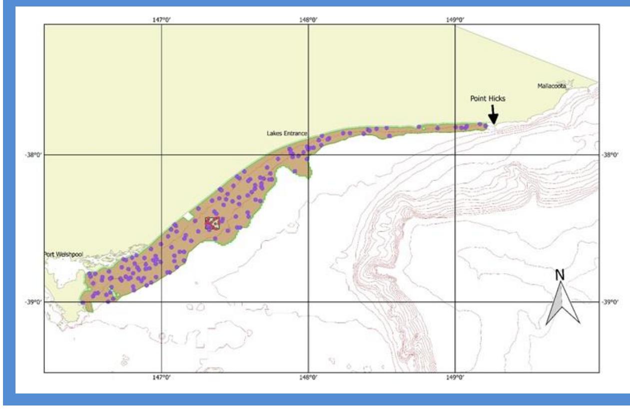
VFA Project 17/646976

Eastern Victorian Ocean Scallop Fishery

2017-18 Abundance Survey



Matt Koopman, Ian Knuckey, Annique Harris
and Russell Hudson

2018

fishwell CONSULTING

Victorian Fisheries AUTHORITY

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ISBN 978-0-9954122-5-5

Title: Eastern Victorian Ocean Scallop Fishery – 2017-18 Abundance Survey

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Koopman, M., Knuckey, I., Harris, M. and Hudson, R. (2018). Eastern Victorian Ocean Scallop Fishery – 2017-18 Abundance Survey. Report to the Victorian Fisheries Authority. Fishwell Consulting. 42pp.

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

Executive Summary

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

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

Recent anecdotal information suggested that there had been some level of recovery of the stock and that commercially viable beds may be available for fishing. The Victorian Fisheries Authority considered there was merit in conducting a biomass survey of the fishery during 2017/18 to inform management arrangements for the following season.

A random stratified survey design was adopted, but a lack of recent commercial fishing activity made it difficult to inform stratification. Instead, we took the approach of allocating half of the available fishing effort to a broad-area survey that covered the fishable area from Point Hicks in the east to Wilsons Promontory in the west, and then allocating the remaining effort to intensively surveying potentially viable scallop beds within this area, each as a separate stratum.

The broad-area stratum was defined based on depth limitations of scallop fishing, GIS habitat layers, past fishing effort and results of past surveys. Total biomass in the broad-area stratum was estimated to be 5,107 t (95% confidence intervals (Cis) ranged 2,226 t–14,372 t), and with 89% of the scallops greater than 80 mm length, estimated biomass greater than 80 mm was 4,545 t (95% CI 1,980 t–12,791 t). The overall density was 1.1 kg per 1000 m^2, or 0.06 individuals per m^2.

Of the nine potential scallop beds identified within the broad-area survey, only one (LE1) was considered worthy of an intensive survey. The estimated total biomass in LE1 was 456 t (95% CIs of 332 t–581 t and, with 84.6% of the weight of scallops greater than 80 mm, the biomass of scallops greater than 80 mm was 386 t (95% CIs of 281 t–491 t). Scallop density in LE1 was 27.7 kg per 1000 m^2 or 0.51 individuals per m^2.

Survey length frequency data suggests recruitment over a number of year classes from the broad-area survey but not in the LE1 stratum. Meat weights were small at 92 and 103 meats per kg from the broad-area and LE1 strata respectively, and median lengths from those strata were 86.3 mm and 84.2 mm. Throughout the survey, 84 species or species groups were recorded as bycatch, which included the catch of two Syngnathids: a Widebody Pipefish (*Stigmatopora nigra*)

and a Spiny Pipehorse (*Solegnathus spinosissimus*). No introduced Northern Pacific Seastars (*Asterias amurensis*) were observed.

Fish Ageing Services have completed their ageing component of this project. After consideration of a range of age estimation techniques, they found that the most repeatable method for Commercial Scallop was to use surface counts on the shell. Age estimates ranged 3–9 years, with a modal age of 4 years. Growth parameters estimates were consistent with those of previous studies on Commercial Scallop from Port Phillip Bay.

