



Australian Government

Australian Fisheries Management Authority

Bass Strait Central Zone Scallop Fishery — 2021 Survey

AFMA Project 2019/0812

June 2021

**Matt Koopman, Ian Knuckey,
Jessica Kube, Michael Davis and
Andrew Sullivan**



Contents

About this document 3

1 Executive Summary 4

2 List of Tables 5

3 List of Figures 5

4 Acknowledgements 7

5 Introduction 8

 5.1 Objectives 8

6 Methods 9

 6.1 Survey Design 9

 6.2 Sampling methods 14

 6.3 Data analysis 14

7 Results 16

 7.1 Survey shots 16

 7.2 Biomass, size and potential commercial catch rates 16

 7.3 Biologicals 17

 7.4 Bycatch 18

8 Discussion 32

9 References 34

10 Appendix 1 - Methods 35

11 Appendix 2 - Time series data 37

Version	Updates	Approver

About this document

© 2021 Fishwell Consulting.

All rights reserved.

ISBN 978-0-6480172-8-8

Title: Bass Strait and Central Zone Scallop Fishery - 2021 Survey

AFMA Project 2019-0812

2021

Ownership of Intellectual Property Rights

Unless otherwise noted, copyright (and any other intellectual property rights, if any) in this publication is owned by the Fishwell Consulting and the Australian Fisheries Management Authority.

This publication (and any information sourced from it) should be attributed to:

Koopman, M., Knuckey, I., Kube, J., Davis, A. and Sullivan, A. (2021). Bass Strait and Central Zone Scallop Fishery - 2021 Survey. AFMA Project 2019-0812. Fishwell Consulting. 39 pp.

Creative Commons Licence

All material in this publication is licensed under a Creative Commons Attribution 3.0 Australia Licence, save for content supplied by third parties, logos and the Commonwealth Coat of Arms.



Creative Commons Attribution 3.0 Australia Licence is a standard form licence agreement that allows you to copy, distribute, transmit and adapt this publication provided you attribute the work. A summary of the licence terms is available from creativecommons.org/licenses/by/3.0/au/deed.en. The full licence terms are available from creativecommons.org/licenses/by/3.0/au/legalcode.

Inquiries regarding the licence and any use of this document should be sent to: ian@fishwell.com.au

Cover photo: Jess Kube

Disclaimer

The authors do not warrant that the information in this document is free from errors or omissions. The authors do not accept any form of liability, be it contractual, tortious, or otherwise, for the contents of this document or for any consequences arising from its use or any reliance placed upon it. The information, opinions and advice contained in this document may not relate, or be relevant, to a reader's particular circumstances. Opinions expressed by the authors are the individual opinions expressed by those persons and are not necessarily those of the publisher, research provider or the AFMA.

Researcher Contact Details

Name: Ian Knuckey
Address: Fishwell Consulting
27A Hesse St Queenscliff, VIC 3225
Phone: +61 3 5258 4399
Web: www.fishwell.com.au



1 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 2000 t) or Tier 2 (catches $>$ 2000 t) management arrangements. 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 2021 research surveys.

Four commercial fishing vessels were selected by an independent panel to conduct the 2021 scallop surveys: the Dell Richey II, Northern Star, Odete C and the Rachel Maree, however due to required maintenance, the Northern Star became unavailable. During May 2021, stratified random surveys were conducted using these vessels on three beds off Flinders Island, six beds off King Island and three beds off Apollo Bay. Choice and prioritisation of these beds was made based on previous surveys and commercial catches from 2020, and with input from the Scallop Resource Assessment Group (ScallopRAG) and the Industry Co-Management Committee. Beds surveyed in 2021 were a combination of new beds and beds that had been previously surveyed. Of the new beds for 2021, two were off Flinders Island, one off King Island and two near the Apollo beds. The number of random survey points allocated to each bed generally ranges 15 – 25, depending on the size of the bed, but also reflects what an observer can reasonably monitor during one twelve-hour day.

Random stratified surveys were successfully undertaken on twelve scallop beds off Flinders Island, King Island and Apollo Bay. Beds were selected based on a combination of previous surveys, distribution of 2019 and 2020 catch and effort, advice from ScallopRAG, and marks provided by industry. In total, 316 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 20,582 t at the three Apollo beds, 13,142 t at the three Flinders Beds and 17,454 t at the King Island beds. The total biomass greater than 85 mm at all sites combined was 64,002 t. The percent of Commercial Scallops greater than 85 mm was more than 90% at most sites, while only 14.2%, 23.5% and 74.2% of Commercial Scallops were greater than 85 mm at KI-7, JH-E and KI-9 respectively, all three sites with significant recruitment observed. Densities in individuals per m² ranged 0.221 at AB2-E to 3.167 at The Hill.

Survey results were presented to ScallopRAG on 15/6/2019 and the Scallop Management Advisory Committee (ScallopMAC) on 18/6/2019.

2 List of Tables

Table 1. Description of beds surveyed since 2015. See Figure 1 for maps of beds.....	11
Table 2 Inputs used in biomass calculations.	18
Table 3 Names, nicknames (used in this report) surveyed in 2021 and area of polygons (km ²).	18
Table 4 Total commercial catch (t) and the number of vessels that fished within each 2021 survey bed during the 2020 fishing season based on logbook data. Records coloured red are confidential – they were used in the analyses but removed for final report.	19
Table 5. Biomass estimates, 95% confidence limits and number of tows included in analyses. Note that both densities have been adjusted for a 33% assumed dredge efficiency.	20
Table 6. Percent weight of scallops > 85 mm (catch weighted by weight), and biomass estimates 95% confidence limits for scallops greater than 85 mm.	21
Table 7. Number of length measurements (N), median, mean and standard error (SE) of scallops measured, and % of scallops measured (catch weighted by weight) less than and greater than 85 mm and mean number of meats per kg of scallops greater than 85 mm from each bed.	21
Table 8. 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.	22
Table 9. Catch of each species in each bed. (u) refers to undifferentiated species recorded at a higher taxonomic level.	22
Table 10. Summary of data used to inform the 2021 ScallopRAG and ScallopMAC recommendation for harvest strategy requirements and TAC.	33
Table 11. Gonad maturation scheme for macroscopic field staging of scallops (taken from Semmens <i>et al.</i> , 2019).	35

3 List of Figures

Figure 1 History of beds surveyed off Flinders Island (top left panel), King Island (top right panel) and Apollo Bay (lower panel) from 2015 to 2 019.	10
Figure 2. Scallop density (kg / 1000 m ²) within the FI, FIN-TS and FIS-NB beds 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.	24
Figure 3. Scallop density (kg / 1000 m ²) within the KI-BDE, KI-BDSE and KI-10 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.	25

Figure 4. Scallop density (kg / 1000 m²) within the KI-Mid, KI-7, KI-9 and JH-E 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. 26

Figure 5. Scallop density (kg / 1000 m²) within The Hill, AB2-E and 5 Hours sites. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches. 27

Figure 6. Log transformed A) length and weight, B) length and height, C) length and width and D) height and width from each bed. 28

Figure 7. Catch weighted size frequency from shots included in biomass estimates from each bed. The vertical line is at 85 mm..... 29

Figure 8. Frequency of combined meat and gonad weights of scallops >85 mm measured from each bed binned into 2 g weight categories. 30

Figure 9. Percent of scallops at each stage from each bed based on macroscopic staging criteria shown in Figure 12. 30

Figure 10. Percent catch composition by weight from all beds. 31

Figure 11. Percent composition of clappers, live scallop, new single and old single shell from each Bed. 32

Figure 12. Photos of scallops representing 1 and 2) Developing or spent; 3 and 4) Maturing or atretic (reabsorbing eggs as spawning is delayed) and 5 and 6) Partially spawned taken from Semmens *et al.*, 2019)..... 36

Figure 13. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the FI bed. 37

Figure 14. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI-BDE bed..... 37

Figure 15. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI-BDSE bed..... 38

Figure 16. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI-7 bed. 38

Figure 17. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI-9 bed. 39

Figure 18. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the AB2-E bed..... 39

Figure 19. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the JH bed. Note that there was smaller mesh used during the 2019 survey to capture a greater percentage of the juvenile scallops. 40

4 Acknowledgements

We would like to thank Glen Wisby and the crew of the Odete C and John, Graham and Dusty Cull and crew of the Rachel Maree and Stuart and John Richey and the crew of the Dell Richey II for all of their assistance and hard work in undertaking the 2021 survey. We also appreciate the efforts of Andy and Jake Watts for endeavouring to make the Northern Star available for the survey. Dusty Cull and Jake Watts provided valuable information used to define the new Apollo and Flinders Beds. The observers Jessica Kube, Michael Davis and Andrew Sullivan worked very hard to collect all data required to a high quality standard. Heather Johnston (AFMA), provided the logbook data used to guide the survey design. Heather, together with ScallopRAG, ScallopMAC and the BSCZSF Co-Management Committee provided valuable input into the survey logistics and design.

5 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 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 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 ≥ 1500 tonnes in total of high density scallops of a minimum size of 85 mm. The season begins with a 1000 t total allowable catch (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 2021 stratified random surveys.

5.1 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, ScallopRAG and ScallopMAC.

6 Methods

6.1 Survey Design

Survey methods follow those of Knuckey *et al.* (2015), modified from those described in Harrington *et al.* (2008). Initially, four vessels were selected to undertake the survey, but due to maintenance only three vessels ended up being used to undertake a stratified random survey of scallop beds, each with independent observers onboard to collect all of the necessary survey data.

The 2015 survey covered three beds off King Island and one 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 (Figure 1, 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 AB-3, AB-4, FI-3 and FI-4 were not surveyed. In 2019 as well as the Flinders Island bed, Apollo Bay 1 and 2 were surveyed, and two new beds (one stretching south-east of KI Bluedot Extended and another called the JH bed comprising high density of juvenile scallops) were added. To protect the juveniles at 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. The beds surveyed in 2021 were based on previous surveys and advice from the ScallopRAG and the BSCZSF Co-Management Committee. Changes to the beds surveyed since 2015 are outlined in Table 1.

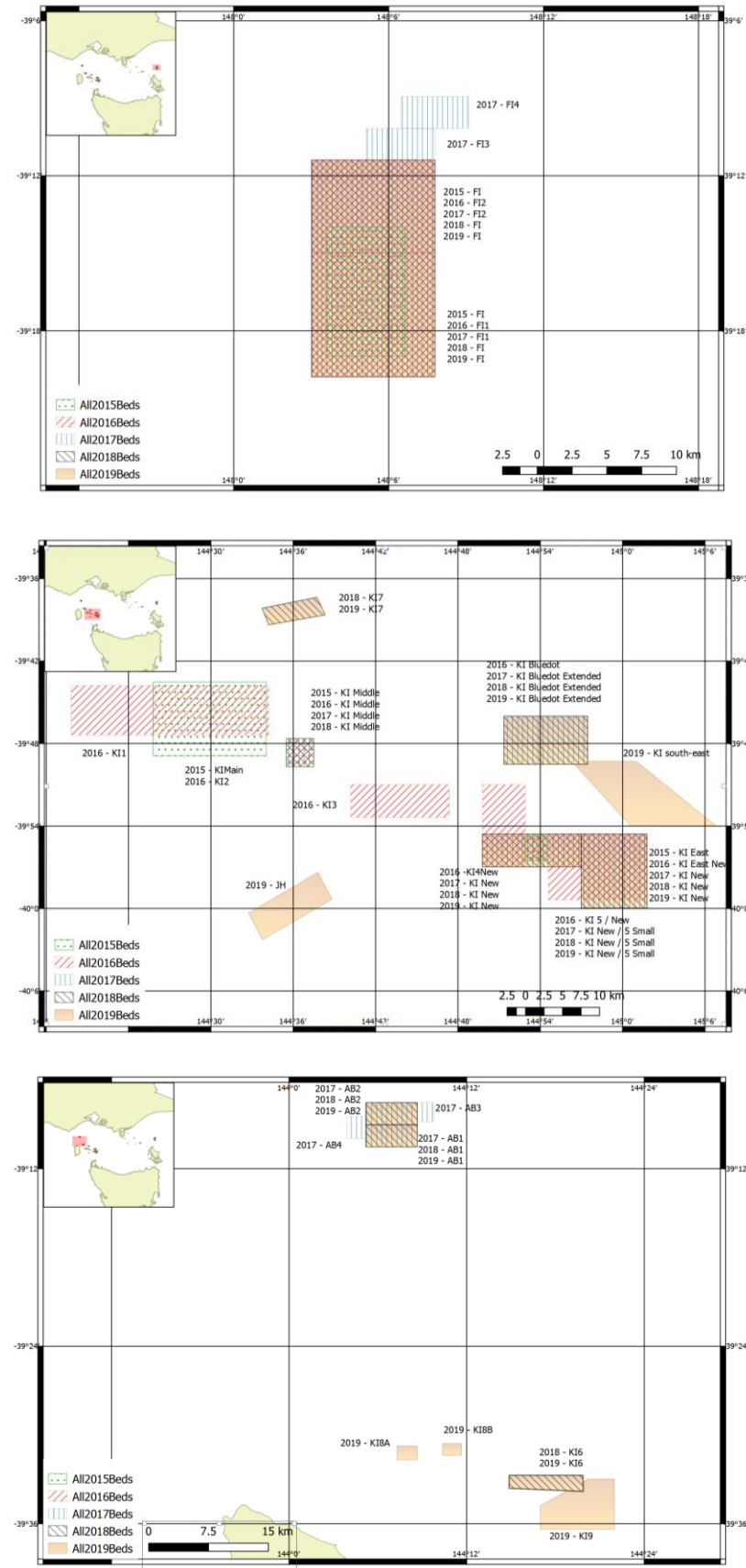


Figure 1 History of beds surveyed off Flinders Island (top left panel), King Island (top right panel) and Apollo Bay (lower panel) from 2015 to 2019.

