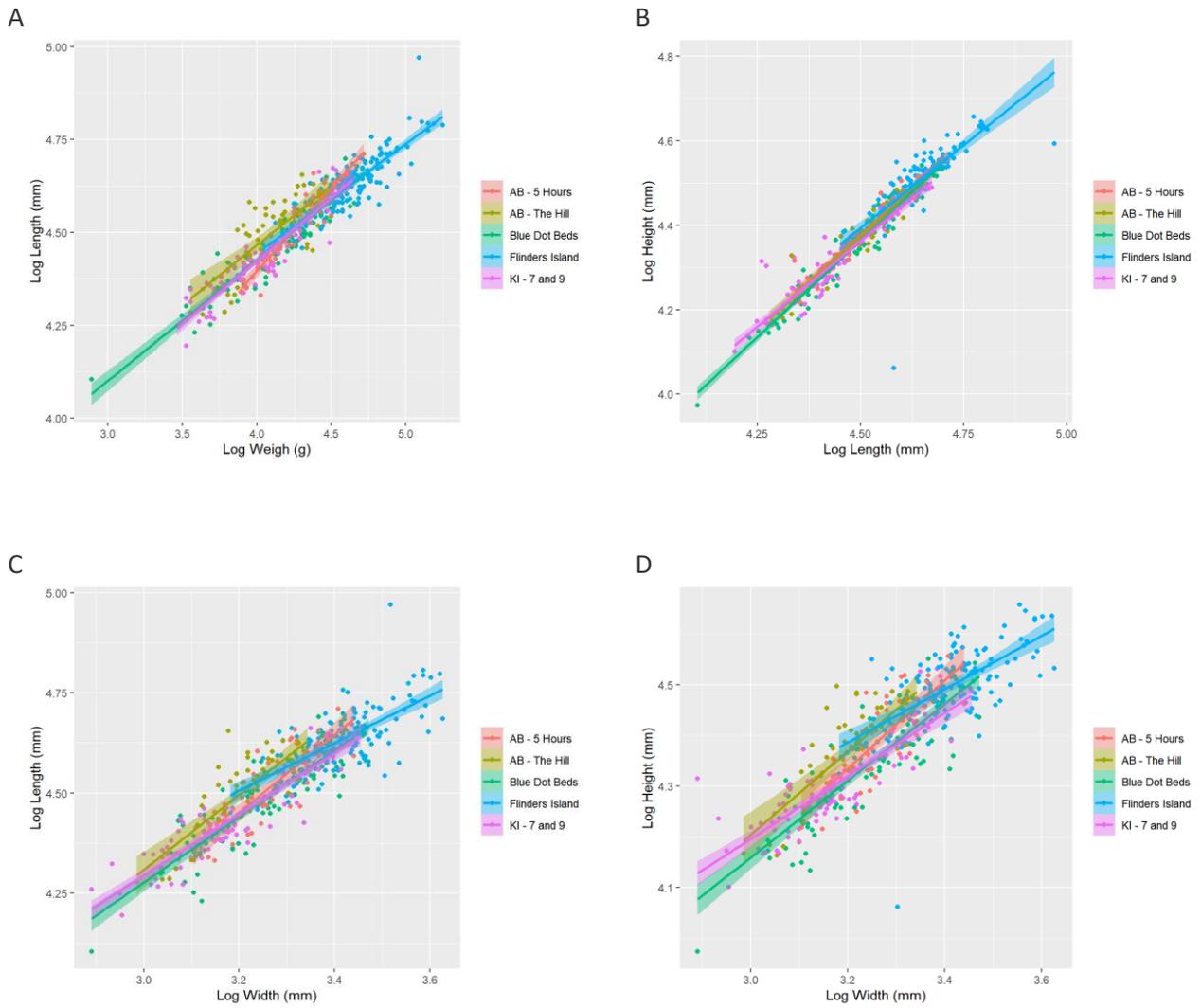


Figure 7. Log transformed A) length and weight, B) length and height, C) length and width and D) height and width from each area bed.

