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Bass Strait and Central Zone Scallop Fishery — 2015 Survey

Ian Knuckey, Matt Koopman
and Michael Davis

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

Executive Summary

At the start of each fishing season, the Australian Fisheries Management Authority (AFMA) provides a research catch allowance and/or a 150t total allowable catch (TAC) to enable fishers to search for commercially viable scallop beds. Industry members must then undertake research surveys to determine if the fishery can remain open under a Tier 1 (catches ≤ 2000 t) or Tier 2 (catches > 2000 t) management arrangement. Research surveys must carry an independent observer or electronic monitoring that is able to verify catch quantity, shell size and any other scientific data required to determine biomass estimates. This report provides the results of the 2015 research surveys.

During May 2015, surveys were conducted onboard the fishing vessel Insta-Gator on one bed off Flinders Island and three beds off King Island. Exploratory fishing was first undertaken in the Flinders Island Bed to define the extent of the bed, and an additional 10 random survey tows were undertaken within that area. Areas of the three beds off King Island were pre-defined, and 20 random tows were allocated to the large King Island Main Bed, and 10 each allocated to the smaller King Island Middle Bed and King Island East Bed. Targeted commercial tows were also undertaken at the Flinders Island Bed and the King Island Main Bed to provide estimates of potential commercial catch rates.

Biomass estimates for the Flinders Island Bed (2,289.7 t) and King Island Main Bed (8,448.9 t) were both greater than 1,500 t, even when only scallops greater than 85 mm wide were included (1,973.7 t and 8,448.8 t respectively). Biomass in the two smaller King Island beds were estimated at 623.4 t and 472.9 t. Based on targeted tows, potential catch rates were of 270 kg / hr and 632 kg / hr for the Flinders Island Bed and King Island Main Bed respectively.

Scallops were generally larger at the King Island beds compared to Flinders Island. Discard rates based on catch-weighted length frequencies were 6.6% for the King Island Main Bed, less than 0.4% for the two small King Island beds and 19.4% for the Flinders Island Bed. Meat grades ranged 47–62 meats per kg at King Island, while they were much smaller at Flinders Island at an average of 85 meats per kg. The gonads of most scallops examined were at stage 4–5.2, with some stage 3 gonads at Flinders Island and some stage 5.3 gonads at the King Island beds.

Catch composition was dominated by live Commercial Scallops at all beds, in particular two small King Island beds (80%–82%). Both the King Island Main Bed and Flinders Island Bed had a high proportion of new single shell (9% and 11%), and catch from the Flinders Island Bed comprised 28% old single shell by weight.

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Acknowledgements

We would like to thank Allan Barnett, the skipper and crew of the Insta-Gator for all of their assistance and hard work in undertaking the 2015 survey. Stuart Richey (Richey Fishing), Jayson Semmens (IMAS) and Steve Shanks (AFMA) provided valuable input into the survey logistics and design. Thanks to Claire Taylor (AFMA) for edits to the draft report.

Introduction

The main target species in the Bass Strait Central Zone Scallop Fishery (BSCZSF) is the Commercial Scallop, *Pecten fumatus*. Commercial Scallops living 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 generally is subject to high spatial and temporal variability in recruitment and abundance, variable growth and mortality, and rapidly changing meat yield and reproductive condition. This variability means that management of Commercial Scallops has to be adaptable to sometimes rapidly changing circumstances, yet still ensure protection of the resource in line with the *Commonwealth Fisheries Harvest Strategy Policy 2007* (HSP).

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

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

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

At the start of each fishing season, the Australian Fisheries Management Authority (AFMA) provides a research catch allowance and/or a 150t total allowable catch (TAC) to enable fishers to search for commercially viable scallop beds, defined as "*…an area or scallop bed containing no greater than 20 per cent of scallops of a size less than 85 mm"*. To increase the TAC above 150t, 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 ≤2 scallop beds that contain ≥1500 tonnes in total of high density scallops of a minimum size of 85mm. The season begins with a 1000t TAC that can be increased to 2000 t if good catches are achieved.
- **Tier 2 management arrangements** require initial closure of ≤2 scallop beds that contain ≥3000 tonnes in total of scallops of a minimum size limit of 85mm of high density. The season begins with a 2000t 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 2015 research survey.

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 and ScallopRAG.

Methods

Survey Design

Survey methods have been modified based on those described in Harrington *et al.* (2008). A commercial scallop vessel was used to undertake a random stratified survey of scallop beds with an independent observer onboard to collect all of the necessary survey data. Three general survey areas were identified before the survey, two off King Island and one off Flinders Island (Appendix Figure 14).

An initial exploratory survey comprising 20 tows was conducted on the Flinders Island bed to define a rectangular extent of the bed with north/south latitudes and east/west longitudes roughly defined by catch rates >50kg / shot (Figure 1). Once defined, 10 random tow locations (selected from all ¼ minute latitude and longitude combinations within the boundary) were surveyed within the rectangular stratum.

Because the distribution of scallops at King Island were better understood by industry, the boundaries of three separate beds (strata) were defined prior to the trip, enabling the random survey to begin without the need for exploratory fishing. 20 random tow locations was allocated to the larger King Island Main Bed, and 10 random tow locations were allocated to each of the King Island Middle Bed and King Island East Bed. To be considered a valid tow, the vessel must dredge within 100 m of the tow location provided (Appendix Figure 15). A Lotek LAT1400-64kb temperature-depth logger was attached to the dredge at the start of the first tow, and set to record an observation every two minutes.

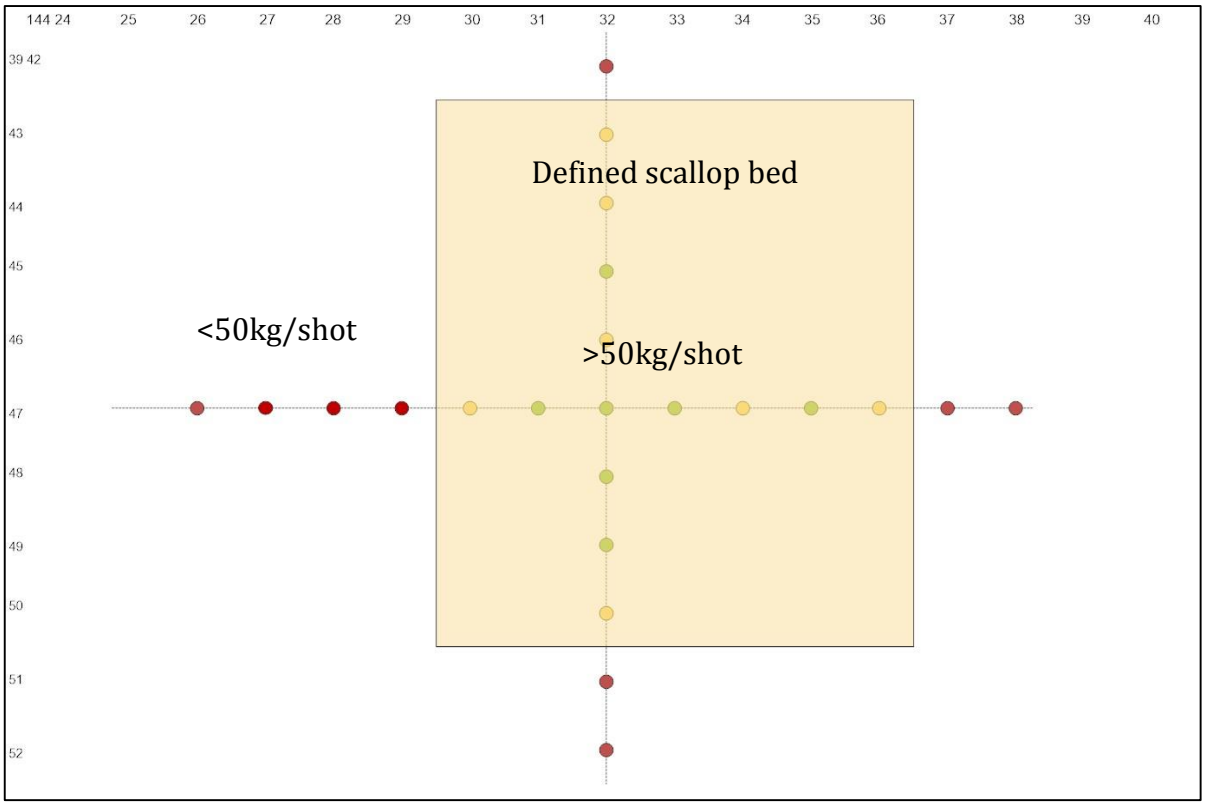

Figure 1. Example of rectangular area of a defined viable bed comprising 1 stratum. Dredge swept area will be extrapolated out to the area of this rectangle.