Table 1. Description of beds surveyed since 2015. See Figure 1 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 1. This bed remained unchanged from the 2017 to 2019 surveys.
	AB-1 and AB-2	Seven exploratory marks off King Island 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 Apollo 1 and 2 bed boundaries remained unchanged during the 2018 and 2019 surveys. For the 2021 survey, only AB2 was surveyed, and the northern boundary was moved north to cover relatively high levels of commercial effort in that area.
	KI-6	Examination of 2018 commercial catch and effort data revealed significant catches in a large area at approximately longitude $144^{\circ} 17'$, latitude $39^{\circ} 32'$. The vessels mapped out this area to provide a smaller area with high density scallops with the boundaries shown in Figure 1. 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 $144^{\circ} 36'$, latitude $39^{\circ} 38'$. The vessels mapped out this area to provide a smaller area with high density scallops with the boundaries shown in Figure 1. 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 RAG recommendations) after exploratory revealed low densities there.

Previously surveyed	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 FI2 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 (Figure 1). The bed boundaries remained unchanged from the 2018 survey and was resurveyed in 2019 and 2021.
	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.
	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.
	JH	An industry member provided two marks that bound a line of exploratory shots 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.
	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.
	KI-Mid	This bed remained unchanged from 2015, 2016, 2017 and 2018. In accordance with RAG recommendations, five exploratory shots were conducted at this bed during 2021 revealing low densities (no scallops were caught), and so KI-7 was surveyed instead.

Bed Type	Name	Description
Exploratory / New Beds	KI-10	Significant catches were taken from an area to the south-east of the KI-BDSE site during 2020. KI10 is a new bed that surrounds that catch.
	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.
	Five hours	Industry members provided marks about 19 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.
	Flinders Island 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.
	Flinders Island 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.

For the 2021 survey, Scallop RAG recommended including the following beds:

1. Apollo Bay 2 (extended)
2. Blue Dot Extended
3. Blue Dot South East
4. King Island 9
5. King Island 10 (exploratory mark)
6. JH extended
7. The Hill north (exploratory mark)
8. 5 hours
9. Flinders Island
10. Flinders Island North/ The Sisters (exploratory mark)
11. Flinders Island South/ North of Babel (exploratory mark)
12. King Island Middle

And that in accordance with the guidance provided in the BSCZSF Principles for Prioritising Survey Bed, the RAG recommended that if the first five exploratory shots at King Island Middle yield less than 50 kg per shot on average, then subject to the discretion of the skipper and observer on board, the survey vessel should move onto King Island 7 and no biomass estimate is to be obtained for King Island Middle.

Survey bed names were given nick names to simplify for tables and figures. These are shown in Table 3 and are used throughout this report.

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 Tool. Additional survey points were allocated to each bed as “backup sites”, to be used where “primary sites” were unfishable.

During 2021, surveys were conducted onboard the fishing vessels Rachel Maree (Scientific Permit# 1004985), Dell Richey II (Scientific Permit# 1004987) and Odete C (Scientific Permit# 1004989), 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 apart from the trip which surveyed AB2-E, The Hill and 5 Hours bed when loggers were not available. They were set to record an observation at regular intervals so that multiple records would be obtained for each trip.

6.2 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 shell 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 to ensure accuracy and consistency of the measuring board throughout the survey. The sample weight of scallops measured was also recorded.

From every fifth shot, 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) (Figure 12). Adductor meat and gonad were removed from the shell and weighed together to calculate number of meats per kg. Shell height and width were also measured for morphometric analyses.

6.3 Data analysis

All data processing and analysis was undertaken in R (R Core Team, 2021). Estimates of biomass and potential commercial catch rates followed the methods of Semmens and Jones (2014).

6.3.1 Biomass

The internal widths of the dredges used during the survey were measured in accordance with Semmens and Jones (2014). Dredge widths used by the Odete C, Dell Richey II and Rachel Maree were 3.905 m, 3.875 m and 3.930 (Table 2). A dredge efficiency of 33% was assumed.

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

$$S=LxW$$

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

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 shot (kg).

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

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

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

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

Where meanD is the mean density (kg) of scallops per m² swept, t_{n-1} is the t-value for the number of shots (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 “geosphere” (Pebesma, 2018).

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

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

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

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

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 W L f 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%).

6.3.2 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 Harrington, Semmens & Haddon (2008). 2008 Commonwealth Bass Strait Central Zone Scallop Fishery Survey. Survey Final Report. Tasmanian Aquaculture and Fisheries Institute. University of Tasmania

6.3.3 Quality Assurance

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

7 Results

7.1 Survey shots

The 20121 BSCZSF survey was undertaken over four legs during May. During the first leg, the Rachel Maree surveyed The Hill, 5 Hours and AB2-E (see Table 3 for explanations of bed names and nicknames) beds between 5th May 2021 and 8th May 2021. The Dell Richey II conducted exploratory shots at KI-Mid and surveyed KI-7, KI-9 and JH-E between 17th May 2021 and 21st May 2021. The Odete C surveyed KI-BDSE, KI-BDE and KI-10 between 17th May 2021 and 20th May 2021, and FI, FIN-TS and FIS-NB between 17th May 2021 and 20th May 2021. Total area of each bed is shown in Table 3. The 5 exploratory shots at KI-Mid (Figure 4) caught no Commercial Scallops, so in accordance with RAG advice, that bed was replaced with KI-7, while 20 to 31 valid, random, non-targeted tows were undertaken in each of the survey beds (Table 5).

7.2 Biomass, size and potential commercial catch rates

Mean biomass estimates for 5 Hours, AB2-E and The Hill were 3,627 t (95%CI 1,979 t – 5,274 t), 818 t (95%CI 209 t – 1,428 t) and 16,137 t (95%CI 12,261 t – 20,014 t) respectively (Table 5). The percentage of scallops <85mm was greater than 5% at the Apollo beds (Table 6), and consequently mean biomasses of scallops > 85 mm were only slightly lower than total biomass estimates: 3,598 t, 814 t and 15,419 t respectively (Table 6).

Mean biomass estimates for FI, FIN-TS and FIS-NB were 6,477 t (95%CI 1,890 t – 11,065 t), 1,078 t (95%CI 803 t – 1,352 t) and 5,587 t (95%CI 4,319 t – 6,855 t) respectively (Table 5). The percentage of scallops <85mm was greater than 5% at FIN-TS and FIS-NB (Table 6), and consequently mean biomasses of scallops > 85 mm were only slightly lower than total biomass estimates: 1,023 t and 5,337 t respectively (Table 6). The percentage of scallops <85mm at FI was about 10%, and the mean biomasses of scallops > 85 mm was 5,821.

Mean biomass estimates for JH-E, KI-7 and KI-9 were 633 t (95%CI 58 t – 1,208 t), 1,473 t (95%CI 681 t – 2,265 t) and 6,367 t (95%CI 4,700 t – 8,034 t) respectively (Table 5). The percentage of scallops <85mm

were about 76.5% at JH-E, 85.8% at KI-7 and 25.8% KI-9 (Table 6). Resulting mean biomasses of scallops > 85 mm at JH-E, KI-7 and KI-9 were 149 t, 209 t and 4,725 t respectively (Table 6).

Mean biomass estimates for KI-BDE, KI-BDSE and KI-10 were 1,904 t (95%CI 626 t – 3,181 t), 15,550 t (95%CI 12,146 t – 18,954 t) and 4,351 t (95%CI 3,699 t – 5,003 t) respectively (Table 5). The percentage of scallops <85mm at KI-BDE, KI-BDSE and KI-10 were about 9.6%, 15.8% and 4.5% (Table 6), resulting in mean biomasses of scallops > 85 mm of 1,721 t, 13,099 t and 4,154 t respectively (Table 6).

Densities in kg/1000m² for the Flinders beds are shown in Figure 2. At FI, zero and low densities were observed in the north and increased towards the south-east. Densities were relatively consistent throughout FIN-TS, however there were some zero catches near the middle of the bed. Medium to high densities were very consistently recorded from throughout the FIS-NB bed.

There was a wide range of densities recorded in the KI-BDE be, from zeros and low densities in the north-west to medium-high densities in the east, and some low and medium densities in the south-west (Figure 3). Densities were consistently high throughout KI-BDSE and KI-10.

All 5 tows conducted at KI-Mid caught zero Commercial Scallops (Figure 4). KI-7 tows increased in density from the south-west to the north-east, however the north of the bed was under sampled, and the two shots conducted in the northern half had low densities. Tows at KI-9 had consistently medium-high densities, highest in the south. Many zero shots were recorded throughout JH-E scattered throughout some low density tows.

Densities at The Hill were very high, particularly in the north of the bed, with two low density shots in the south-east (Figure 5). Apart from one medium density shot in the north-east, catches were zero and low throughout most of AB2-E. Like at The Hill, densities at 5 Hours were very high in the north of the bed, with some low and zero densities in the centre-south.

Estimated densities in numbers at the Apollo beds ranged from 0.221 individuals per m² at AB2-E to 3.167 individuals per m² at The Hill (Table 5). A high density was recorded at FIS-NB (1.566 individuals per m²), with lower densities at FIN-TS (0.751 individuals per m²) and FI (0.602 individuals per m²). High densities were observed at the KI-BDSE (2.928 individuals per m²), KI-10 (2.776 individuals per m²), KI-7 (2.300 individuals per m²) and KI-9 (2.820 individuals per m²). Densities at JH-E and KI-BDE were 0.183 and 0.331 individuals per m² respectively.

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.

7.3 Biologicals

Mean length of scallops measured from beds ranged 80.6 mm at JH-E to 105.8 mm at AB2-E (Table 7). Length frequency distributions from all sites are shown in Figure 7. Significant recruitment was observed at JH-E, KI-7, KI-9 and KI-BDSE, while small signs of recruitment were observed at FI, FIN-TS, KI-10 and The Hill. Beds that had similar size frequency distributions (potentially indicating they are subject to related recruitment events) are FI and FIN-TS, JH-E and KI-7, KI-BDSE and KI-10 and 5 Hours and The Hill. It must be noted however that there is considerable spatial separation between JH-E and KI-7. Scallop meats of shells greater than 85 mm length were greatest at FIN-TS and FIS-NB and smallest at JH-E (Figure 8). Overall, most meats were less than 15 g, and meats per kg ranged 71 at FIS-NB to 128 at The Hill (Table 7). The larger meat weights at the Flinders sites is reflected in the maturity stages (Table 11), with the highest proportion

of stage 2 gonads at FI, FIN-TS and FIS-NB. The greatest proportion of stage 3 gonads were at JH-E, KI-9, 5 Hours and KI-7.

Comparison of length-weight regressions 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 Flinders Island, King Island and Apollo ($p < 0.0001$). Looking at beds within the Flinders area, it was clear the length weight relationship was different between the FIS-NB site and the other two from that area. No difference was observed for the Apollo beds, or between the KI-10, KI-BDE, KI-BDSE beds. These were grouped. There was no evidence of a difference in length-weight relationships between KI-7 and the JK-E sites and these were also combined, however KI-9 was different and so kept separate. Separate length-weight relationships were calculate for each sub area (Table 9). Scatterplots of each combination of size measurements (including total weight) shown in Figure 6.