Results of the 2017/18 survey cannot be directly compared to those of the previous (2012) survey because of the different methods of allocating survey sites, however scallop densities were similar between the two. Densities from the 2012 survey were “less than 1 kg scallops per 1000 m^2”.

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Acknowledgements

We would like to thank Andy Watts, Ian Rule and the crew of the Northern Star for all of their assistance and hard work in undertaking the survey. Appreciation to Stuart Richey, John Richey, Graham Cull, John Cull and other industry members (including those from outside of the scallop fishery) for providing information that guided exploration for survey beds. We also thank Kyne Krusic-Golub, Simon Robertson and other staff from Fish Ageing Services for assistance with the ageing component of this project.

Introduction

The main target species in the Victorian (Ocean) Scallop Fishery is the Commercial Scallop, *Pecten fumatus*. Commercial Scallops in wild populations live for between five and nine years, but have been observed to die-off rapidly after only three to five years in some situations (Haddon *et al.*, 2006). 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 can be difficult due to the patchiness of the resource. Although the Victorian (Ocean) Scallop Fishery extends twenty nautical miles out from the Victorian coast line, large portions of these waters are not suitable for Commercial Scallop fishing. The majority of commercial fishing is targeted towards high density scallop aggregations in spatially distinct 'beds' in eastern Victoria.

Commercial Scallops are taken by a vessel using a dredge towed along the ocean floor with a tooth-bar to deflect scallops from the seafloor into the dredge basket. The fishery is managed using a statutory consultation process that involves fishers, fishery scientists and fishery managers. Information from a range of sources including scientific research, stock assessments and data from other Bass Strait scallop fisheries is considered in setting the annual total allowable commercial catch (TACC). Although only 10–15 boats operate in the fishery, the number of commercial access licences is capped at 91 and each licence holder is given an equal share of the TACC. Transfer of quota between licence holders occurs during the season, under a system of "individual transferable quotas" (ITQs), facilitated by the Victorian Fisheries Authority (VFA) under the Department of Economic Development, Jobs, Transport and Resources (DEDJTR) (Victorian Fisheries Authority, 2018).

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

Recent anecdotal information from Danish seine fishermen working off Victoria's east coast suggested that there had been some level of recovery of the stock and commercially viable beds may be available for fishing. Based on this, and significant scallop beds being found recently in Bass Strait (Knuckey *et al.*, 2015, 2016, 2017), VFA considered that there was merit in conducting a biomass survey of the Victorian scallop fishery during 2017/18 to inform management arrangements for the following season.

Traditionally, fisheries surveys to determine abundance are designed and analysed as randomized stratified surveys (RSS), whereby a population is divided into a number of relatively homogeneous subgroups (strata) to improve the precision of the abundance estimate by reducing sampling error. Survey sites with a known “swept-area” are then randomly allocated to each stratum (of known area) allowing a mean biomass to be estimated for each stratum. The weighted mean of each stratum has less variability than the arithmetic mean of a simple random sample of the entire population.

Typically, the stratified design of such an RSS would be informed by detailed analysis of shot-by-shot catch per unit effort (CPUE) data from commercial logbooks. This data would provide information on areas of high/low abundance from which the area of the fishery would be stratified, and the between shot variability that would allow estimation of the precision associated with the biomass estimate. Unfortunately, a number of issues precluded this approach to the current survey. There has been little or no fishing in the Fishery during the past decade, which severely limits the recent information available on the locations of scallop beds from which one would normally stratify the fishery. Further, the catch and effort data is aggregated by day (rather than shot) and by 10-minute grids (rather than latitude and longitude), which further eroded the ability for precise stratification and to conduct a power analysis to determine likely precision around any biomass estimate. These shortcomings in the available data, the spatio-temporal patchiness of scallop beds, combined with our experience in other Bass Strait scallop surveys led us to approach this survey as explained below.

Only a certain amount of resources (survey days) were available for the survey. We considered that expending all survey effort on a “broad-area” survey of the entire eastern fishery would likely result in many shots with zero scallop catches, and an extremely uncertain biomass estimate. This information would have limited use for management of the fishery. Rather, we took the approach of allocating half of the survey effort to a broad-area survey that that covered the fishable area from Point Hicks to Wilsons Promontory, and half towards intensive surveying of specific scallop beds as separate strata, which may have been identified from within the broad-area survey or based on information from industry members. It was hoped that biomass estimates of these smaller beds would have less uncertainty than the broad-area survey, and provide information that could be better used to inform fishery management decisions.