Sampling methods

For each shot, estimates were made of weight of: total live scallop catch, retained and discarded live scallops, dead shell and all retained and discarded 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 50 scallops was collected from each shot before they went through the tumbler. The observer measured the width of those scallops using the electronic measuring board supplied by Jason Semmens of the Institute for Marine and Antarctic Studies. The first and last scallop from each shot measured by the measuring board was also measured by hand using digital callipers. This was done 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 Table 10 and Table 11 based on

Harrington *et al.,* (2010) (see Appendix). Adductor meat and gonad were removed from the shell and weighed together to calculate number of meats per kg.

Data analysis

All data processing and analysis was undertaken in R (R Core Team, 2014), and density plot created using the package "mapplots" (Gerritsen, 2014). Estimates of biomass and potential commercial catch rates followed the methods of Semmens and Jones (2014).

Biomass

The width of the dredge was measured at 4.25 m and in accordance with Semmes and Jones (2014), a dredge efficiency of 33% was assumed (Table 1).

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

$S=LxW$

Where L is the tow distance (m) and W is the width of the dredge (m). Tow distance was calculated in two different ways:

- The "speed-duration" method in which tow distance is calculated using an average tow speed (3 knots) multiplied by tow duration; and,
- The "straight-line" method where the straight-line distance between start and end tow positions is calculated.

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

$C^{standardised} = (C/S)x1000$

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

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

$B = meanD * A * 3.03 / 1000$

Upper 95% CL

=

$((meanD + (t_{n-1} \times SE_{meanD})) \times A)*3.03 / 1000$

Lower 95% CL

=

$((meanD - (t_{n-1} \times SE_{meanD})) \times A)*3.03 / 1000$

Were meanD is the mean density of scallops per m^2 swept, t_{n-1} is the t –value for the number of shots (n) -1, SE_{meanD} is the standard error of meanD and A is the total stratum area (m^2). The area of each bed was calculated using the R package "geosphere" (Hijmans et al., 2015).

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

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

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

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

Potential commercial catch rates

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

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

$$C^{tow} = D_{1000} \times 3$$

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

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

$$C^{hour} = C^{tow} \times 4$$

Potential commercial catch rates were calculated separately on data from random survey tows and targeted tows.

Biologicals

The width-weight relationship was first calculated with area (King Island and Flinders Island) as a factor. Neither area (p=0.1147) nor the interaction variable (logWidth:Area; p= 0.1373) were significant, suggesting there is not enough evidence to conclude that there are differences in either the intercepts or the slopes of the width-weight relationships between areas. Consequently, data were pooled for calculation of the width-weight relationship (Figure 2) with R^2=0.86:

$$Weight = 0.00096 \times Width^{2.48294}$$

The width-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.

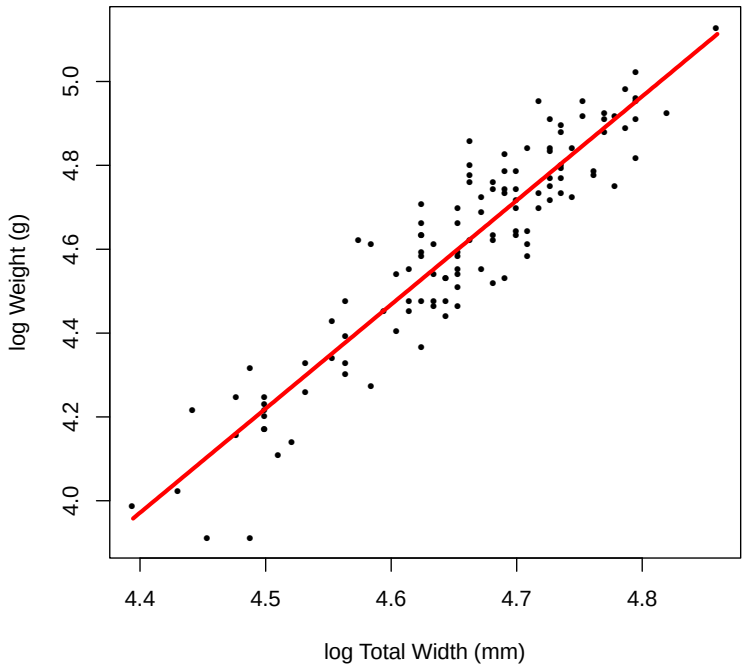

Figure 2. Log transformed width and weight and line of best fit of scallops collected from Flinders Island and King Island.

Quality Assurance

All tow and catch data were recorded in an observer version of ORLAC Dynamic Data Logger (DDL), which includes quality insurance protocols including automatic data capture (time, date and position), field restrictions, range checks, mandatory fields and lookup tables. All data were manually error checked against data sheets before loading into the shore version of ORLAC DDL. This database is regularly backed up, and used to extract data for analyses. A subset of outputs were reproduced and compared using an alternative software package. Scallops were measured using the electronic measuring board supplied, with the first and last scallop from each shot measured by both the measuring board and by hand using digital callipers. 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, ScallopRAG and ScallopMAC members for comment. Where required, comments were addressed in preparation of the final report.

Results

Survey shots

A total of 50 non-targeted tows were undertaken during 15/5/2015–16/5/2015 off the Flinders Island Bed. The area of the bed was refined based on exploratory fishing of the area, resulting in a rectangular stratum (Figure 3) defined by the coordinates shown in Table 2, with an area of approximately 40.5 km^2. Thirty three of the 50 non-targeted tows were positioned within that area, however three of the exploratory tows were excluded because they were undertaken within a small area in close succession suggesting targeting. This left a total of 30 tows (20 exploratory and 10 random) within this area to be included in biomass estimates. Overall (commercial, exploratory and survey tows), depths fished ranged 37.9–57.4 m and bottom temperatures ranged 13.8–15.3°C.

Coordinates that defined the three King Island beds (Figure 3) are shown in Table 2. The total areas of the King Island Main Bed, King Island Middle Bed and King Island East Bed are approximately 117.4 km^2, 11.0 km^2 and 7.3 km^2 respectively. All but one of the prescribed random tows were undertaken in each of the beds resulting in 20 random tows for biomass estimation in the King Island Main Bed, 10 random tows for the King Island Main Bed, and nine random tows for the King Island East Bed. Overall (commercial and survey tows), depths fished ranged 36.9–51.4 m and bottom temperatures ranged 12.3–14.3°C.

Biomass, size and potential commercial catch rates

Estimated mean biomass within the Flinders Island Bed using the speed-duration method was 2,381.4 t, with lower and upper 95% confidence limits of 1927.7 t and 2835.0 t respectively (Table 3). Using discard rate of 13.8% (86.2% > 85 mm) mean biomass for scallops > 85mm was 2053.3 t with lower and upper 95% confidence limits of 1662.2 t and 2444.5 t respectively (Table 4). Using the straight-line method, biomass estimates were slightly lower at 2289.7 t and 1973.7 t for total biomass and biomass greater than 85 mm respectively (Table 5, Table 6).

Estimated mean biomass in within the King Island Main Bed was 7960.1 t using the speed-duration method, with lower and upper 95% confidence limits of 5606.9 t and 10313.3 t respectively (Table 3). Mean biomass was slightly higher using the straight-line method at 8448.9 t (Table 5). Using a discard rate of 2.9% (97.1% > 85 mm), mean biomass of scallops greater than 85 mm within the King Island Main Bed was 7729.3 t and 8203.9 t for the two methods respectively (Table 4, Table 6). Mean biomass estimates for the King Island Middle Bed and King Island East Bed using the speed-duration method are 578.4 t and 427.8 t and 623.4 t and 472.9 t using the straight-line method (Table 3, Table 5). Discard rates were 0% for both of those beds.