7.4 Bycatch

A total of 79 different species / groups were identified during the survey (Table 9), and catch composition varied greatly between beds (Figure 10). Overall, live Commercial Scallops comprised 35% of the catch, while Old Single Shell (26%), other Broken Shell (18%) and Sponge (8%) comprised the largest other components of the catch. Ascidiars comprised relatively high proportions of the catch at FIS-NB and JH-E (Figure 10).

One high risk species, a Southern Blue-Ringed Octopus, was recorded from a tow at FI. One TEP species, a Spiney Pipehorse, was recorded from a tow at KI-10. One species of interest, an Australian Handfish, was recorded from a tow at KI-9.

Considering only the four different scallop “groups” (Commercial Scallops, old single, new single, and clappers), FI and KI-BDE had a much higher percentage of old single shell (more than 70%) than other beds (Figure 11). 5 Hours, AB2-E, The Hill and KI-10 had the highest proportion of live Commercial Scallop (>75%). Only Small amounts of clappers were recorded from some beds.

Table 2 Inputs used in biomass calculations.

Inputs	Dell Richey II	Odete C	Rachel Marea
Dredge width	3.930 m	3.905	3.875
Dredge efficiency	33%	33%	33%

Table 3 Names, nicknames (used in this report) surveyed in 2021 and area of polygons (km²).

Bed	Nickname	Total Area (km ²)
Flinders Island	FI	107.32
Flinders Island North - The Sisters	FIN-TS	13.49
Flinders Island South - North of Babel	FIS-NB	31.47
The Hill North	The Hill	60.53

Bed	Nickname	Total Area (km2)
FiveHours	5 Hours	23.61
Apollo2 Extended	AB2-E	30.21
KI Middle	KI-Mid	10.99
King Island 7	KI-7	14.53
King Island 9	KI-9	36.39
JH - Extended	JH-E	62.83
King Island Bluedot SE	KI-BDSE	66.95
King Island Bluedot Ext	KI-BDE	56.53
King Island 10	KI-10	17.13

Table 4 Total commercial catch (t) and the number of vessels that fished within each 2021 survey bed during the 2020 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		
FIN-TS	140	5
FIS-NB	453	6
The Hill	xxx	2
5 Hours	xxx	2
AB2-E	130	5
KI-Mid		
KI-7		
KI-9	230	7
JH-E		
KI-BDSE	xxx	4
KI-BDE		
KI-10	xxx	4
Outside of beds	814	9
Total	2593	9

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

Area	Bed	Number of tows	Mean density (kg/1000 m 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)
Apollo	5 Hours	25	153.6	169.0	1979	3627	5274	608	1.745
	AB2-E	25	27.1	48.9	209	818	1428	107	0.221
	The Hill	25	266.6	155.2	12261	16137	20014	1056	3.167
Sub-total		75				20582			
Flinders	FI	30	60.4	114.5	1890	6477	11065	239	0.602
	FIN-TS	30	79.9	54.4	803	1078	1352	316	0.751
	FIS-NB	26	177.6	99.8	4319	5587	6855	703	1.566
Sub-total		86				13142			
King	JH-E	24	10.1	21.7	58	633	1208	40	0.183
	KI-10	25	254.0	92.2	3699	4351	5003	1006	2.776
	KI-7	20	101.3	116.4	681	1473	2265	401	2.300
	KI-9	25	175.0	111.0	4700	6367	8034	693	2.820
	KI-BDE	31	33.7	61.6	626	1904	3181	133	0.331
	KI-BDSE	30	232.3	136.2	12146	15550	18954	920	2.928
Sub-total		155				17454			
Total		316				64002			

Table 6. Percent weight of scallops > 85 mm (catch weighted by weight), and biomass estimates 95% confidence limits for scallops greater than 85 mm.

Area	Bed	% weight > 85 mm	Lower 95% CL (t)	Estimated Biomass (t)	Upper 95% CL (t)
Apollo	5 Hours	99.2	1963	3598	5232
	AB2-E	99.5	208	814	1421
	The Hill	95.5	11715	15419	19123
Sub-total				19831	
Flinders	FI	89.9	1699	5821	9943
	FIN-TS	95.0	763	1023	1283
	FIS-NB	95.5	4126	5337	6548
Sub-total				12181	
King	JH-E	23.5	14	149	284
	KI-10	95.5	3531	4154	4776
	KI-7	14.2	97	209	321
	KI-9	74.2	3488	4725	5961
	KI-BDE	90.4	566	1721	2875
	KI-BDSE	84.2	10231	13099	15966
Sub-total				24055	
Total				56067	

Table 7. Number of length measurements (N), median, mean and standard error (SE) of scallops measured, and % of scallops measured (catch weighted by weight) less than and greater than 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
5 Hours	940	97	97.0	0.2	0.8	99.2	90
AB2-E	847	106	105.8	0.2	0.5	99.5	96
The Hill	1216	96	93.9	0.4	4.5	95.5	128
FI	1085	96	94.4	0.3	10.1	89.9	77
FIN-TS	1654	98	97.3	0.2	5.0	95.0	76
FIS-NB	1525	99	99.9	0.3	4.5	95.5	71
JH-E	319	78	80.6	0.5	76.5	23.5	114
KI-10	1515	94	92.4	0.2	4.5	95.5	85
KI-7	842	77	78.3	0.3	85.8	14.2	NA
KI-9	1255	94	86.0	0.5	25.8	74.2	93
KI-BDE	915	90	90.0	0.2	9.6	90.4	86
KI-BDSE	2168	93	89.4	0.3	15.8	84.2	85

Table 8. 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
FIS-NB	50	-4.737	1.936	0.42
Flinders Island	99	-6.501	2.381	0.78
Blue Dot Beds	169	-7.024	2.482	0.76
KI-9	50	-7.564	2.575	0.918
JK-E/KI-7	65	-12.580	3.700	0.678
Apollo Bay	127	-7.659	2.649	0.70

Table 9. Catch of each species in each bed. (u) refers to undifferentiated species recorded at a higher taxonomic level.

Species	Catch (kg)												
	5 Hours	AB2-E	The Hill	FI	FIN-TS	FIS-NB	KI-10	KI-BDE	KI-BDSE	KI-Mid	JH-E	KI-7	KI-9
Commercial Scallop	2428.6	461.8	4540	1297	2116.9	2824.8	7081.3	787.5	5790	0	117.4	1080.3	2270
Clappers	20	3.3	19.2	5.48	21.38	6.7	44	13	124	0	0.5	24	71
New Single	76	54.5	134	224.3	529.2	807	620	182	937	0.7	251	84	413
Old Single	217	44	241	4412	1373.7	1340.6	1000	7290	1780	0.8	252.5	2136	2801
Algae - Phyllospora											0.3	0.7	0.5
Angel Shark					22.4								
Ascidian (U)			6	138	110.4	1726.4	120	60	33	5	407	74	147
Australian Angelshark												10	
Australian Handfish													0.05
Australian Tulip Shell							65	80	80				
Banded Stingaree	0.6	0.7	1.5	0.06	3	5.1		3.2		1	1.4	12	1.6
Beaked Salmon					0.2								
Blue Warehou										0.2			
Brittlestars (U)				0.47	4								0.1
Bug	0.5	0.1	0.2	0.4	0.35			0.1				0.1	0.2
Butterfly Gurnard		0.2											
Cockle 1				59.2	0.7	108							
Cocky Gurnard	0.4	1.6	0.2				0.2		0.2	0.2	0.5	0.1	1
Common Gurnard Perch									0.1				
Common Stinkfish	0.5											0.9	
Cowrie (U)				0.08									
Crab (U)			0.2	0.67	0.77	0.5							
Cuttlefish (U)	1												
Dog Cockles						2.5							
Doughboy Scallop	10.2		6.2	14.98	28.5		30	0.1	97			102.5	50
Draughtboard Shark							3				3	42	0.2
Elephantfish									1				
Eleven-Arm Seastar	99					36.7		53	105		41	95	5
Fish (U)		0.2											
Flounder (U)				0.4									0.1
Greenback Stingaree		1		0.09	3.48	2.2					0.3		
Gurnard - Undifferentiated				0.08	0.45	0.5							
Hard Coral	4										10	30	
Hermit Crab (U)	2.3	1.6	3.7	33.33	126.8	69.9	80.5	4	18	0.9	6	14.2	13
Holothurian (U)	9.2	1.2	26							0.4	4.6	32	
Leatherjackets - Undifferentiated													0.2
Maori Octopus							12	3.6	8.1				
Melbourne Skate									3				
Nudibranch (U)				0.01									
Octopus (U)	4.3	3.3	5.9	3.49	1.71	1.4					1.1	30	34.1
Oysters				17.6	10	218.2	20						
Painted Stinkfish	0.2												
Pale Octopus				7.4	9.9	9.4	36	2	11.5				
Peacock Skate							2						
Polychaete Worm (U)	0.1	0.1		0.01	0.05	0.05						0.1	0.2
Pufferfish (U)												0.4	
Queen Scallop						3							
Razorfish (U)	1.7	3.7	2.9	2.36		6.5					0.3	0.3	0.1
Red Cod											0.3		
Red Gurnard											0.2		
Sandyback Stingaree							3						
Sawshark													3
Scorpionfish (U)					0.5								
Sea Urchin (U)			6.2	12.31	16.4								
Seapen (U)	1.2		5.5	0.5							0.5		

BSCZSF – 2021 Scallop Survey

Species	Catch (kg)												
	5 Hours	AB2-E	The Hill	FI	FIN-TS	FIS-NB	KI-10	KI-BDE	KI-BDSE	KI-Mid	JH-E	KI-7	KI-9
Seastar (U)	0.5	0.3	1.5	0.9	0.09	0.4							
Shark Egg (U)											0.1		
Shaw Cowfish												0.2	0.2
Skate (U)						3							
Sole (U)				0.16	0.6								
Southern Blue-Ringed Octopus				0.16									
Southern Sand Flathead						1							
Sparsely-Spotted Stingaree	0.3	1.9	2					2	3.5	0.2	3	2.2	0.3
Spider Crab (U)		18.8	0.5	35	62.7	10.9	46	19	50	375			200
Spiny Pipehorse							0.1						
Sponge (U)	234	34	476	1007.5	227.4	284	375	732	201		209	925	1753
Sponges (Coral)			10				32	2					
Stargazers - Undifferentiated	1.3	5.5		6.5	12.9	6					5.3		
Stingray (U)				2	9								
Substrate - Broken Shell	20	6	122	4010	2081	1740.1	985	1675	1725	1.2	155	303	2510
Substrate - Rock	60	6	20								325	27	26
Tasmanian Numbfish		0.3						2		0.2		0.8	0.3
Thornback Skate	0.4		0.8										
Tiger Flathead	0.6	0.6	0.8					0.3	0.5		0.2		
Velvet Leatherjacket		0.1											
Venus Shells	0.1		0.3										
Volute (U)	1	5.3	4	5.29	5	4.5		4.4	0.2	1.2	0.1	10	3.1
Whelk	1.3	6.1	2.8	37.15	50.5	71		0.4	4.1	2.6	71.8	140	8
Whitespotted Skate							1	2	3				