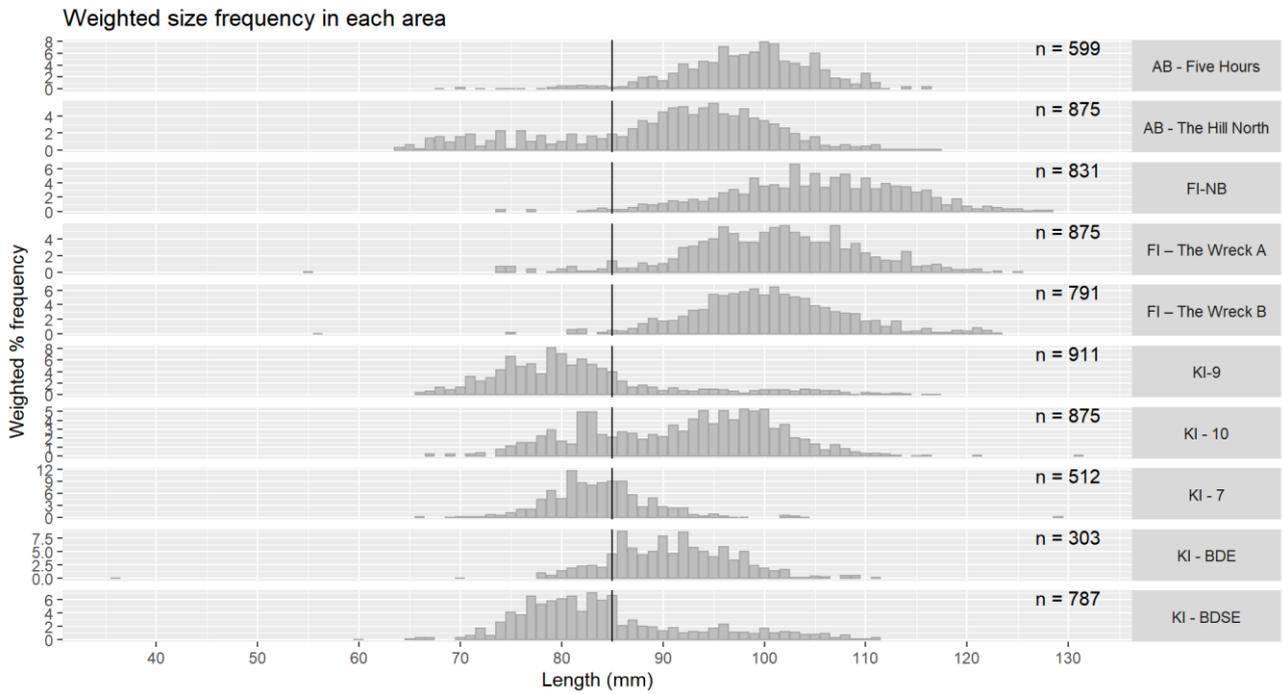


Figure 8. Catch weighted size frequency from tows included in biomass estimates from each bed. The vertical line is at 85 mm.

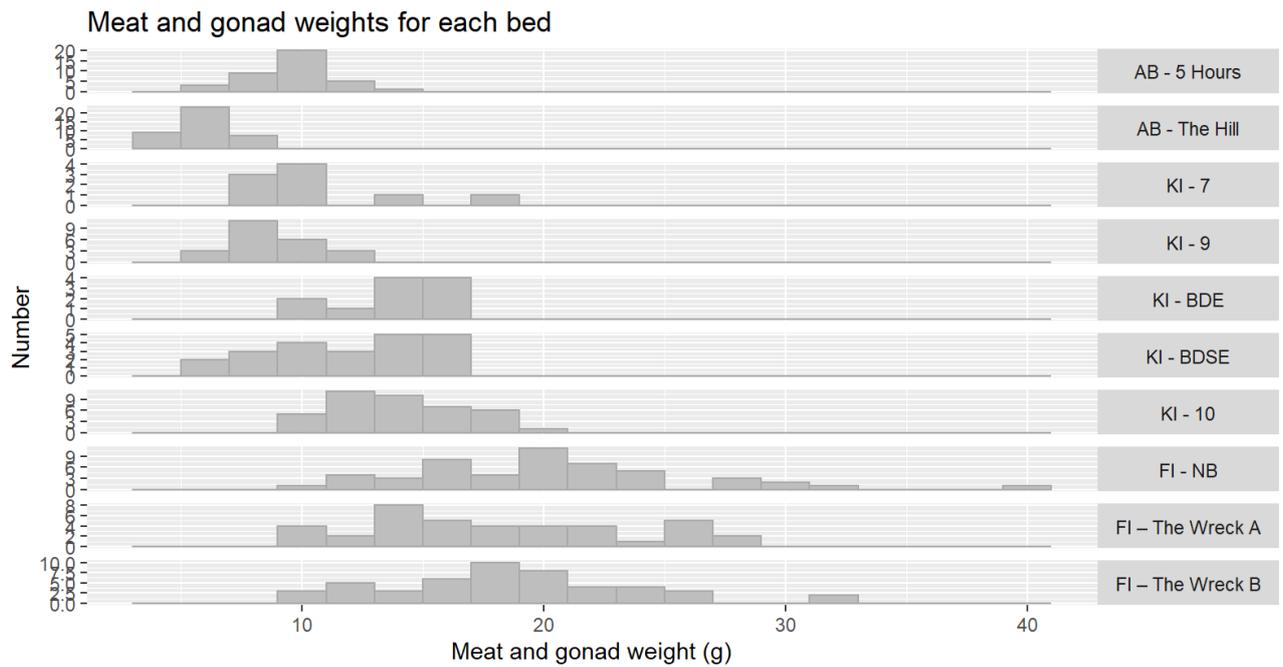


Figure 9. Frequency of combined meat and gonad weights of scallops >85 mm measured from each bed binned into 2 g weight categories.