Densities of scallops within each bed (using non-targeted tows only) are show in Figure 5–Figure 8. Mean densities ranged 17.4–22.4 kg / 1000 m^2 using the speed-duration method, resulting in potential commercial catch rates of 208–269 kg / hr (Table 3). Using the straight-line method, mean densities ranged 18.7–23.8 kg / 1000 m^2, and potential commercial catch rates ranged 224–285kg / hr (Table 5).

Targeted tows were only conducted in the Flinders Island Bed and King Island Main Bed. Mean densities were 22.5 / 1000 m^2 and 52.7 / 1000 m^2 respectively, resulting in potential commercial catch rates of 270 kg / hr and 632 kg / hr (Table 7).

Biologicals

Median and mean widths of scallops (not catch-weighted) from Flinders Island were 92 mm and 91.65 mm respectively, with 19.4% (by number of catch-weighted length-width frequencies) of scallops being less than 85 mm (Table 8, Figure 9). Scallops were generally much larger on the King Island Beds with mean and median widths of 104–107 mm. A total of 6.6% of catch-weighted scallops measured were less than 85 mm at the King Island Main Bed. There were no scallops measured less than 85 mm at the King Island Middle Bed, and only one scallop at King Island East Bed was less than 85 mm (0.3% of the catch-weighted total). In calculation of percent of weight of scallops less than 85 mm to apply to biomass estimates, this becomes less than 0.1% of the catch-weighted total.

Reflecting the smaller size in samples measured, scallop weight from Flinders Island averaged only 85 meats per kg, compared with 47–62 meats per kg from the King Island beds (Table 8, Figure 10).

Gonads from 12.5% of scallops examined from Flinders Island were Stage 3, 42.5% at Stage 4, 40% at Stage 5.1 and the remaining 5% at stage 5.2 (Figure 11). No Stage 3 gonads were observed at the King Island beds, however stage 5.3 gonads were observed at all three. King Island Main Bed and King Island East Bed were dominated by scallops with stage 5.1 and 5.2 gonads, while 65% of scalloped examined from King Island Middle Bed had Stage 4 gonads.

Bycatch

A total of 45 different bycatch species / groups were identified during the surveys (Table 9). The catch was dominated by Commercial Scallops on all beds, particularly at King Island East Bed and King Island Middle Bed where they comprised 80% and 82% of the catch respectively, compared to 32% and 41% at Flinders Island and the King Island Main Bed (Figure 12). Common bycatch included old and new single scallop shell, substrate, sponge, Spider Crabs and Doughboy Scallop.

Considering only the four different scallops "groups" (Commercial Scallops, old single, new single, and clappers), Flinders Island had a much higher percentage of old single shell (~40%) than other beds (<6%) (Figure 13). King Island Main Bed had the highest proportion of new single shell (~19%), while the other two King Island beds were heavily dominated by live scallops (>90%).

Table 1. Inputs used in biomass calculations for Flinders Island Bed and King Island Beds.

Inputs	Values
Dredge width	4.25 m
Dredge efficiency	33%

Table 2. Boundaries of each scallop bed (decimal degrees) and area of each polygon (m^2).

Boundary	Flinders Island	King Island		
		Main Bed	Middle Bed	East Bed
Northern latitude	-39.23333	-39.72570	-39.79400	-39.91250
Southern latitude	-39.31667	-39.81533	-39.82850	-39.94217
Western longitude	148.06000	144.42950	144.59117	144.88200
Eastern longitude	148.11067	144.56700	144.62467	144.90800
Total area (m^2)	40,509,147	117,383,237	11,001,623	7,330,016

Table 3. Biomass estimates, 95% confidence limits and number of tows included in analyses using distance calculated from the speed-duration method.

Estimate	Flinders Island	Main Bed	King Island Middle Bed	East Bed
Lower 95% CL (t)	1927.7	5606.9	293.8	309.6
Mean Biomass (t)	2381.4	7960.1	578.4	427.8
Upper 95% CL (t)	2835.0	10313.3	863.0	546.1
Mean density (kg / 1000 m^2)	19.4	22.4	17.4	19.3
Number of tows	30	20	9	10

Table 4. Percent weight of scallops greater than 85 mm, and biomass estimates 95% confidence limits for scallops greater than 85 mm calculated using the speed-duration method.

Estimate	Flinders Island	Main Bed	King Island Middle Bed	East Bed
% weight > 85 mm	86.2%	97.1%	100.0%	100.0%
Lower 95% CL (t)	1662.2	5444.3	293.8	309.5
Mean Biomass (t)	2053.3	7729.3	578.4	427.7
Upper 95% CL (t)	2444.5	10014.3	863.0	545.9

Table 5. Biomass estimates, 95% confidence limits and number of tows included in analyses using the straight-line method. Note that identical densities for the Flinders Island Bed and King Island Middle Bed are not an error.

Estimate	Flinders Island	Main Bed	King Island Middle Bed	East Bed
Lower 95% CL (t)	1838.6	5964.4	307.5	349.4
Mean Biomass (t)	2289.7	8448.9	623.4	472.9
Upper 95% CL (t)	2740.8	10933.3	939.2	596.5
Mean density (kg / 1000 m^2)	18.7	23.8	18.7	21.3
Number of tows	30	20	9	10

Table 6. Percent weight of scallops greater than 85 mm, and biomass estimates 95% confidence limits for scallops greater than 85 mm calculated using the straight-line method.

Estimate	Flinders Island	Main Bed	King Island Middle Bed	East Bed
% weight > 85 mm	86.2%	97.1%	100.0%	100.0%
Lower 95% CL (t)	1584.8	5791.4	307.5	349.4
Mean Biomass (t)	1973.7	8203.9	623.4	472.9
Upper 95% CL (t)	2362.6	10616.3	939.2	596.5

Table 7. Mean density, standard error of mean density, potential commercial catch rate and number of tows included in analyses from targeted tows using the straight-line method. Note that targeted tows were not conducted at King Island Middle Bed or King Island East Bed.

Estimate	Flinders Island	King Island Main Bed
Mean density (kg / 1000 m^2)	22.5	52.7
S.E. Density	1.5	1.5
Catch rate (kg / hr)	270	632
Number of tows	40	69

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

		Width (mm)			85 mm		Meats / kg
Bed	N	Median	Mean	SE	%<	%>	Mean
Flinders Island	1426	92	91.65	0.22	19.4%	80.6%	85
KI Main Bed	1309	105	104.09	0.26	6.6%	93.4%	52
KI Middle Bed	515	107	107.36	0.27	0.0%	100.0%	62
KI East Bed	502	106	105.64	0.29	0.3%	99.7%	47

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

	Catch (kg)				
	Flinders Is.	King Island			
Common Name		Main Bed	Middle Bed	East Bed	Total
Commercial scallop	1865.15	1458	500	635	4458.15
Clappers	184	24	0.5	6	214.5
New Single	630	336	29	43	1038
Old Single	1657	150	1	3	1811
Ascidian (u)	27	167	6.5	35	235.5
Australian burrfish			1		1
Australian Tulip Shell	53	15.8	3.6	5.5	77.9
Banded Stingaree	1.6	7.2			8.8
Barber perch	0.1				0.1
Brittlestars (u)	0.1				0.1
Brown Algae		1			1
Bug	3.1			0.1	3.2
Cocky gurnard		0.3		0.3	0.6
Common gurnard perch	0.4			0.5	0.9
Common stargazer	4				4
Common stinkfish		0.6			0.6
Crested flounder	0.3				0.3
Doughboy scallop	136	258.6		1.1	395.7
Draughtboard shark	6				6
Echinoderm (u)	1.1				1.1
Eleven armed seastar			26		26
False bailer shell		1			1
Fan-Like Dog-Cockle	26	3			29
Greenback stingaree	0.6	6	4		10.6
Hermit crab (u)	42	5	7	8.7	62.7
Hydroid (u)	44				44
King Island Thickshell-Clam	3	1.2			4.2
Maori octopus	4				4
New Zealand Screw Shell	112				112
Octopus (u)	7.9	7.1	2	0.2	17.2
Pale octopus	4.2				4.2
Pen Shell	12				12
Sea urchin (u)	1				1
Seapen (u)	0.2	4	3.2		7.4
Seastar (u)	0.2	2.3	16.8		19.3
Shaw cowfish			0.1		0.1
Southern blue-ringed octopus	0.3				0.3
Sparsely-spotted stingaree	0.5	2	0.2	2.4	5.1
Spider crab (u)	73	32	7	45	157
Sponge (u)	585	28		5.5	618.5
Substrate		970			970
Substrate - Broken Shell	325	60			385
Substrate - Rock	21				21
Tasmanian numbfish		0.2		0.3	0.5
Tiger flathead		1.1	0.2		1.3
Velvet leatherjacket	0.1				0.1
Total	5830.85	3541.4	608.1	791.6	10771.95