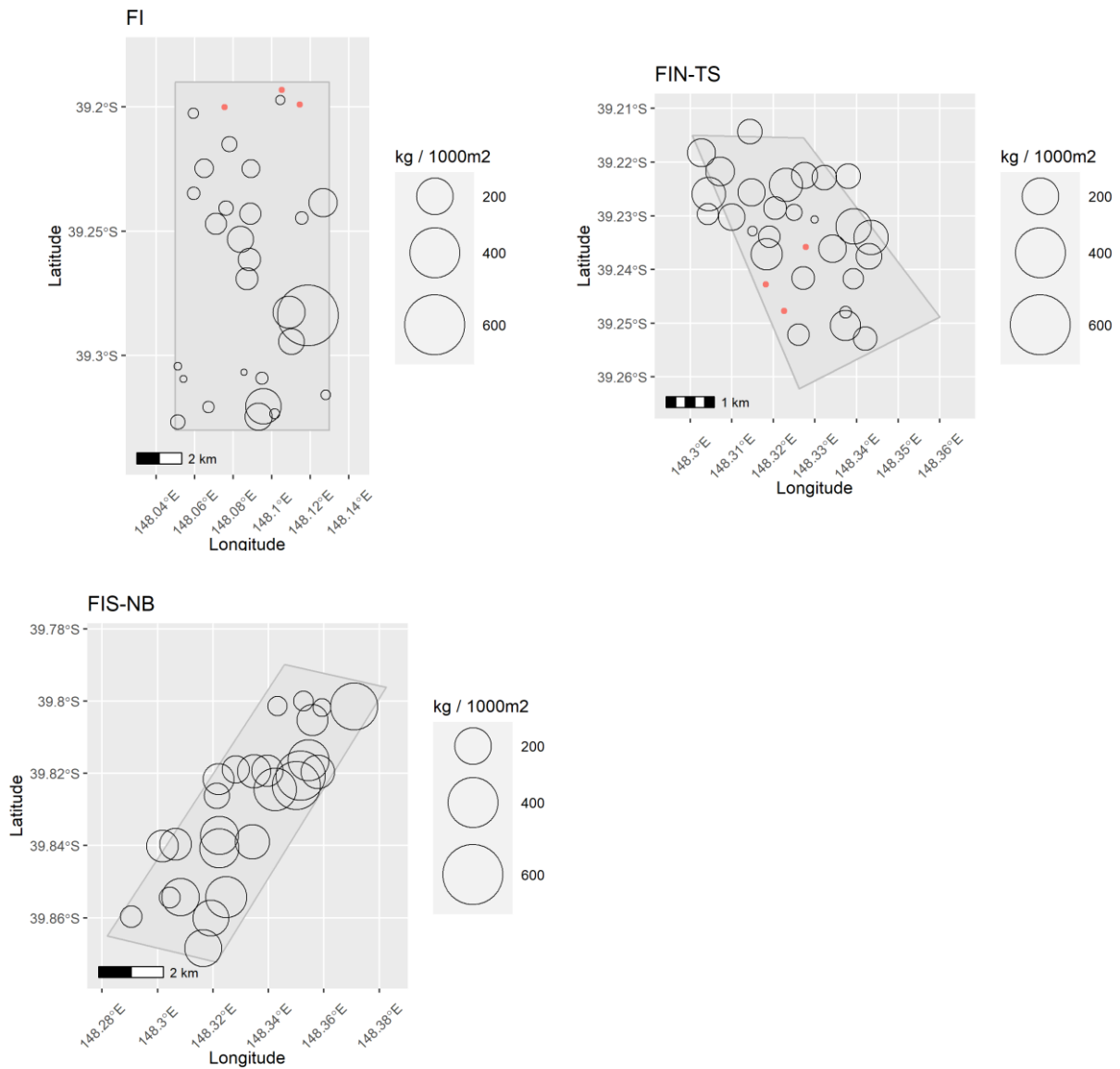


Figure 2. Scallop density (kg / 1000 m²) within the FI, FIN-TS and FIS-NB beds near Flinders Island. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

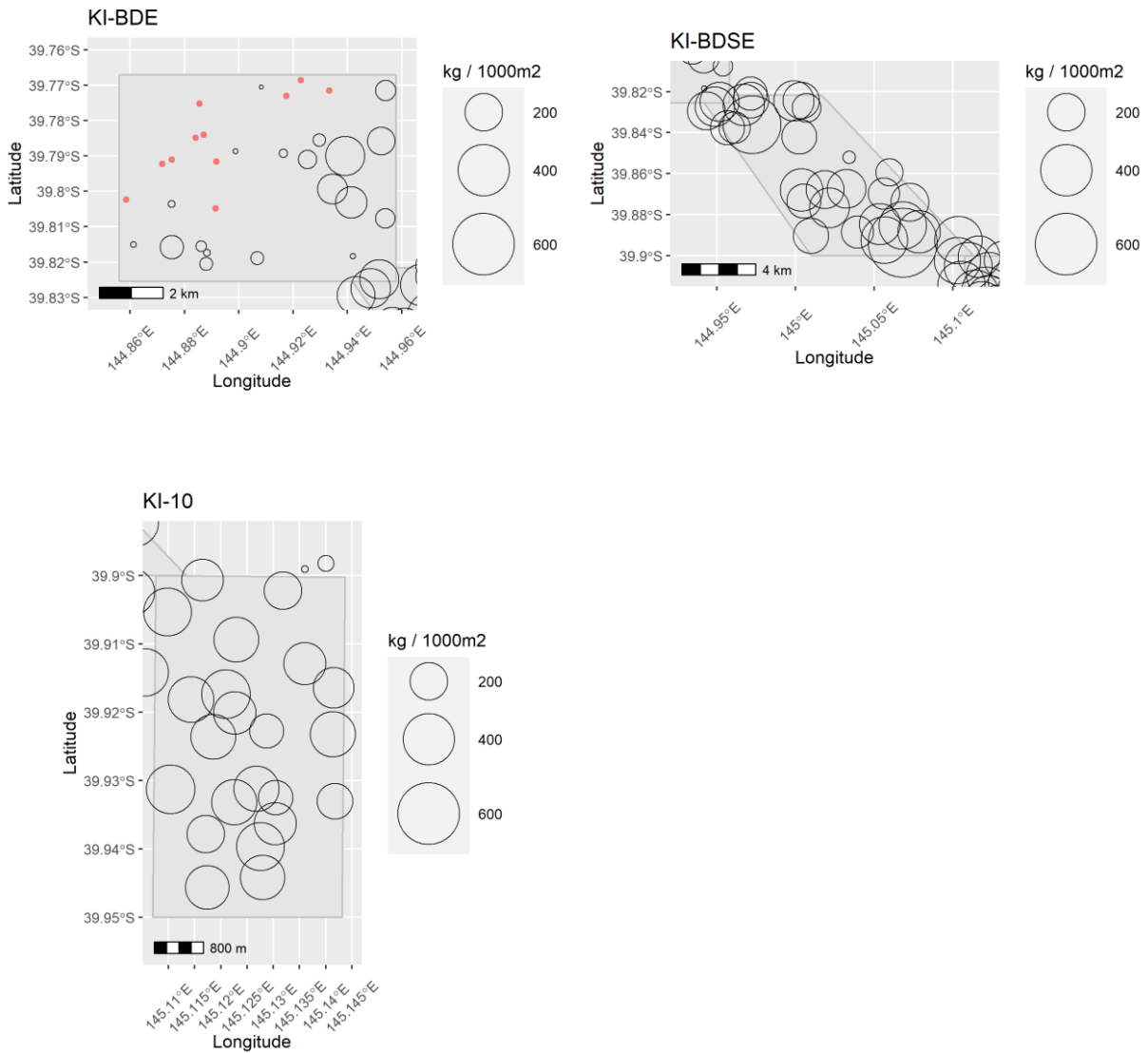


Figure 3. Scallop density (kg / 1000 m²) within the KI-BDE, KI-BDSE and KI-10 beds. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

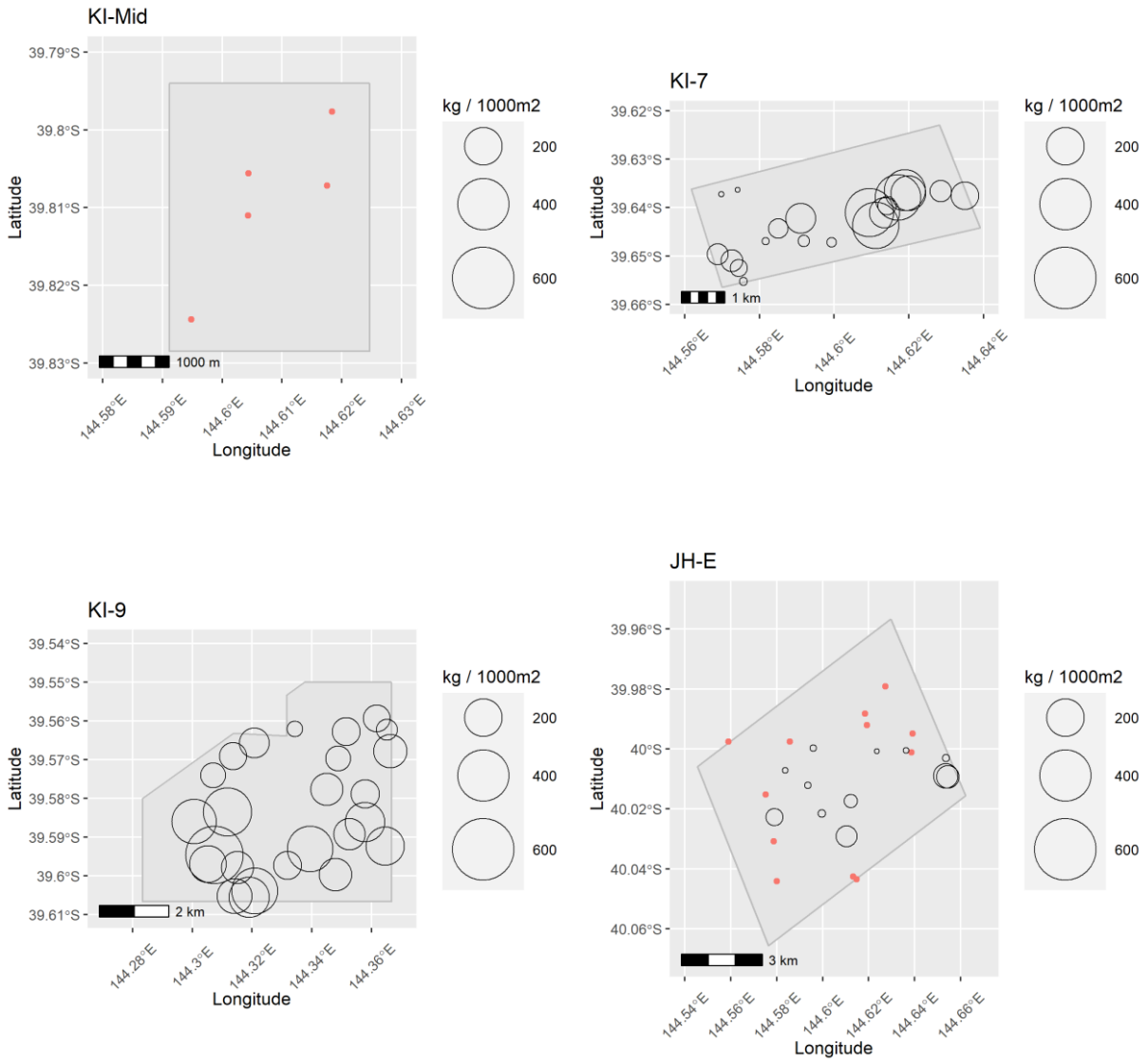


Figure 4. Scallop density (kg / 1000 m²) within the KI-Mid, KI-7, KI-9 and JH-E beds. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

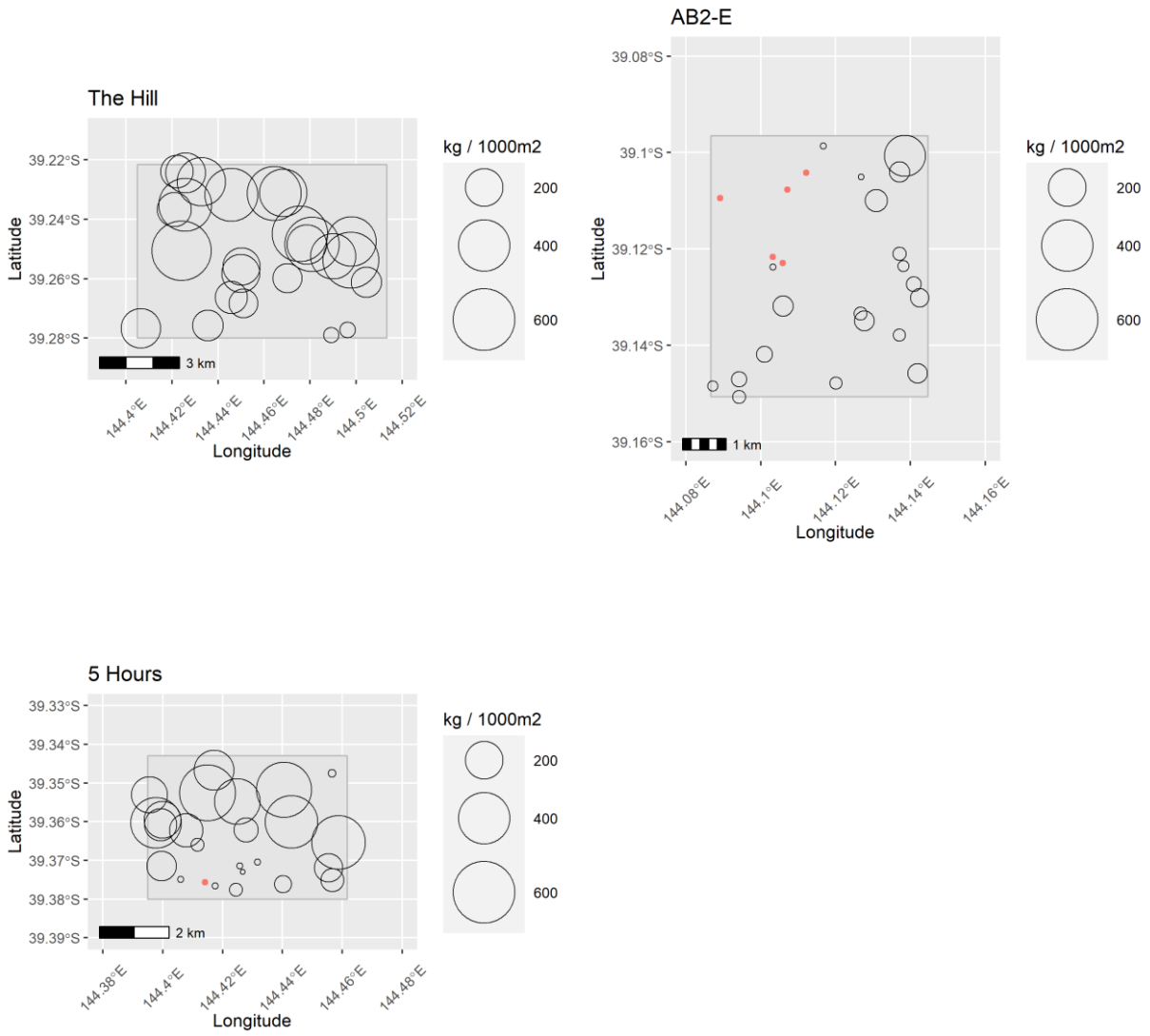


Figure 5. Scallop density (kg / 1000 m²) within The Hill, AB2-E and 5 Hours sites. The top right scale bubbles reflect the estimated scallop density of each tow assuming a dredge efficiency of 33%. Red circles denote zero catches.