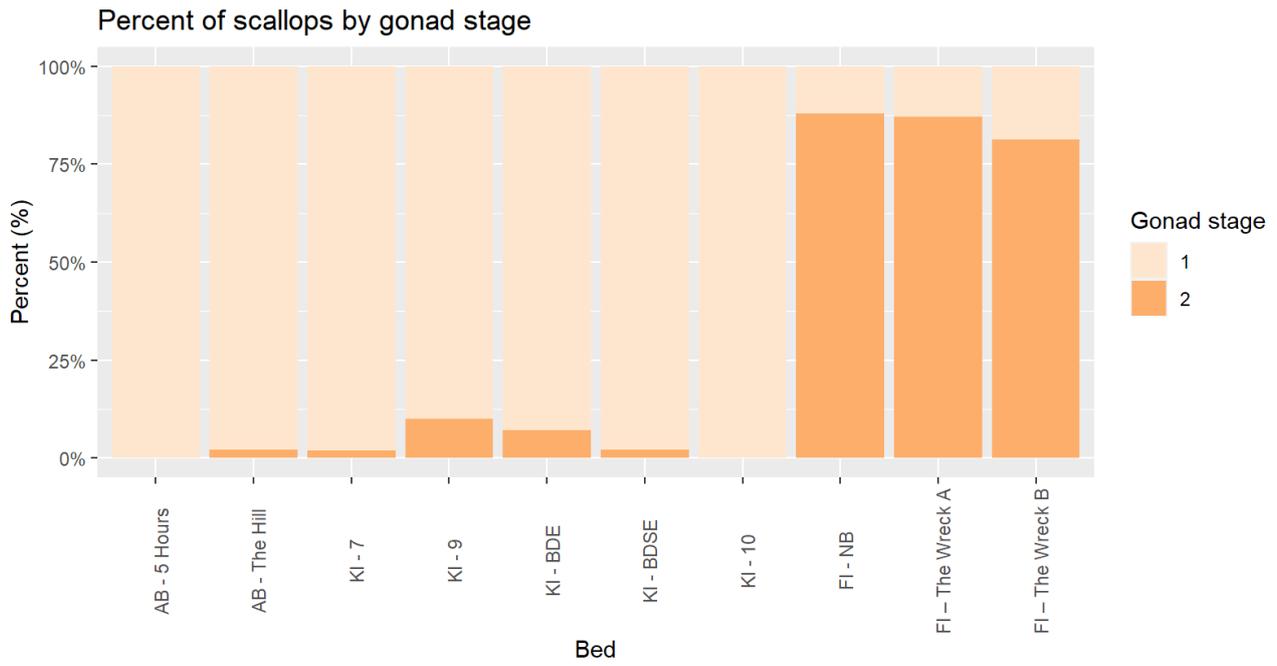


Figure 10. Percent of scallops at each stage from each bed based on macroscopic staging criteria shown in Table 10.

Catch of top 5 species

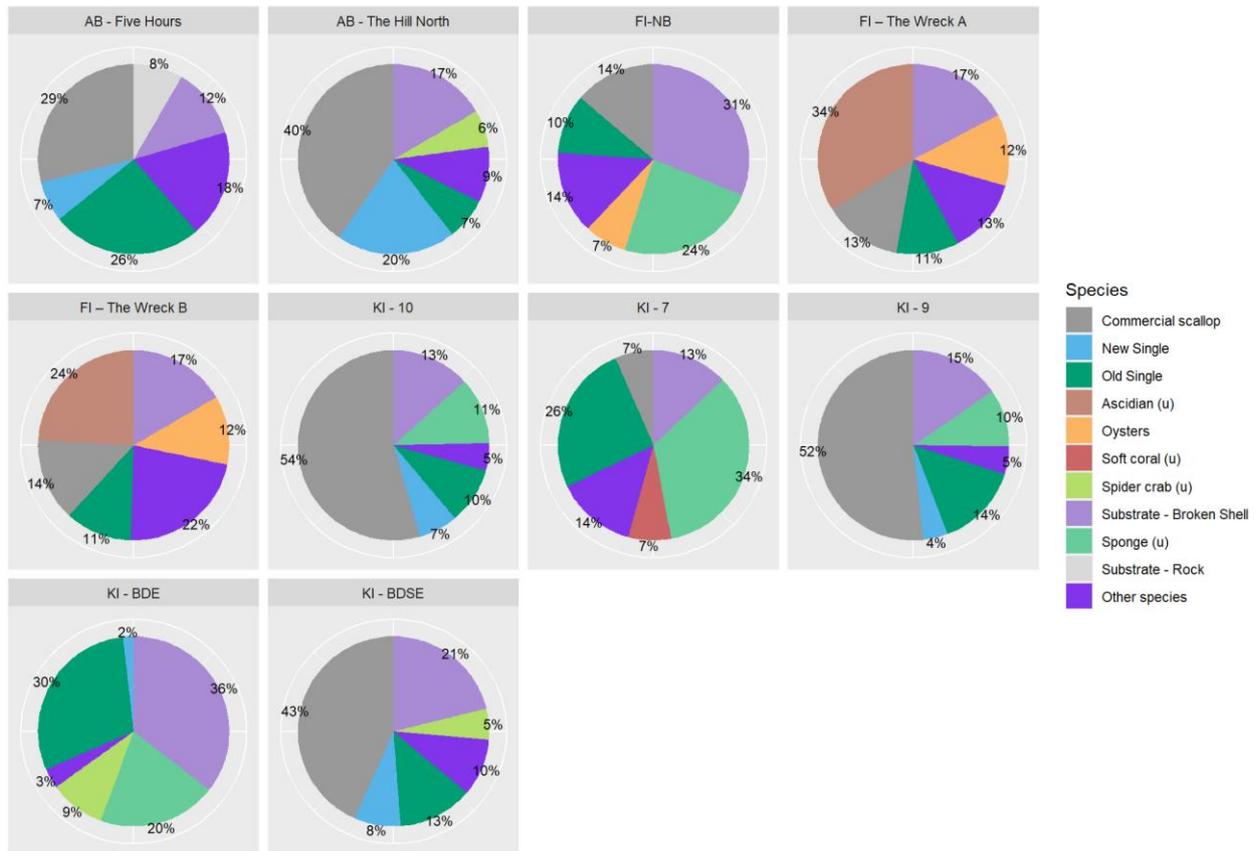


Figure 11. Percent catch composition by weight from all beds.