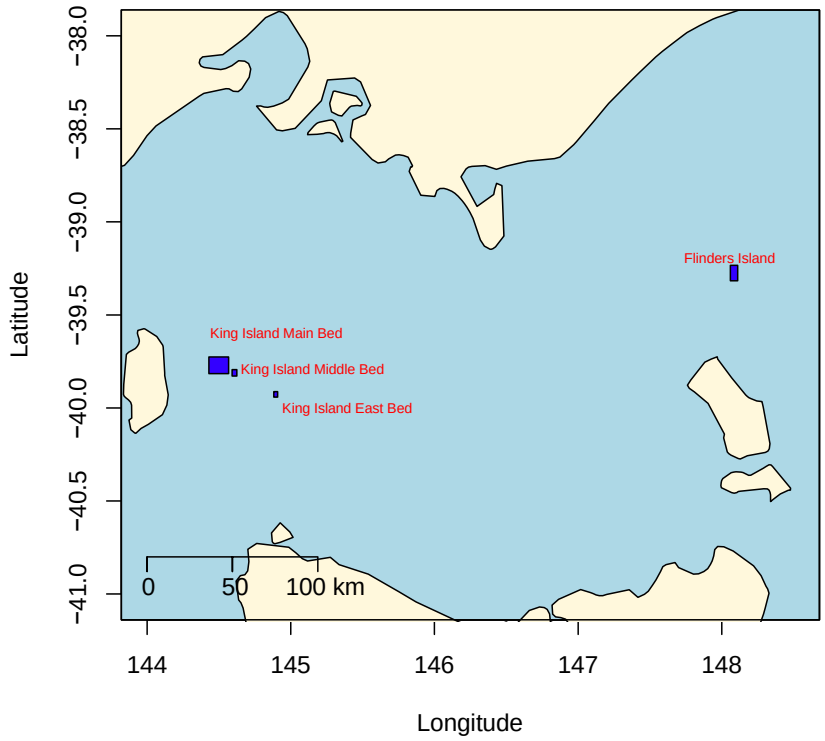

Figure 3. Location of scallop beds surveyed.

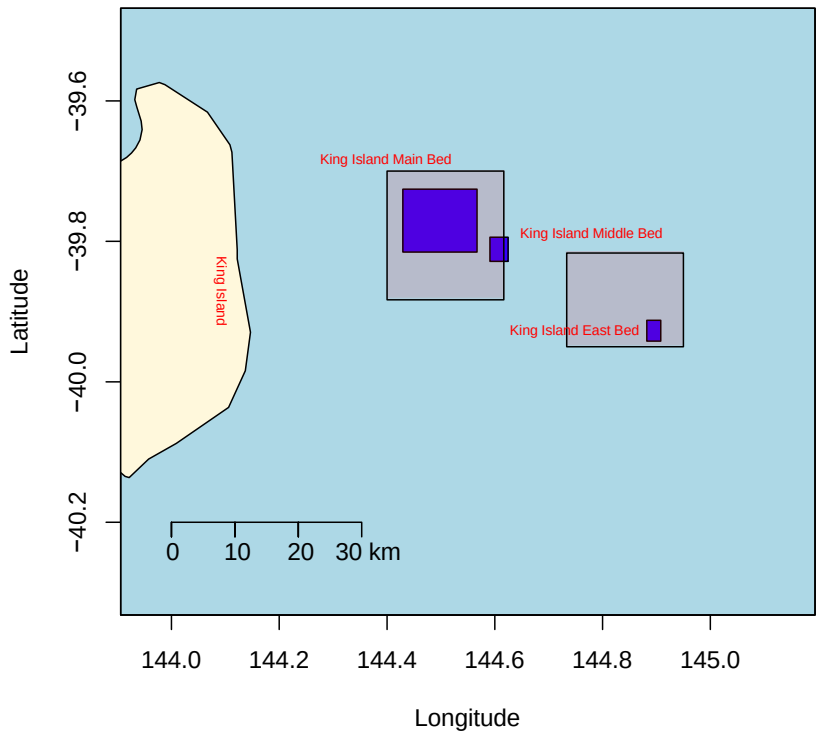

Figure 4. King Island beds (strata) surveyed (blue rectangles) in relation to the original areas that were identified.

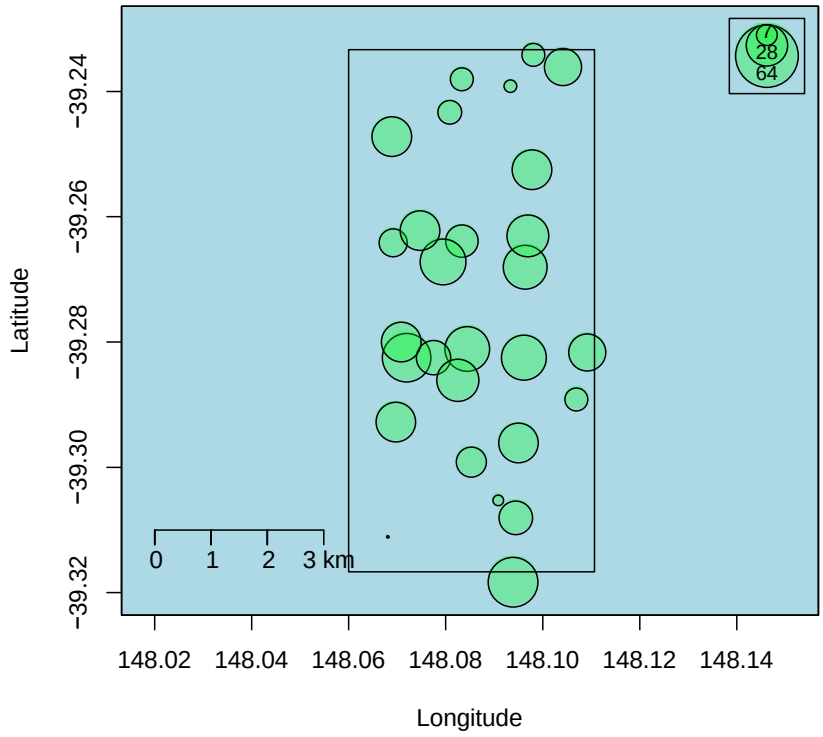

Figure 5. Scallop density (kg / 1000 m^2) within the defined stratum of the Flinders Island bed. The top right scale bubbles reflect the scallop density of each tow. Note that the southernmost tow is shown as outside of the defined bed because density is mapped to start location, but the survey point was within the bed.