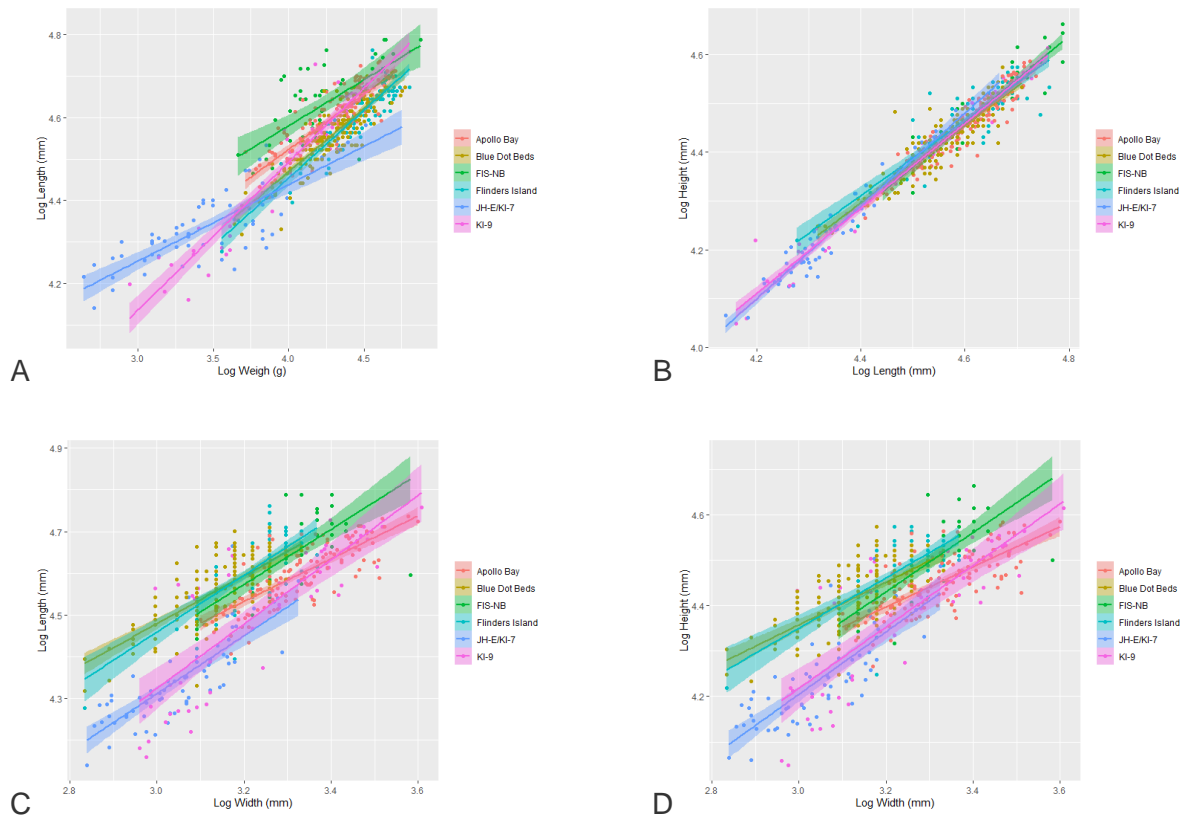


Figure 6. Log transformed A) length and weight, B) length and height, C) length and width and D) height and width from each bed.

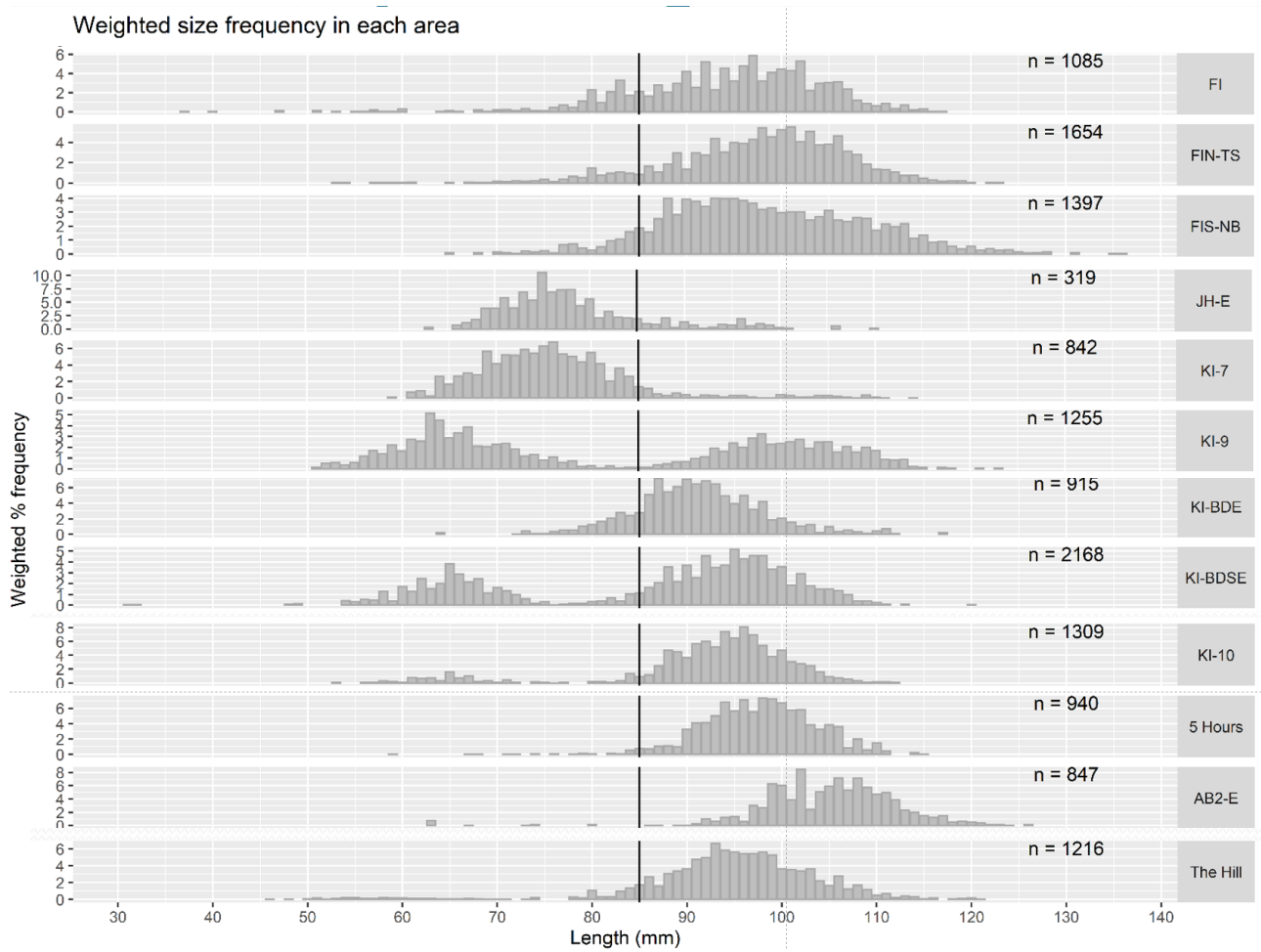


Figure 7. Catch weighted size frequency from shots included in biomass estimates from each bed. The vertical line is at 85 mm.

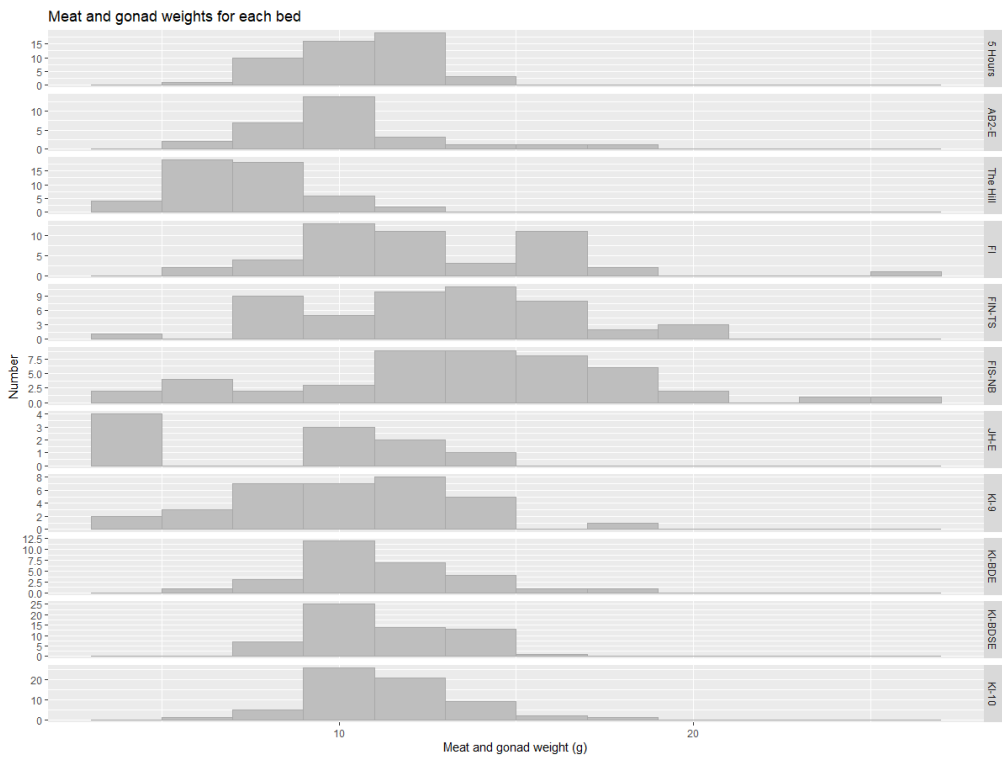


Figure 8. Frequency of combined meat and gonad weights of scallops >85 mm measured from each bed binned into 2 g weight categories.