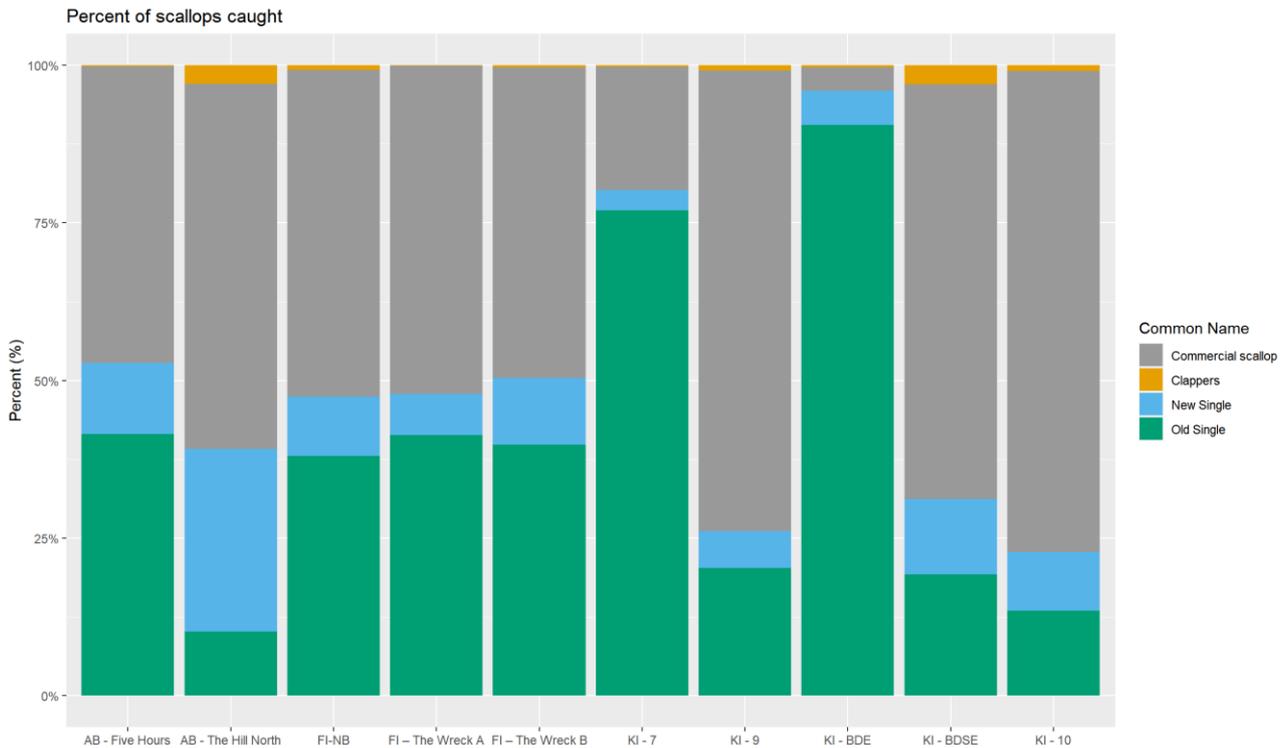


Figure 12. Percent composition of clappers, live scallop, new single and old single shell from each Bed.

4 Discussion

Random stratified surveys were successfully undertaken on ten scallop beds off FI, KI and AB. Beds were selected based on a combination of previous surveys, distribution of catch and effort, advice from ScallopRAG and marks provided by industry. In total, 250 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.

Biomass of Commercial Scallops greater than 85 mm was estimated to be 13,064 t at the two AB, 5,005 t at the three FI Beds and 13,824 t at the KI beds (Table 9). Total biomass greater than 85 mm at all sites combined was 31,893 t. The percent of Commercial Scallops greater than 85 mm was more than 80% at most sites, while only 46.9%, 38.2% and 49.4% of Commercial Scallops were greater than 85 mm at KI – 7, KI – 9 and KI – BDSE respectively, all three sites with significant recruitment observed. Densities in individuals per m² ranged 0.05 at KI – BDE to 2.39 at AB – The Hill (Table 9).

These results were presented at the ScallopRAG meeting on 7 June 2022 and at the ScallopMAC meeting on 9 June 2022.

Table 9. Summary of data used to inform the 2022 ScallopRAG and ScallopMAC recommendation for harvest strategy requirements and TAC.

Area	Bed	Estimated biomass (t)	% weight > 85 mm	Estimated biomass (t >85mm)	Density (ind/m ² >85mm)	Mean length (mm)	Mean Meats / kg >85mm
Apollo	AB-5 Hours	1,037	97.8	1,014	0.43	97	98
	AB-The Hill	14,601	82.5	12,050	2.39	93	158
Sub-total		15,638		13,064			
Flinders	FI - The Wreck A	1,578	97.8	1,544	0.34	101	54
	FI - The Wreck B	1,856	99.1	1,839	0.43	100	52
	FI-NB	1,632	99.4	1,622	0.36	105	48
Sub-total		5,066		5,005			
King	KI - 10	3,860	82.3	3,178	2.06	95	70
	KI - 7	313	46.9	147	0.14	83	91
	KI - 9	10,482	38.2	4,007	1.17	87	108
	KI-BDSE	12,707	49.4	6,278	0.97	88	80
	KI - BDE	234	91.4	214	0.05	91	70
Sub-total		27,596		13,824			
Total		48,300		31,893			

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Appendix 1 – Methods

Table 10. Gonad maturation scheme for macroscopic field staging of scallops (modified from Semmens *et al.*, 2019).²

Stages	Description
<p>1</p> <p>Developing or spent</p>	<p>Gonad is small, thin, translucent, brownish colour. Intestinal loop usually visible. Ovarian and testicular tissues difficult to differentiate.</p> 
<p>2</p> <p>Maturing or atretic (reabsorbing eggs as spawning is delayed)</p>	<p>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.</p> 
<p>3</p> <p>Partially spawned</p>	<p>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.</p> 