Objectives

1. Estimate the available (>80 mm) scallop biomass in the area of the Victorian (Ocean) Scallop Fishery.
2. Measure the size frequency distribution of scallops in each area to calculate discard rates.
3. Measure a range of biological information from the catch.
4. Trial an age estimation method to provide growth rate and other population parameters.
5. Report results to VFA.

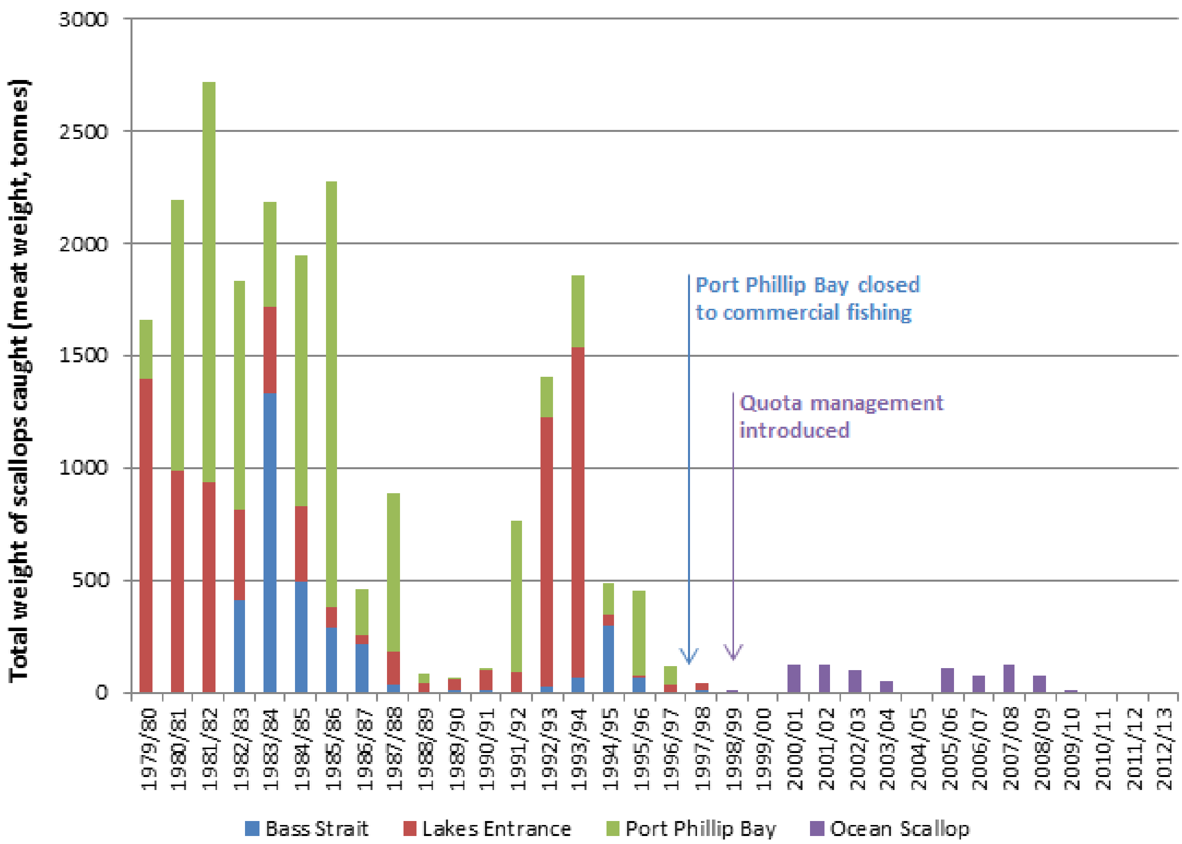

Figure 1. Time series of catch (meat weight, tonnes) in the Victorian Scallop Fishery. Port Phillip Bay was closed to commercial fishing in 1997, and in 1998 the licences for Bass Strait and Lakes Entrance were combined to be called 'Ocean Scallop'. Copied from https://vfa.vic.gov.au/commercial-fishing/scallop (accessed January 2018).