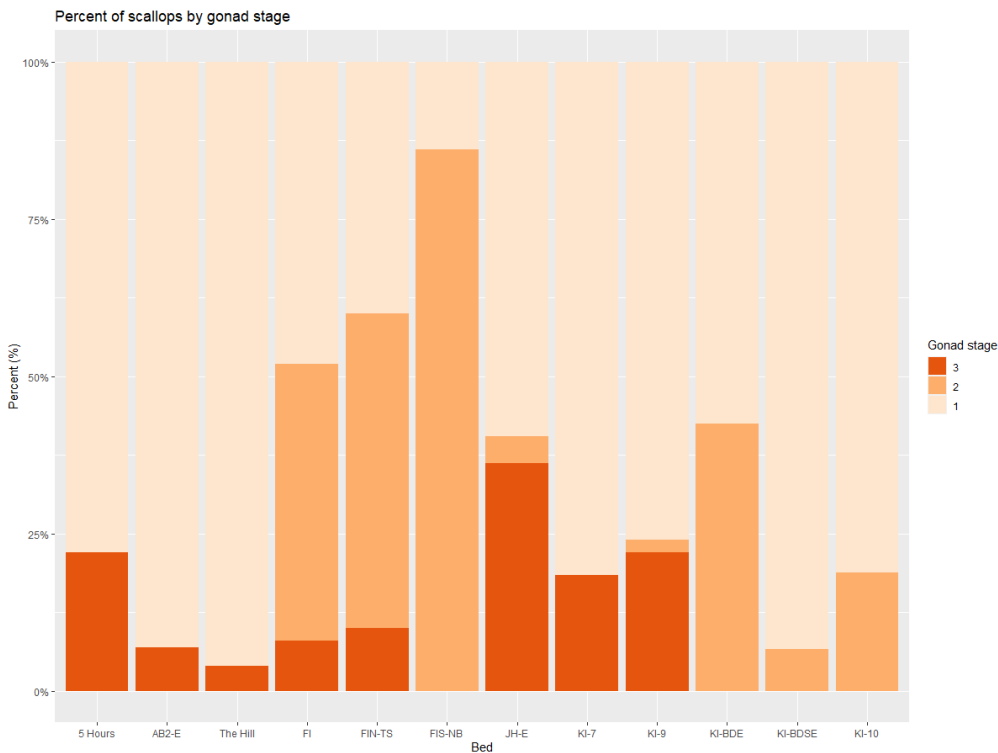


Figure 9. Percent of scallops at each stage from each bed based on macroscopic staging criteria shown in Figure 12.

Catch of top 5 species

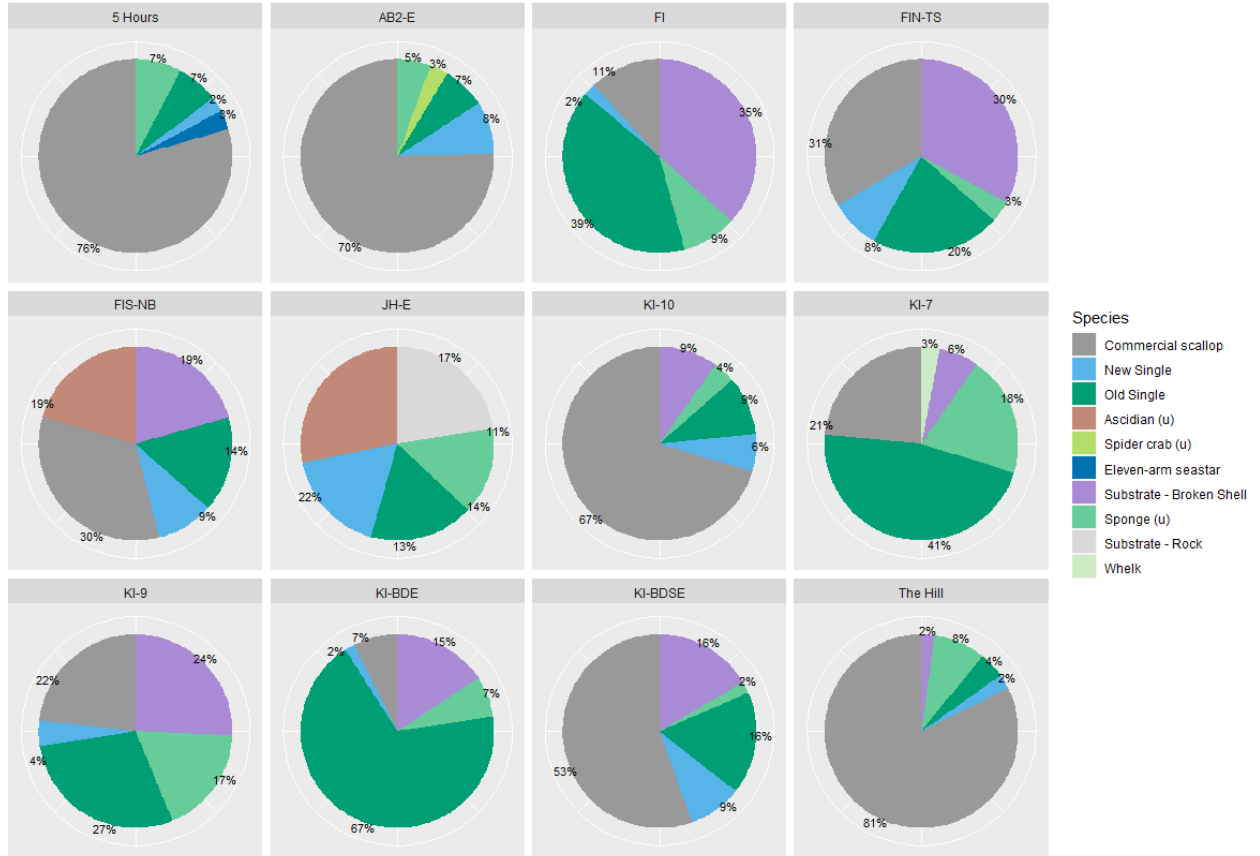


Figure 10. Percent catch composition by weight from all beds.

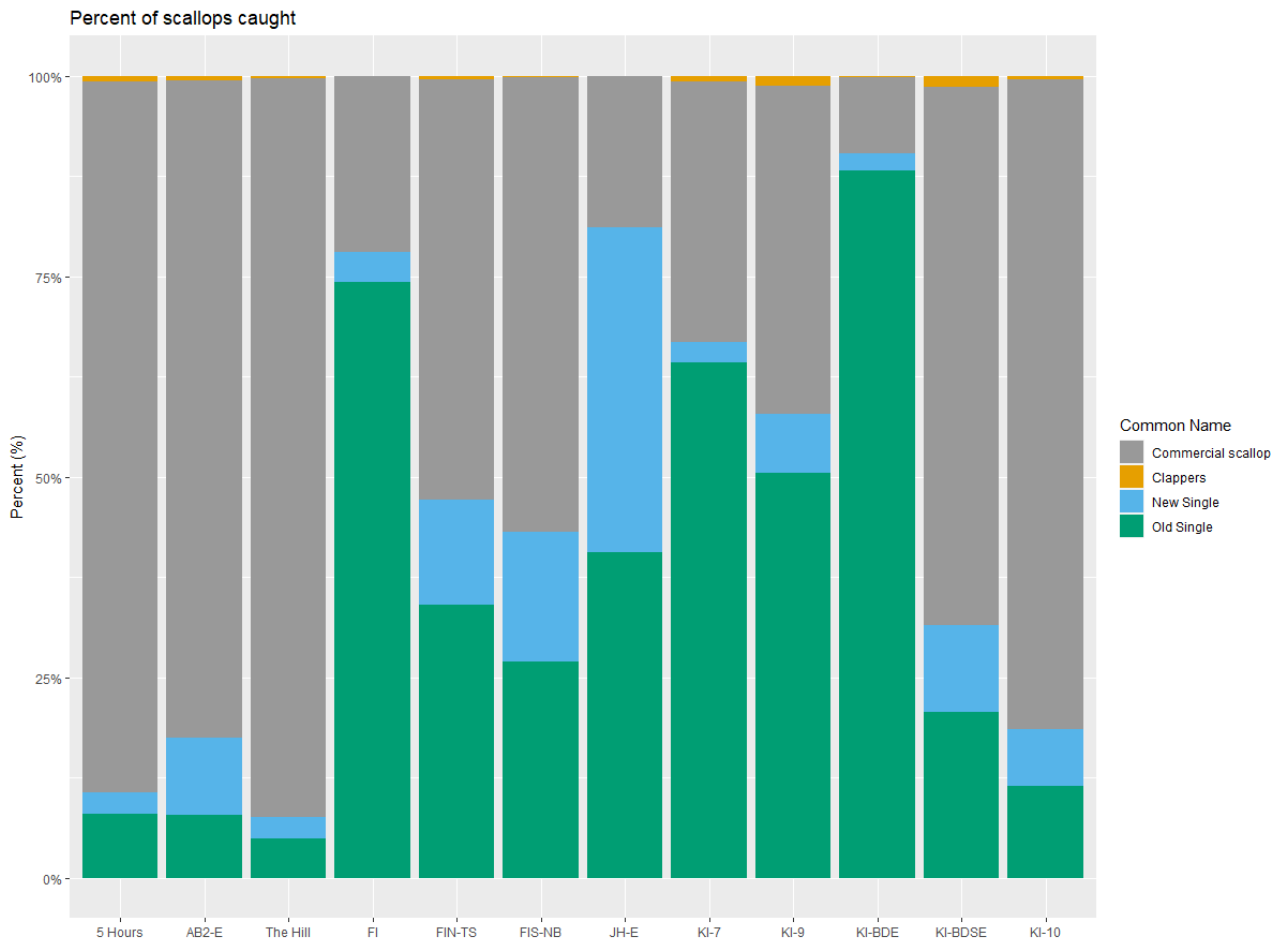


Figure 11. Percent composition of clappers, live scallop, new single and old single shell from each Bed.

8 Discussion

Random stratified surveys were successfully undertaken on twelve scallop beds off Flinders Island, King Island and Apollo Bay. 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, 316 valid, random survey tows were undertaken across 12 beds. Biomass was calculated for each bed using area swept calculated from the straight line distance between the start and end tow points and the measured internal width of the dredges.

Biomass of Commercial Scallops greater than 85 mm at the was estimated to be 20,582 t at the three Apollo beds, 13,142 t at the three Flinders Beds and 17,454 t at the King Island beds (Table 10). Total biomass greater than 85 mm at all sites combined was 64,002 t. The percent of Commercial Scallops greater than 85 mm was more than 90% at most sites, while only 14.2%, 23.5% and 74.2% of Commercial Scallops were greater than 85 mm at KI-7, JH-E and KI-9 respectively, all three sites with significant recruitment observed. Densities in individuals per m² ranged 0.221 at AB2-E to 3.167 at The Hill (Table 10).

These results were presented at ScallopRAG on 15 June 2021 and at ScallopMAC on 18 June 2021.

Table 10. Summary of data used to inform the 2021 ScallopRAG and ScallopMAC recommendation for harvest strategy requirements and TAC.

Area	Bed	Estimated biomass (t)	% weight > 85 mm	Estimated Biomass >85 mm (t)	Density (ind/m ²)	Mean size	Meats / kg (>85 mm)
Apollo	5 Hours	3627	99.2	3598	1.745	97	90
	AB2-E	818	99.5	814	0.221	106	96
	The Hill	16137	95.5	15419	3.167	94	128
	Sub total	20582		19831			
Flinders	FI	6477	89.9	5821	0.602	94	77
	FIN-TS	1078	95.0	1023	0.751	97	76
	FIS-NB	5587	95.5	5337	1.566	100	71
	Sub total	13142		12181			
King	JH-E	633	23.5	149	0.183	81	114
	KI-10	4351	95.5	4154	2.776	92	85
	KI-7	1473	14.2	209	2.300	78	
	KI-9	6367	74.2	4725	2.820	86	93
	KI-BDE	1904	90.4	1721	0.331	90	86
	KI-BDSE	15550	84.2	13099	2.928	89	85
	Sub total	30278		24055			
Total		64002		56067			

9 References

AFMAb, 2009. Ecological Risk Management, Bass Strait Central Zone Scallop Fishery. 18p.

AFMAa, 2012. Bass Strait Central Zone Scallop Fishery, Review of the Bycatch and Discarding Work Plan, 1st June, 2009 to 31st May, 2011. 8p.

Haddon, M., Harrington, J.J. and Semmens, J.M., 2006. Juvenile Scallop Discard Rates and Bed Dynamics: Testing the Management Rules for Scallops in Bass Strait. Tasmanian Aquaculture and Fisheries Institute, Taroona, Tasmania.

Harrington, Semmens & Haddon (2008). 2008 Commonwealth Bass Strait Central Zone Scallop Fishery Survey. Survey Final Report. Tasmanian Aquaculture and Fisheries Institute. University of Tasmania.

Pebesma, E., 2018. Simple Features for R: Standardized Support for Spatial Vector Data. The R Journal 10 (1), 439-446, <https://doi.org/10.32614/RJ-2018-009>

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.

Semmens, J.M., Mendo, Jones, Keane, Leon, Ewing, Hartmann., Institute for Marine and Antarctic Studies, 2018, Determining when and where to fish: Linking scallop spawning, settlement, size and condition to collaborative spatil harvest and industry in-season management strategies, University of Tasmania, Hobart, June. CC BY 3.0

Semmens, J. and Jones, N. (2014). Draft 2014 BSCZSF survey report. Institute for Marine and Arctic Studies. July 2014.