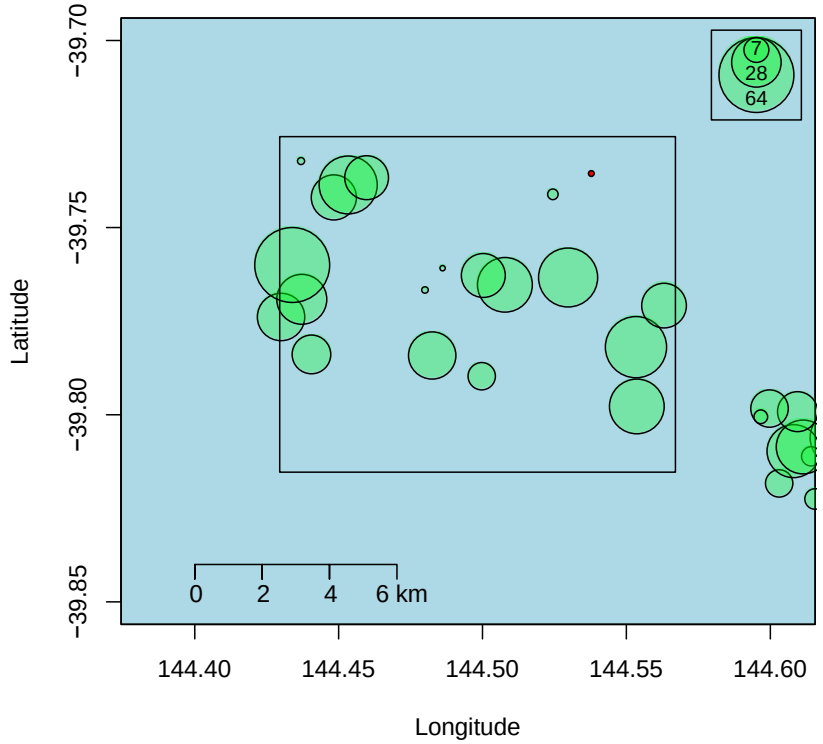

Figure 6. Scallop density (kg / 1000 m^2) within the defined stratum of the King Island Main Bed. The top right scale bubbles reflect the scallop density of each tow. The red bubble denotes no catch. Note that the tows visible in the lower right are from the King Island Middle Bed.

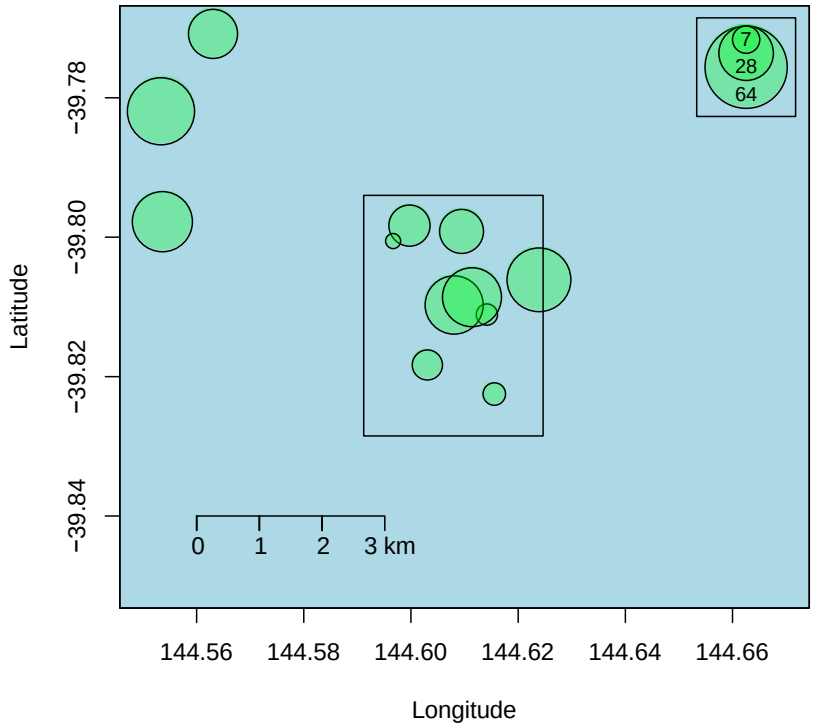

Figure 7. Scallop density (kg / 1000 m^2) within the defined stratum of the King Island Middle Bed. The top right scale bubbles reflect the scallop density of each tow. Note that the tows visible in the upper left are from the King Island Main Bed.

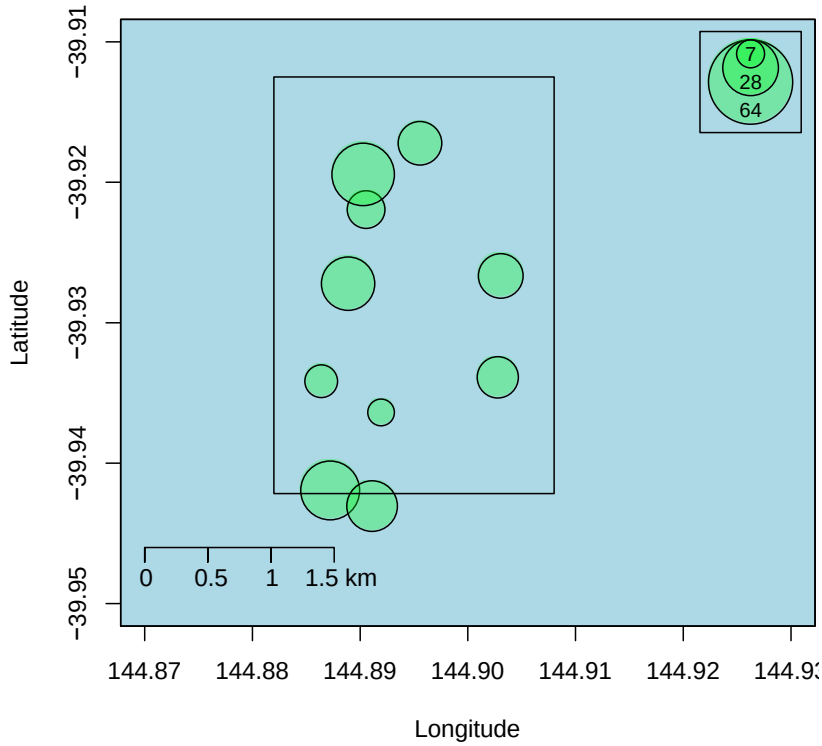

Figure 8. Scallop density (kg / 1000 m^2) within the defined stratum of the King Island East Bed. The top right scale bubbles reflect the scallop density of each tow. Note that the southern-most tow is shown as outside of the defined bed because density is mapped to start location, but the survey point was within the defined stratum.