Methods

Survey Design – Broad-area survey

The area of the Victorian (Ocean) Scallop Fishery extends from the shoreline to 20 nm offshore along the length of the Victorian coast (Victorian Fisheries Authority, 2018), however historically, the vast majority of fishing has been east of Wilsons Promontory (

Figure 2A). The specifications for the research project provided by VFA required “a survey that will provide an estimate of scallop biomass out to 20 nautical miles of the Victorian coastline between Wilsons Promontory and Point Hicks and inform the future sustainable management of the fishery”. Because there are areas within the fishery that cannot be fished using scallop dredges, a primary stratum for the “broad-area” survey was required. Unfishable areas included deep water (the depth within the fishing area reached 200 m in places), very shallow water, heavy reef, oil and gas infrastructure and marine protected areas.

Based on the track of previous surveys (Harrington *et al.*, 2010); Semmens and Jones, 2012), the primary stratum was initially defined as the area of the fishery inside the 40 m depth contour, from Wilsons Promontory in the west to a line running due south from Point Hicks in the east (

Figure 2B). However, this did not entirely encompass the tracks undertaken in previous surveys, nor fine-scale fishing effort data from industry. The shapefile *sed_facies_east.shp* from the National Marine Bioregionalisation of Australia GIS dataset[1] provided a delineation between shale sand and deep carbonate substrate types that appeared to closely follow the outer boundary of fishing effort (Figure 3). The stratum was extended into deeper water between the intersections of the 40 m depth line and the shale sand polygon at about E147˚ 15.1΄ and E148˚ 00.9΄ (

Figure 2C and

Figure 2D). This boundary was simplified to remove several bulges. In addition, marine protected areas were removed (

Figure 2E), and an inshore buffer of about 0.5 nm removed to avoid placing survey shots in very shallow water. The final stratum (

Figure 2F) covers an area of 4,859 km^2.

A total of 150 primary and 50 backup survey sites were randomly allocated to the broad-area stratum using the QGIS (v 2.18.15) Random Points Inside Polygons tool.

Survey Design – Intensive survey

Consideration of areas for intensive surveys included broad-area survey results, past surveys, historic fishing catch and effort data and anecdotal information from fishers from the Victorian (Ocean) Scallop Fishery and other inshore fisheries. Despite catches being highest in the south of the broad-area stratum, there was only one tow that contained enough Commercial Scallops to be considered as a potential bed. This site was discounted from intensive surveys, however, for the following reasons:

- the skipper described this area as being too rough a ground to survey, with lots of unfishable ground and a high chance of losing a dredge;
- the next largest catch (13kg) was 18 km away; and,
- scallop catches in tows around that site were very low (0–2 kg/tow).

Other areas were ranked based on the strength of evidence of scallop aggregations, resulting in seven areas being provided to the skipper for exploratory fishing (Figure 4), and two other areas were suggested by industry members and investigated during the survey. The site LE1 was considered the most likely area for an intensive survey and its perimeter was refined by exploratory fishing (Figure 5). An additional 34 exploratory tows were undertaken in and around the other sites to ascertain potential survey beds (Figure 4). Most areas had 0–3 kg of scallops per tow (Table 1), and none were considered suitable for a targeted survey. Notably, catches from areas chosen for exploratory fishing based on anecdotal information from more than one year ago contained large amounts of dead shell (Table 1).

A total of 25 primary, and 5 backup survey sites were randomly allocated to LE1 using the QGIS (v 2.18.15) Random Points Inside Polygons tool.