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 2 - Time series data

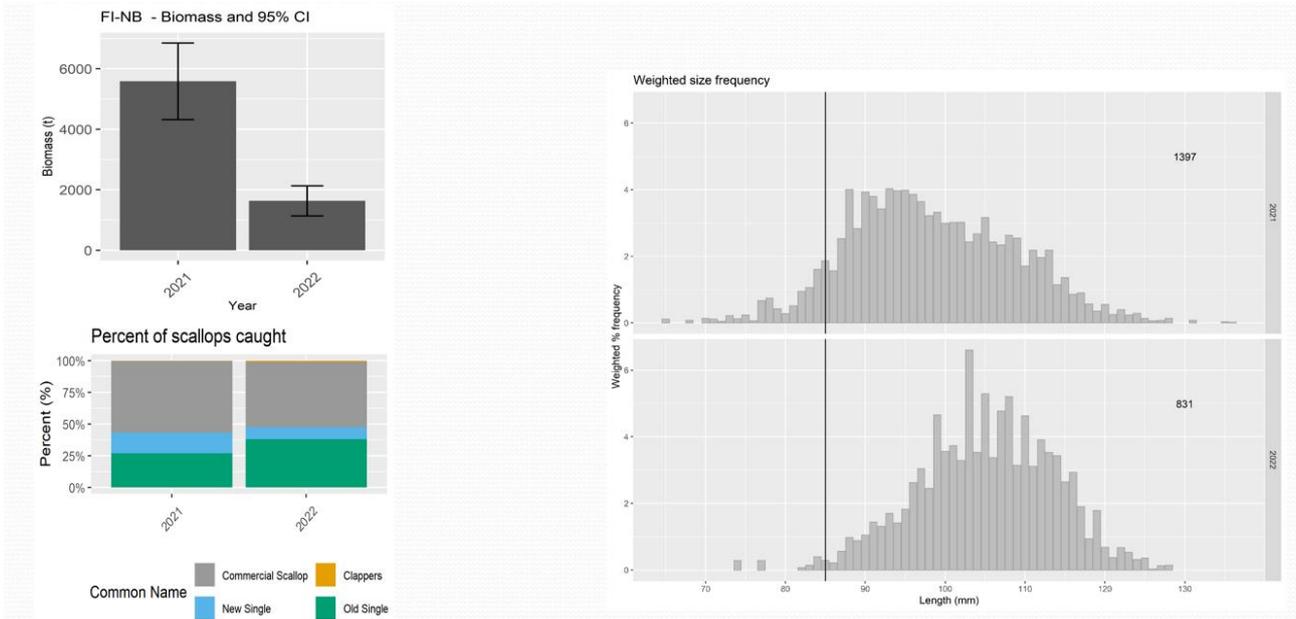


Figure 13. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the FI – North of Babel bed.

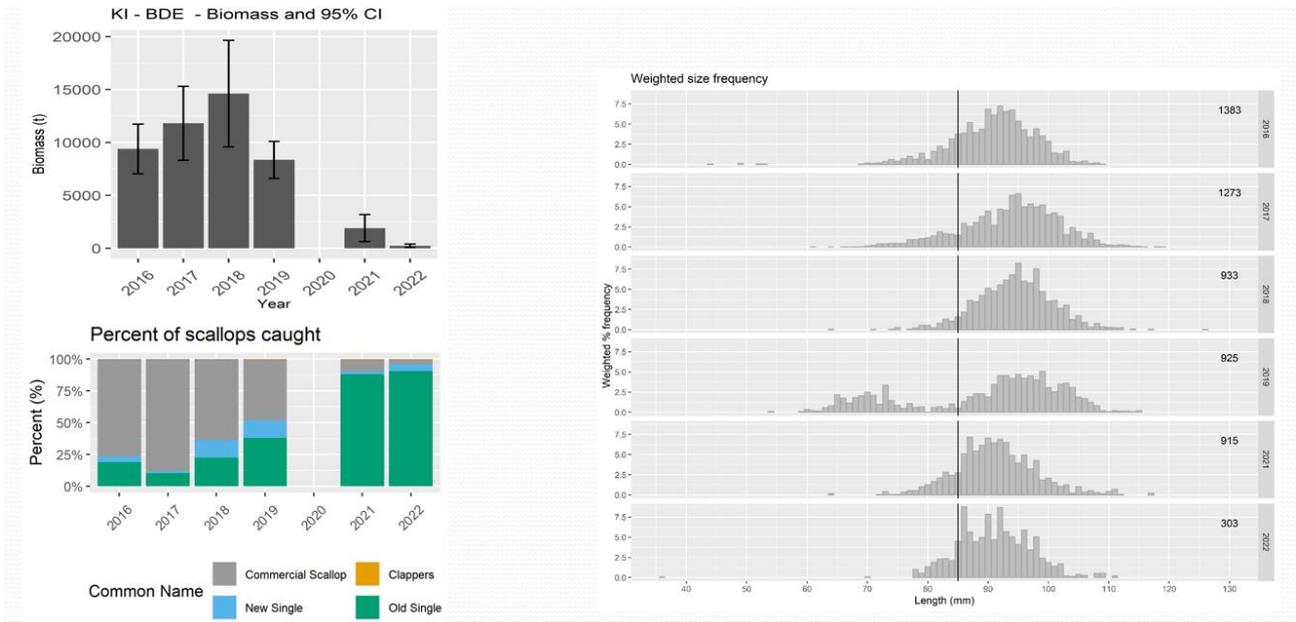


Figure 14. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI – BDE bed.