10 Appendix 1 - Methods

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

Table 11. Gonad maturation scheme for macroscopic field staging of scallops (taken from Semmens *et al.*, 2019).³

³ Semmens, J.M., Mendo, Jones, Keane, Leon, Ewing, Hartmann., Institute for Marine and Antarctic Studies, 2018, 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

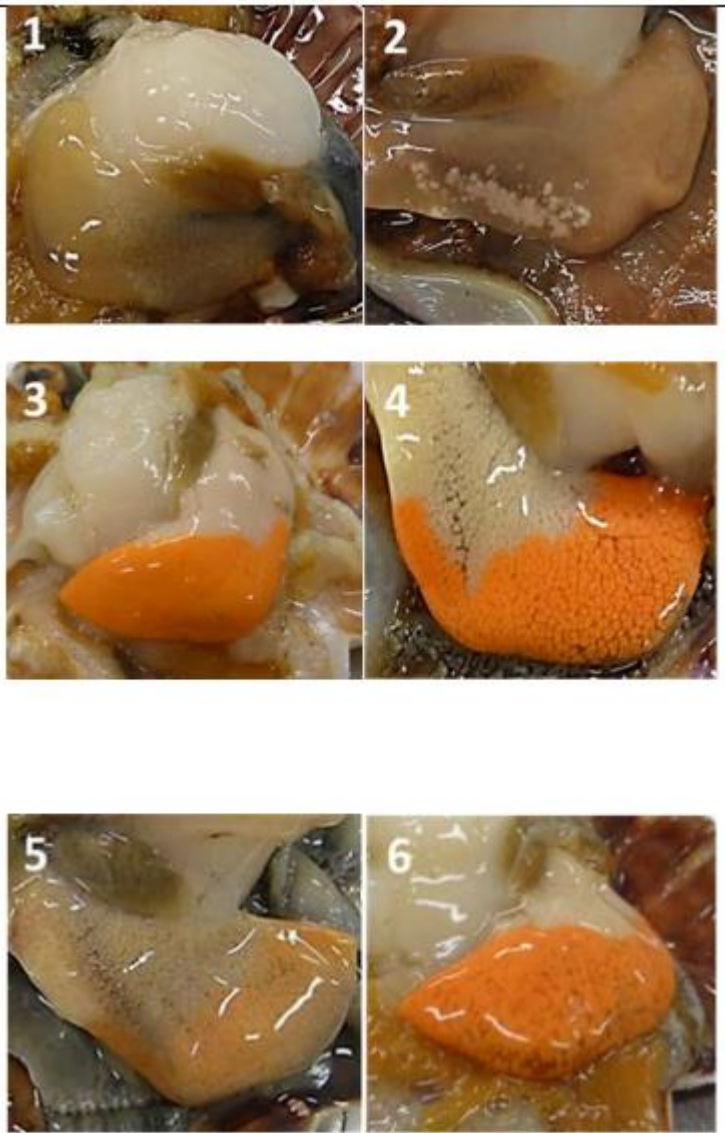


Figure 12. Photos of scallops representing 1 and 2) Developing or spent; 3 and 4) Maturing or atretic (reabsorbing eggs as spawning is delayed) and 5 and 6) Partially spawned taken from Semmens *et al.*, 2019).

11 Appendix 2 - Time series data

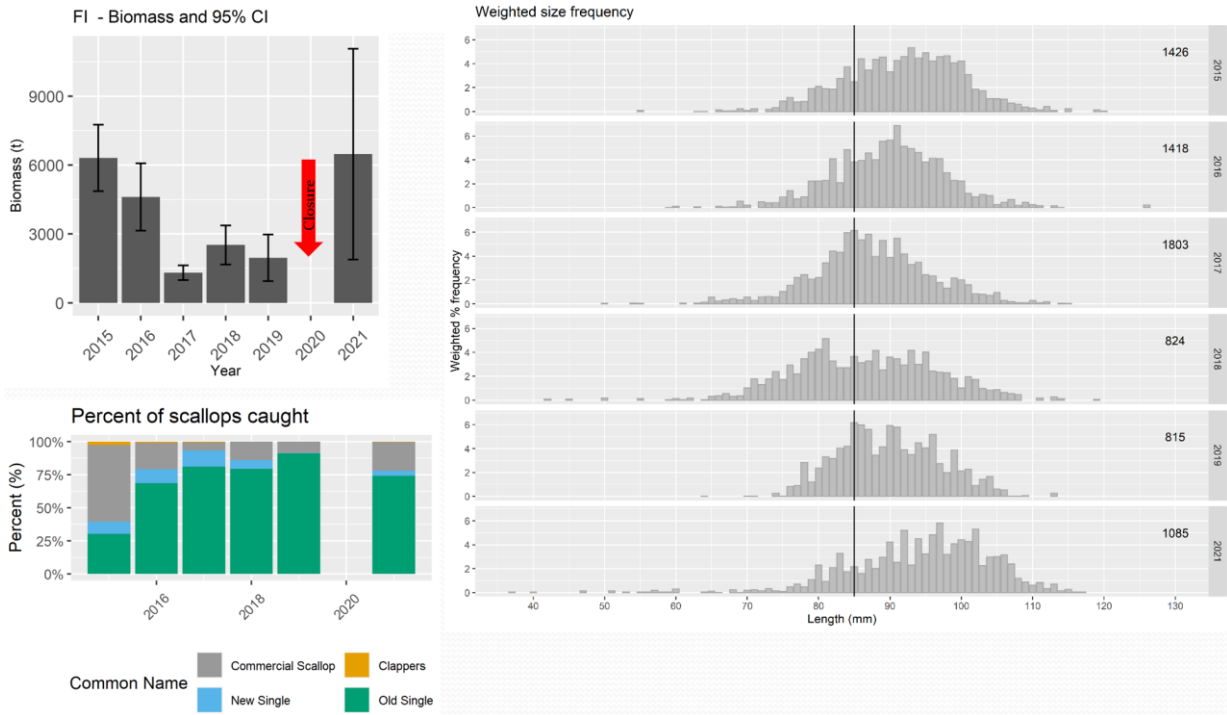


Figure 13. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the FI bed.

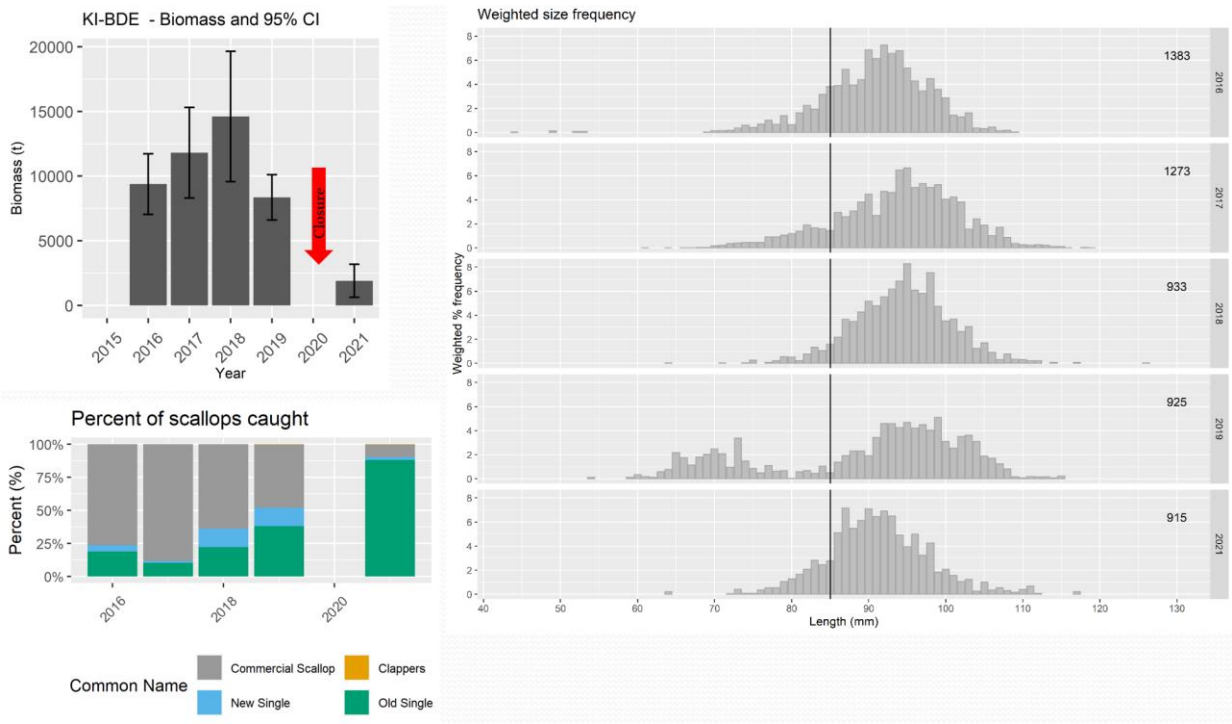


Figure 14. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI-BDE bed.

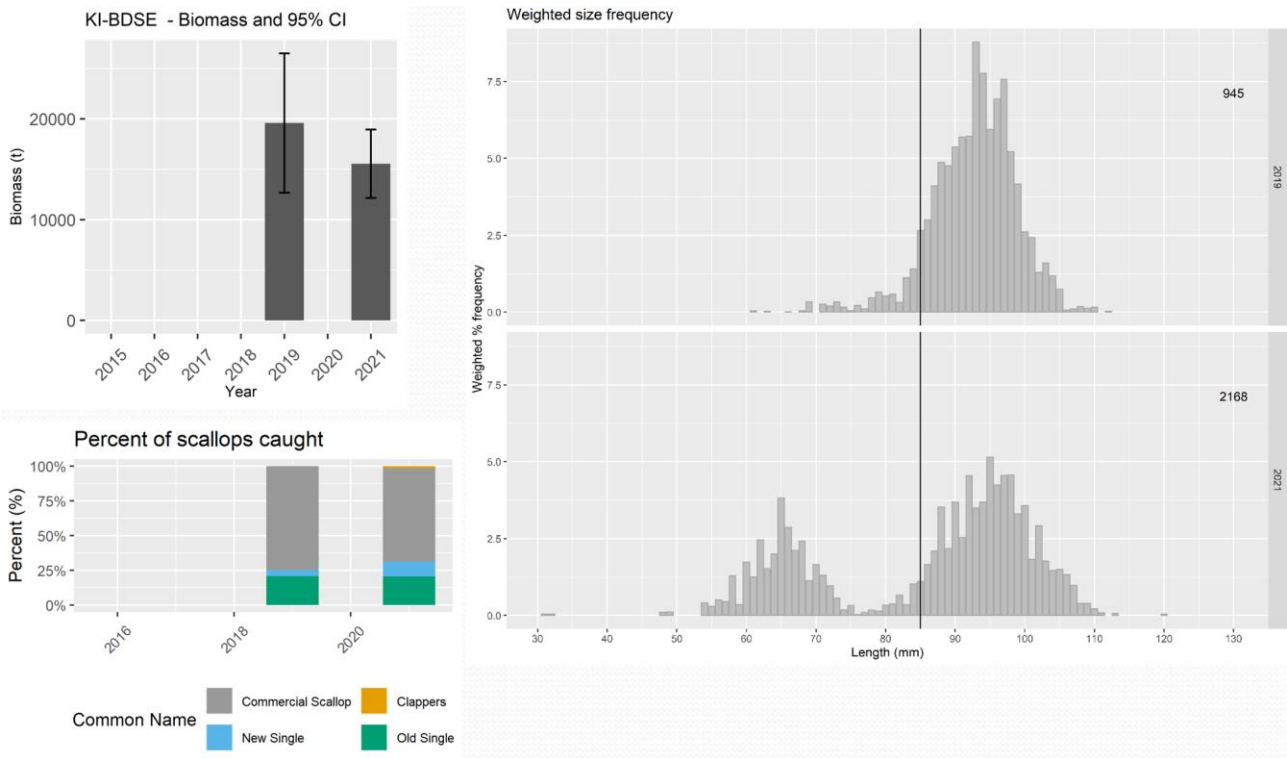


Figure 15. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI-BDSE bed.