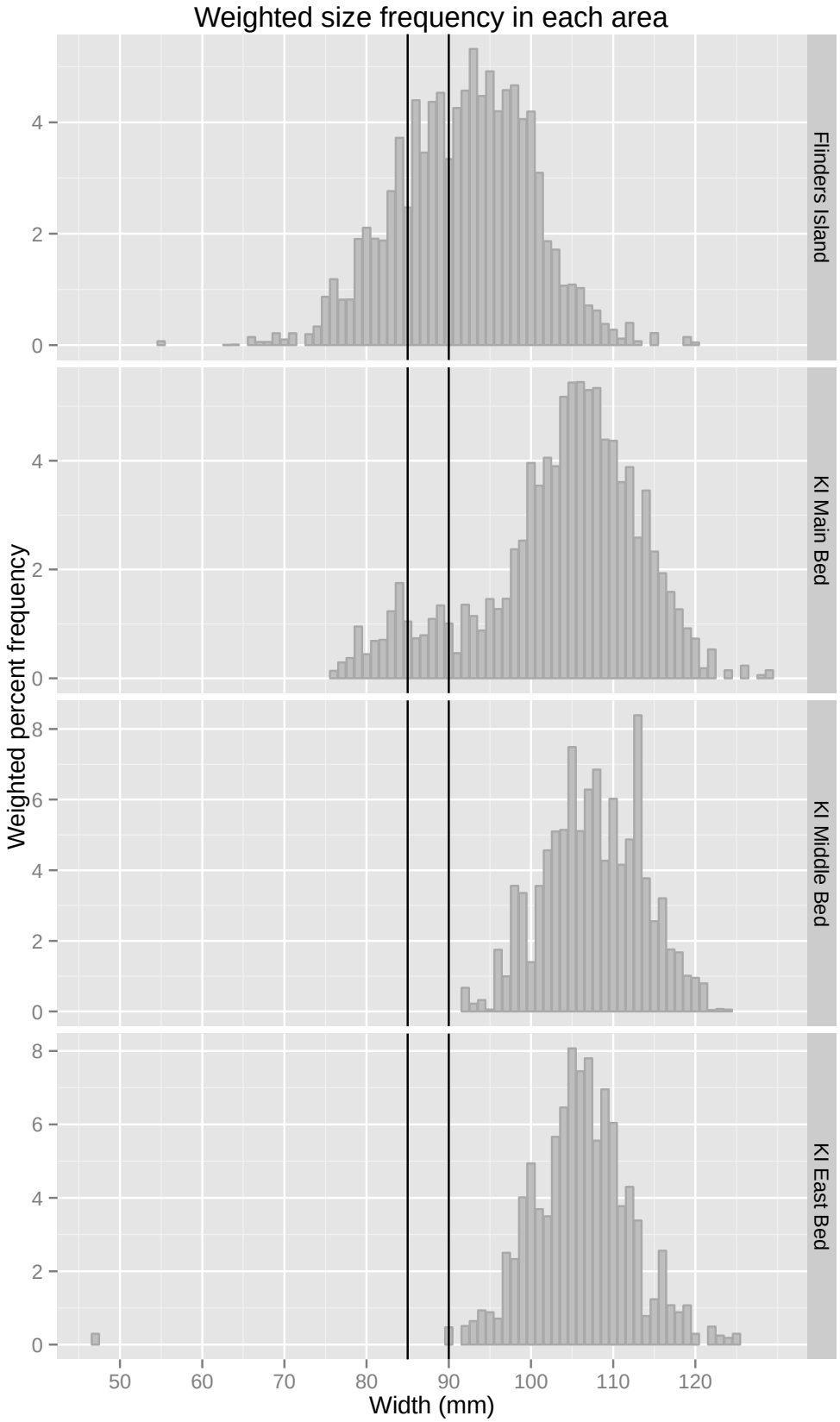

Figure 9. Catch weighted size frequency from shots included in biomass estimates from each bed. Vertical lines at 85 mm and 90 mm. Number of samples and other summary information are shown in Table 8.

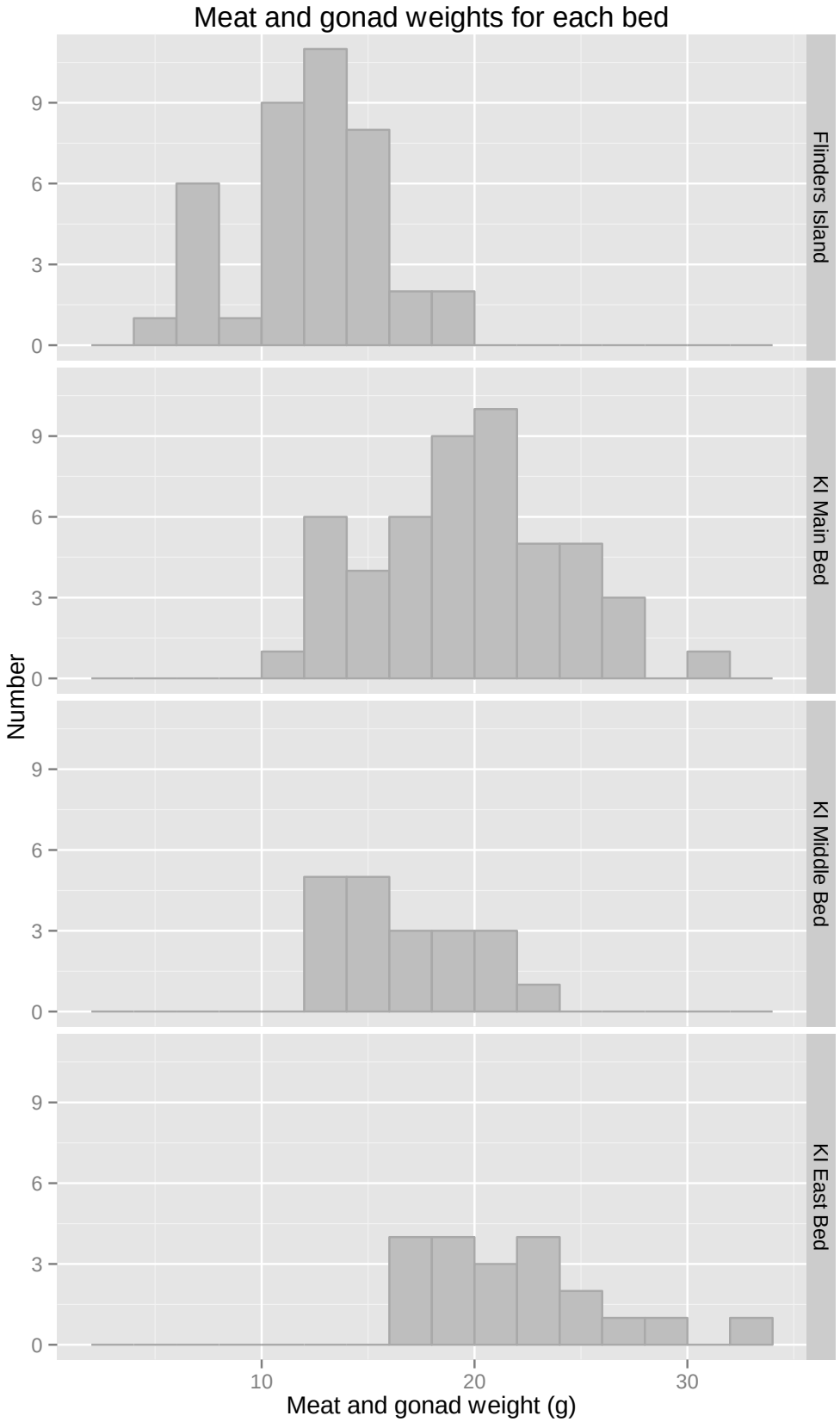

Figure 10. Frequency of combined meat and gonad weights measured from each bed binned into 2 g weight categories.

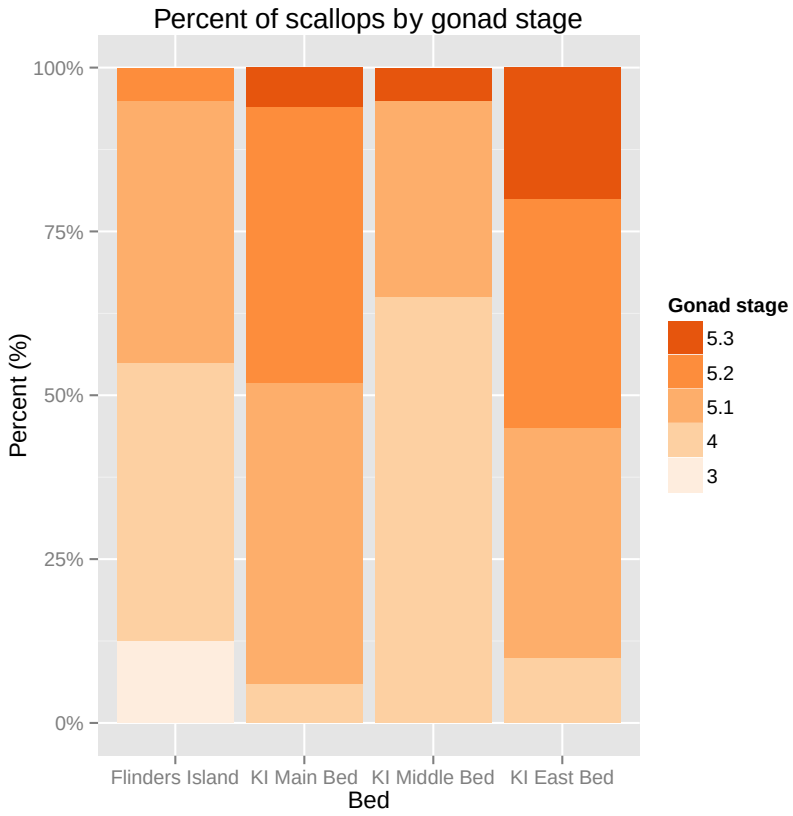

Figure 11. Percent of scallops at each stage from each bed based on macroscopic staging criteria.