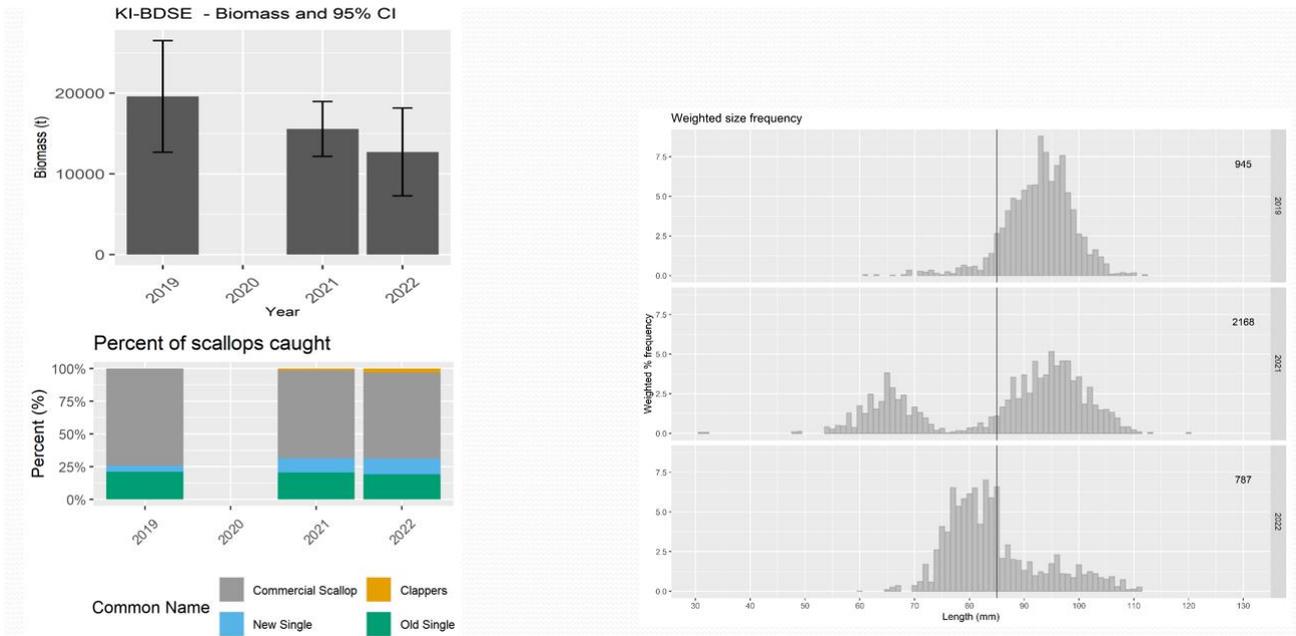


Figure 15. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI – BDSE bed.

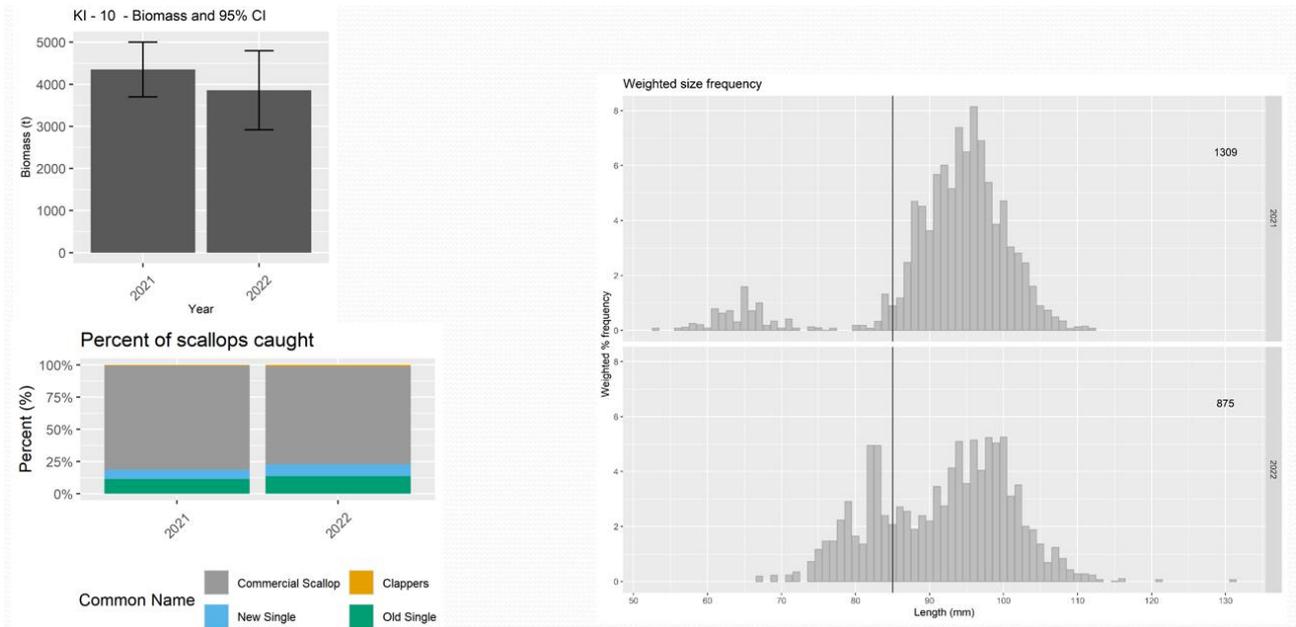


Figure 16. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI – 10 bed.