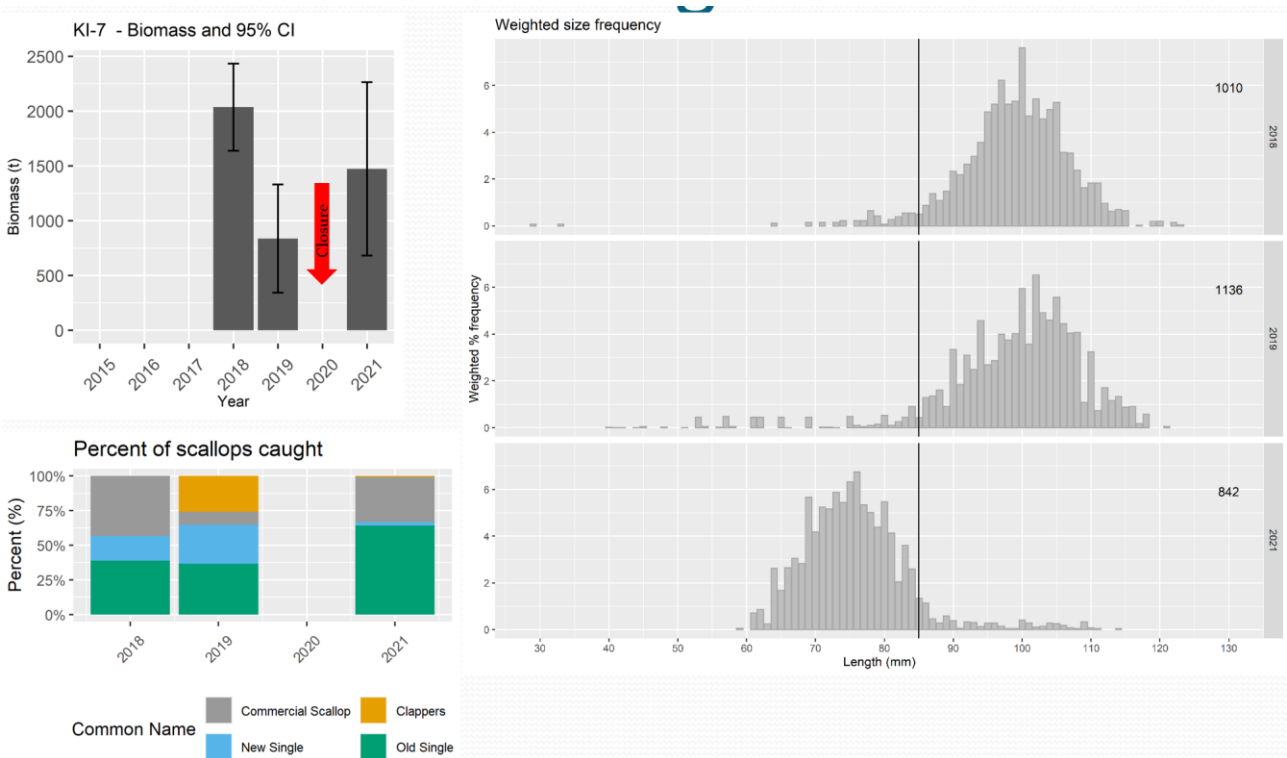


Figure 16. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI-7 bed.

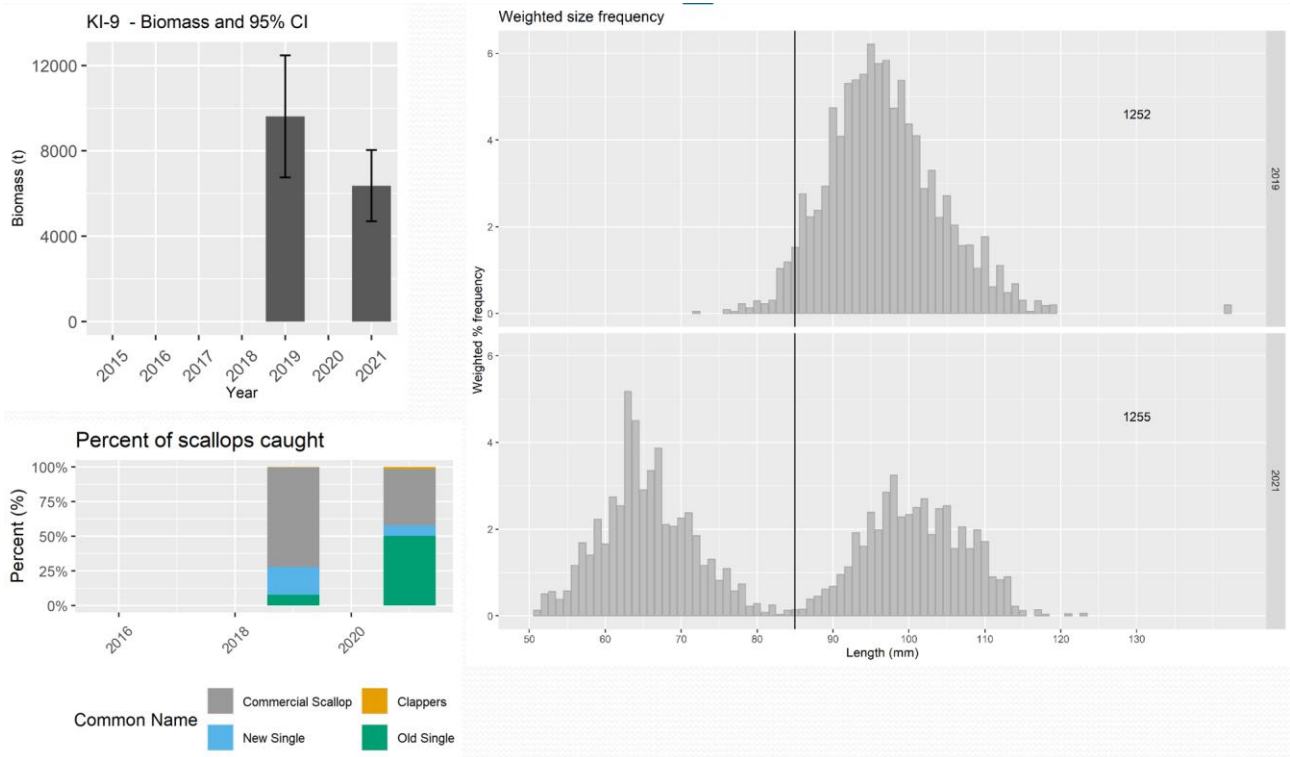


Figure 17. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the KI-9 bed.

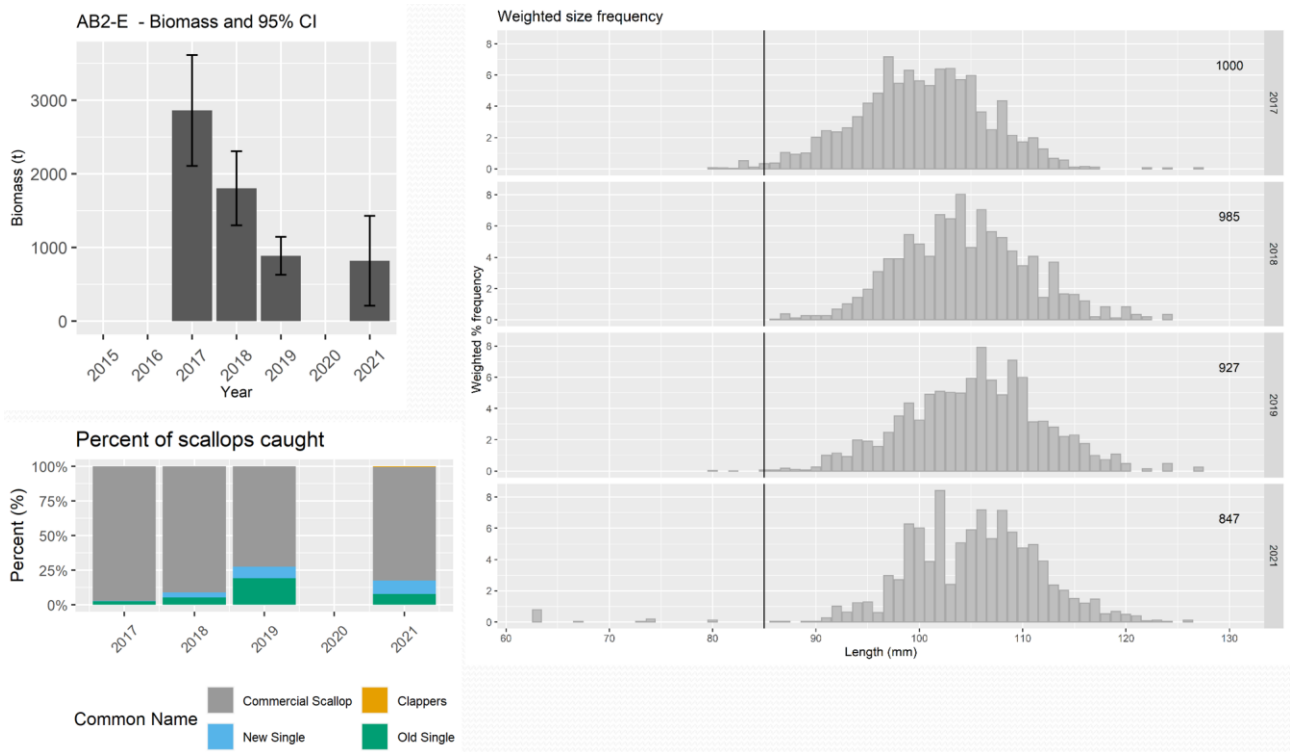


Figure 18. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the AB2-E bed.

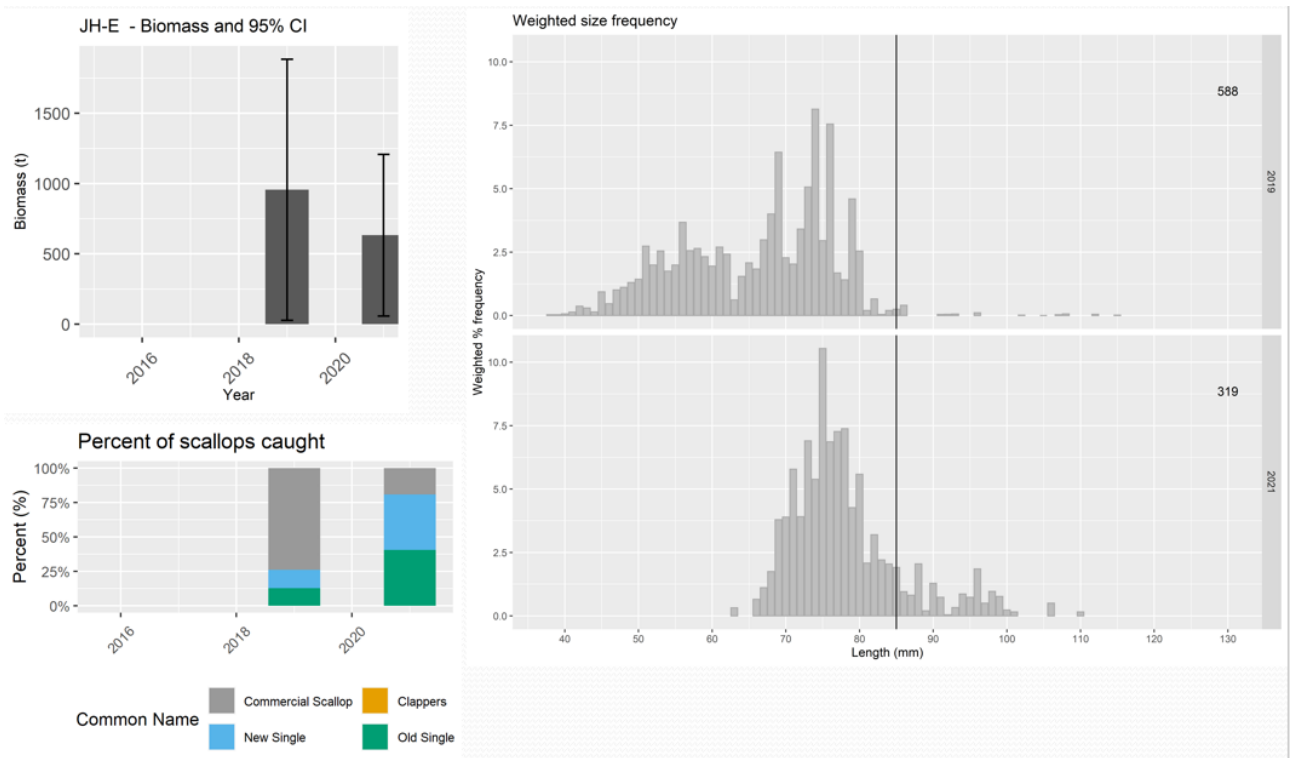


Figure 19. Time series of biomass estimate, size frequency and percent of scallop (live/shell type) at the JH bed. Note that there was smaller mesh used during the 2019 survey to capture a greater percentage of the juvenile scallops.