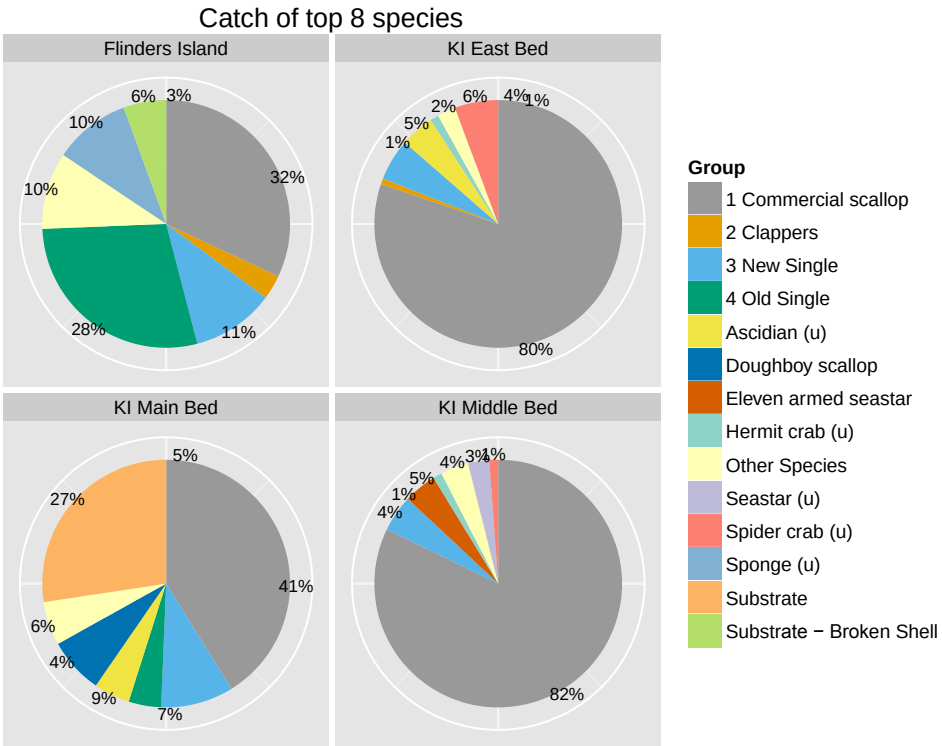

Figure 12. Percent catch composition in each bed sampled by weight.

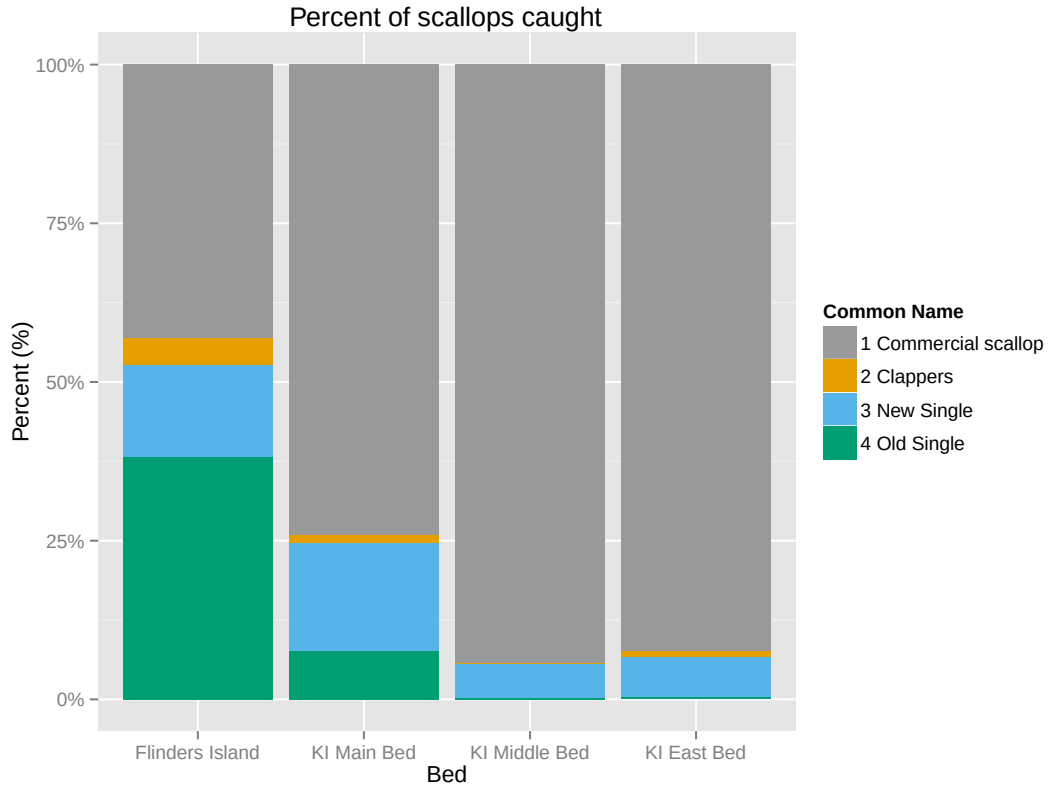

Figure 13. Percent composition of clappers, live scallop, new single and old single shell from each Bed.

Discussion

Random stratified surveys were successfully undertaken on one scallop bed off Flinders Island and three off King Island (Figure 3, Figure 4). Biomass was calculated for each bed using two different methods for calculating area swept: one using average tow speed and tow duration (the speed-duration method); and the other using the calculated straight line distance between the start and end tow points (straight-line method). Biomass estimates between the two methods were similar, but slightly higher for the speed-duration method at the Flinders Island beds, and slightly lower for the King Island Beds. Previous studies have used the straight-line method (Jayson Semmens, pers. comm.), and we also consider this to be more accurate estimate of tow distance given variability in tow speed and currents encountered.

Using the straight-line method, mean biomass at the Flinders Island Bed was 2,289.7 t with lower and upper 95% CLs of 1,838.6 t and 2,740.8 t (Table 5), of which 1,973.7 t were greater than 85 mm width (Table 6). The King Island Main Bed has an estimated biomass of 8,448.8 t with lower and upper CLs of 5,964.4 t and 10,933.3 t (Table 5), of which 8,203.9 t were greater than 85 mm width (Table 6). The two smaller King Island beds had estimated mean biomasses of 623.4 t and 472.9 t.

From research tows, the density of scallops ranged 18.7–23.8 kg / 1000 m^2 using the straight-line method (Table 5). These are less than those reported from the 2014 Flinders Island survey which found mean densities in two areas to be 33.6 kg / 1000 m^2 and 27.9 kg / 1000 m^2

(Semmens and Jones, 2014); the first of those areas overlaps with the Flinders Island Bed from this survey. Because they were derived from random tows, it is understandable that potential commercial catch rates from the 2015 survey (224–285 kg / hr using the straight-line method) would be lower than those reported in 2014 (330–400 kg / hr) from more targeted tows. Using targeted tows from the current survey, potential commercial catch rates were of 270 kg / hr and 632 kg / hr for the Flinders Island Bed and King Island Main Bed respectively (Table 7).

Scallops were larger at Flinders Island during 2015 compared with the previous year with an average width of 91.65 mm (Table 8, Figure 9) compared with 90.94 mm and 88.67 mm in the two Flinders Island beds sampled in 2014 (Semmens and Jones, 2014). Despite a small increase in mean width, the discard rate (by number) was slightly higher (19.4%) in 2015 compared to the overlapping area from 2014 (17.59%). Scallop sizes were much larger at the King Island beds, with mean widths of 104.09–107.36 mm and discard rates of 0–6.6%.

Scallop condition (meats per kg) were higher at King Island than Flinders Island (Table 8, Figure 10), and gonads were generally at a later stage than at Flinders Island (Figure 11). Only samples from Flinders Island contained scallops with stage 3 gonads, while only King Island samples contained scallops with stage 5.3 gonads.

Catches from the Flinders Island Bed comprised a high proportion of old single shell, and combined with clappers and old single shell, dead scallop shell comprised 42% of the total catch, of which live Commercial Scallop made up 32% of the total catch (Figure 12). Catches from the King Island Main Bed comprised 41% live Commercial Scallop, 27% substrate and 9% single shell. Catches from the other two King Island beds were more dominated by live Commercial Scallop, making up more than 80% of the total catch.