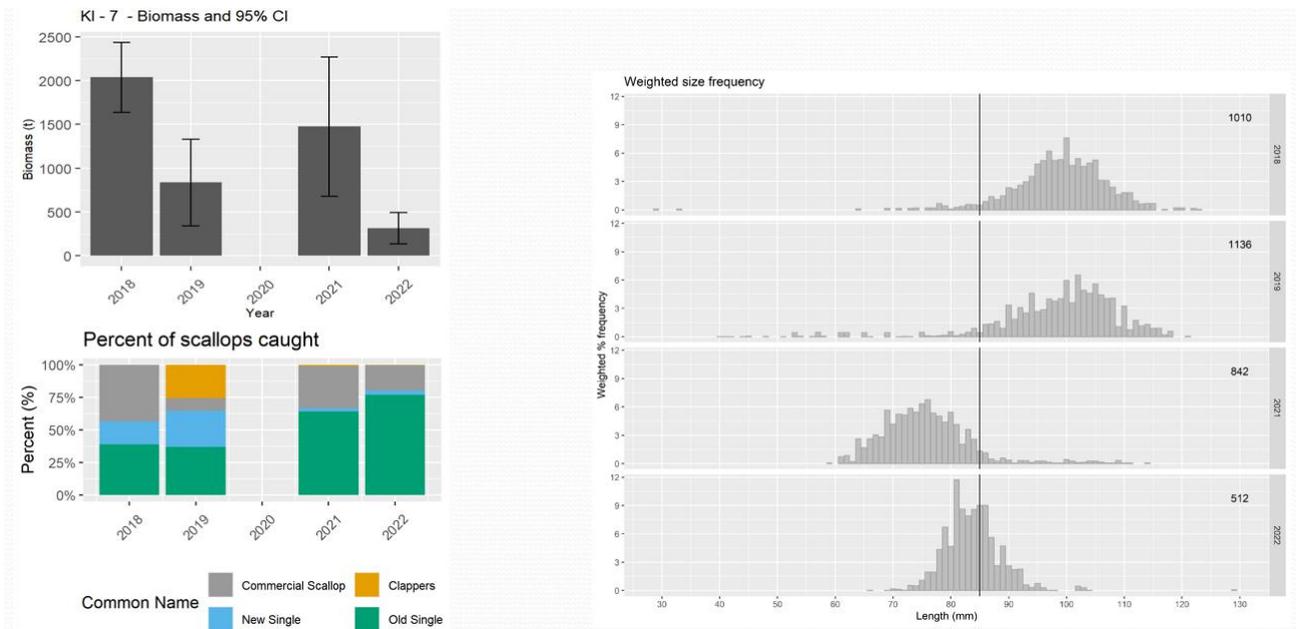


Figure 17. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI – 7 bed.

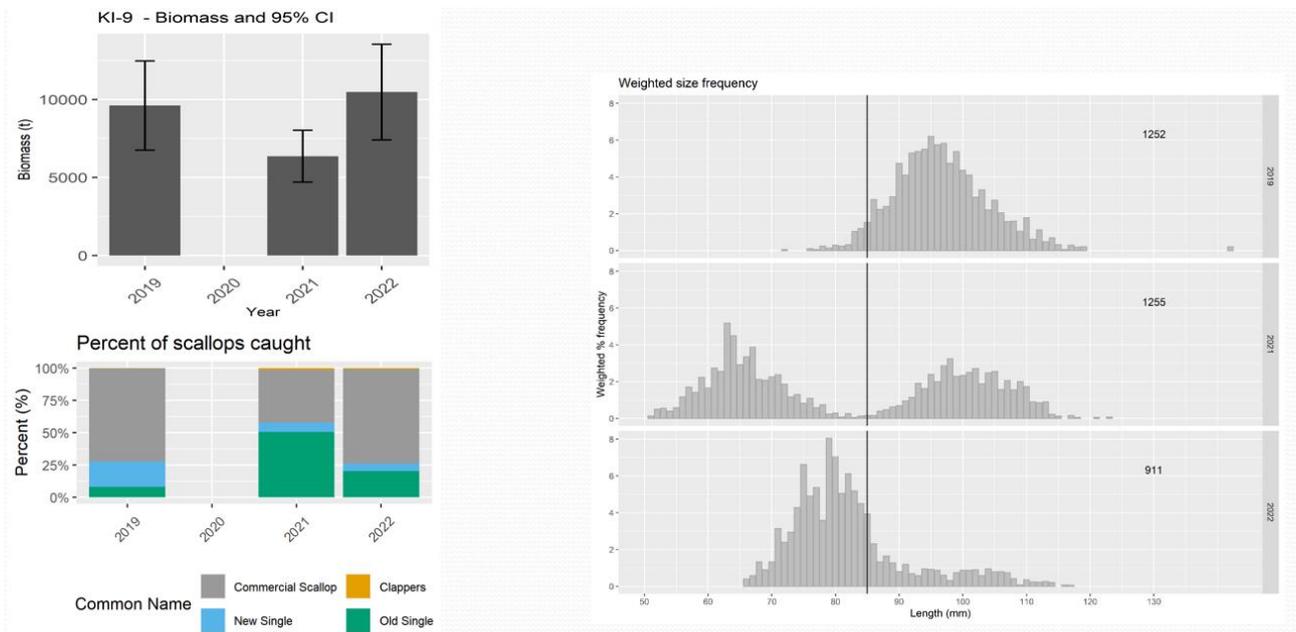


Figure 18. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI – 9 bed.

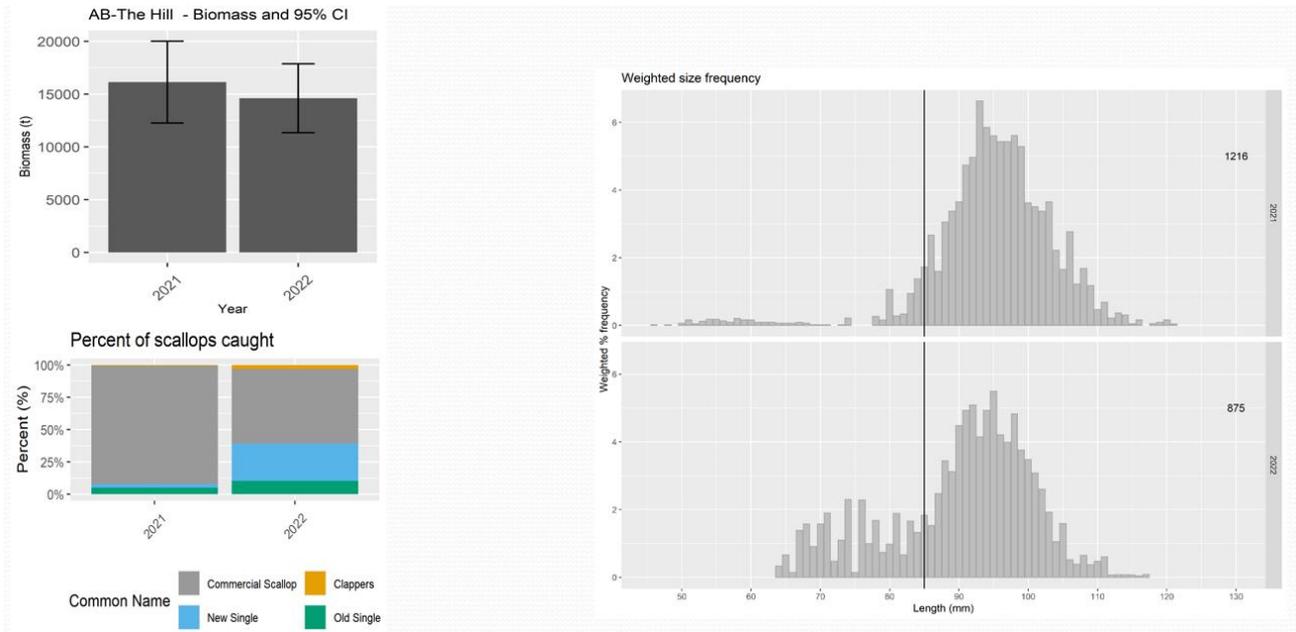


Figure 19. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the AB – The Hill.

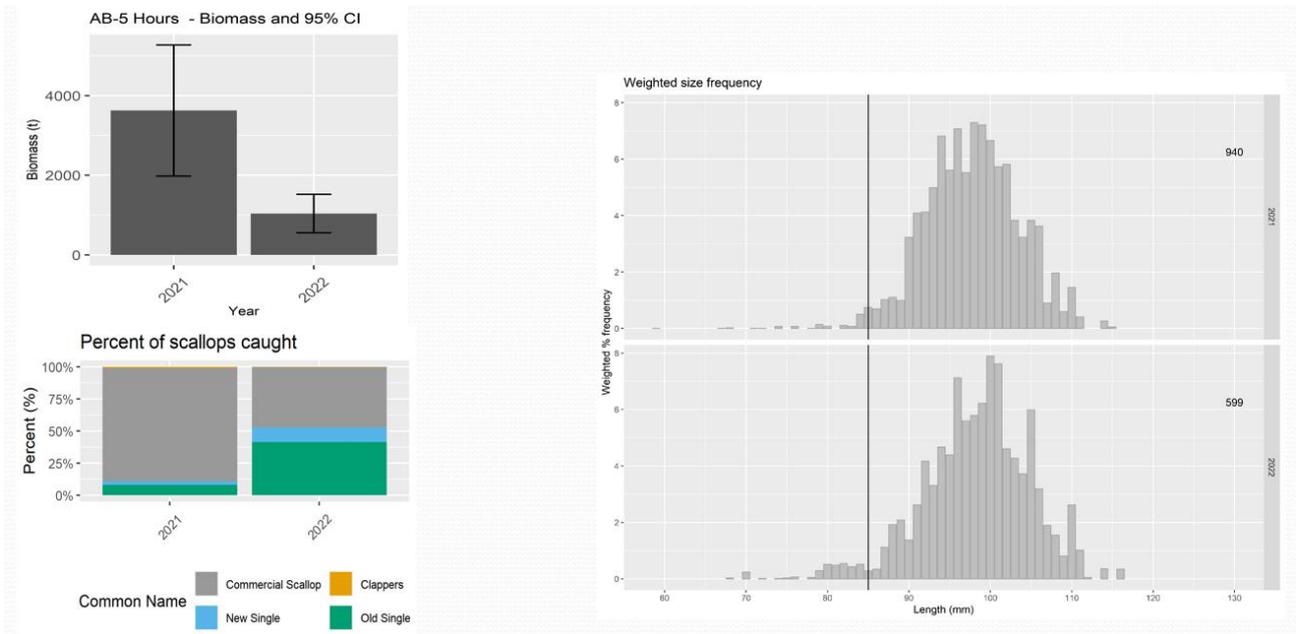


Figure 20. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the AB – Five Hours.