References

Gerritsen, (2014). Mapplots: Data Visualisation on Maps. R package version 1.5. http://CRAN.R-project.org/package=mapplots

Haddon, M., Harrington, J. and Semmens, J. (2006). Juvenile Scallop Discard Rates and Bed Dynamics: Testing the Management Rules for Scallops in Bass Strait. FRDC Project 2003/017. 175pp

Harrington, J.J., MacAllistar, J., Semmens, J.M. (2010). Assessing the immediate impact of seismic surveys on adult commercial scallops (*Pecten fumatus*) in Bass Strait. Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, 2010.

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

Hijmans, R.J., William, E. and Vennes, C. (2015). Geosphere. http://cran.r-project.org/web/packages/geosphere/geosphere.pdf

R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

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

Appendix – background information and methods

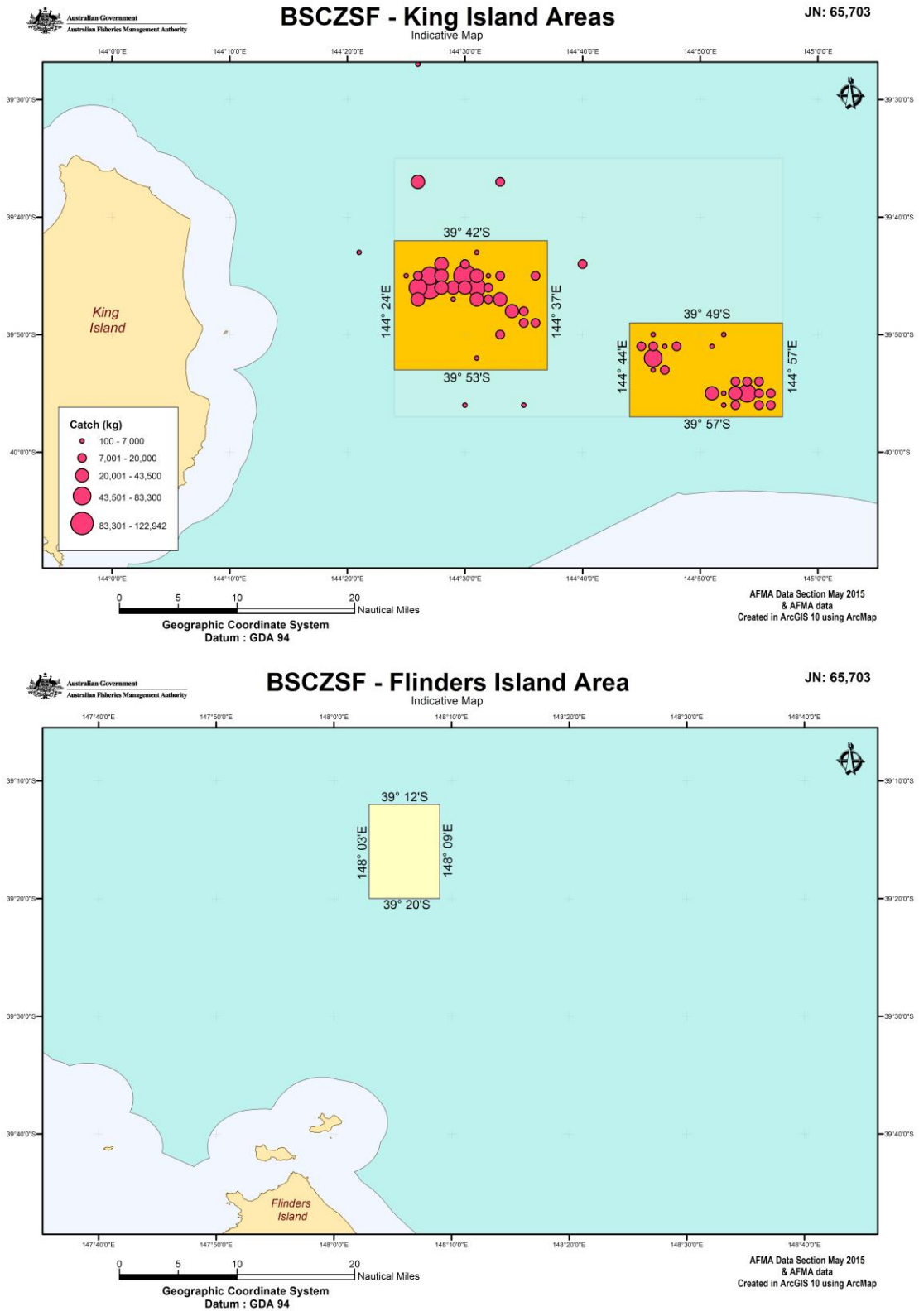

Figure 14. Scallop beds to be surveyed during 2015. The King Island beds will be called King Island West and King Island East.

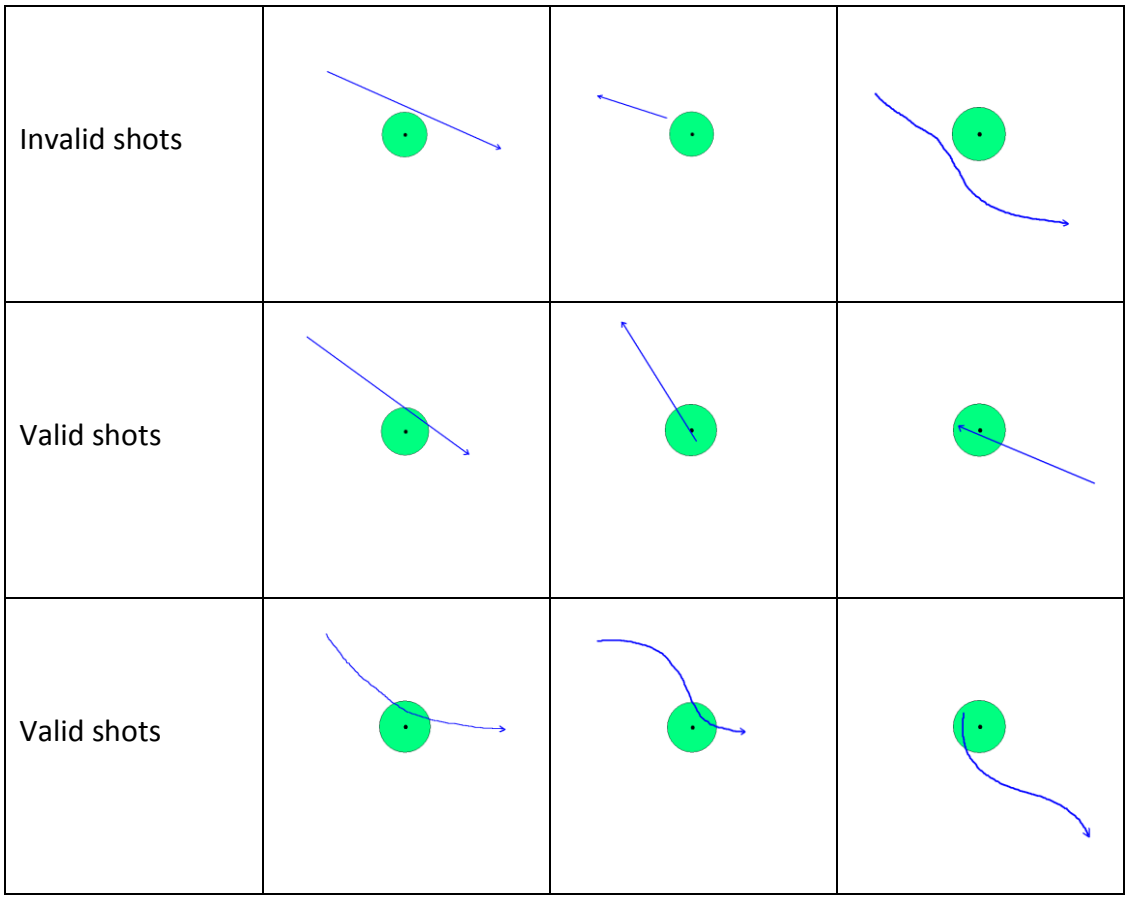

Figure 15. How to conduct a valid survey shot. Green circle is 100 m radius.

Table 10. Gonad maturation scheme for macroscopic field staging of scallops (taken from Harrington et al., 2010).

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

Table 11. Gonad maturation scheme for macroscopic field staging of scallops (taken from Harrington et al., 2010).

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