[1] https://data.gov.au/dataset/2005-national-marine-bioregionalisation-of-australia/resource/d861a53b-4850-40fd-826f-d6909222c140

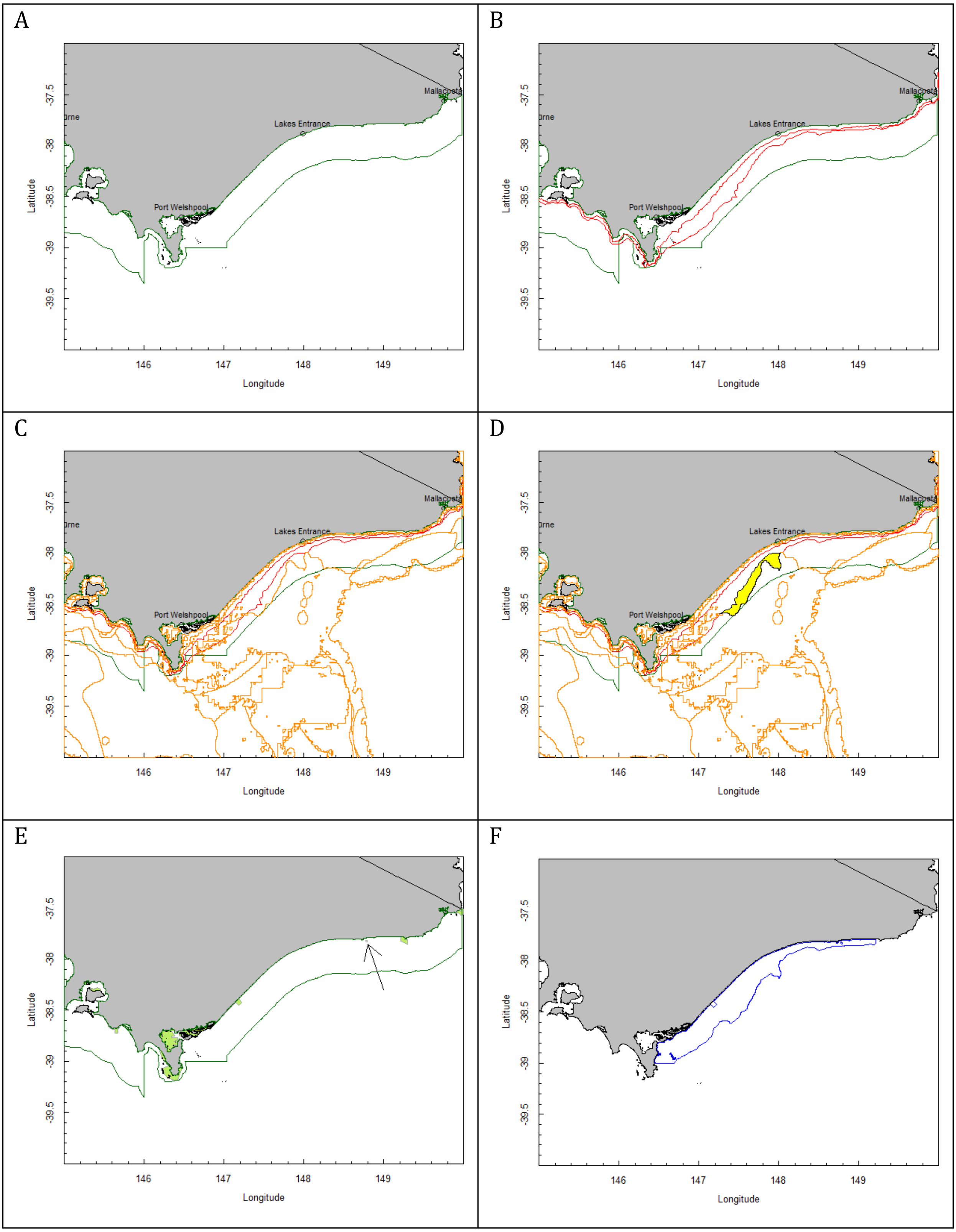
A
B
C
D
E
F
Lakes Entrance
Port Welshpool
Latitude
-37.5
-38
-38.5
-39
-39.5
Longitude
146
147
148
149

Figure 2. Maps showing development of the broad-area stratum. A) boundaries of the Victorian Ocean Scallop Fishery; B) the 20 m and 40 m depth contours; C) the sediment shape layer; D) the section of the shale sand added to the stratum in yellow; E) Marine Protected areas; and F) the final broad-area stratum.

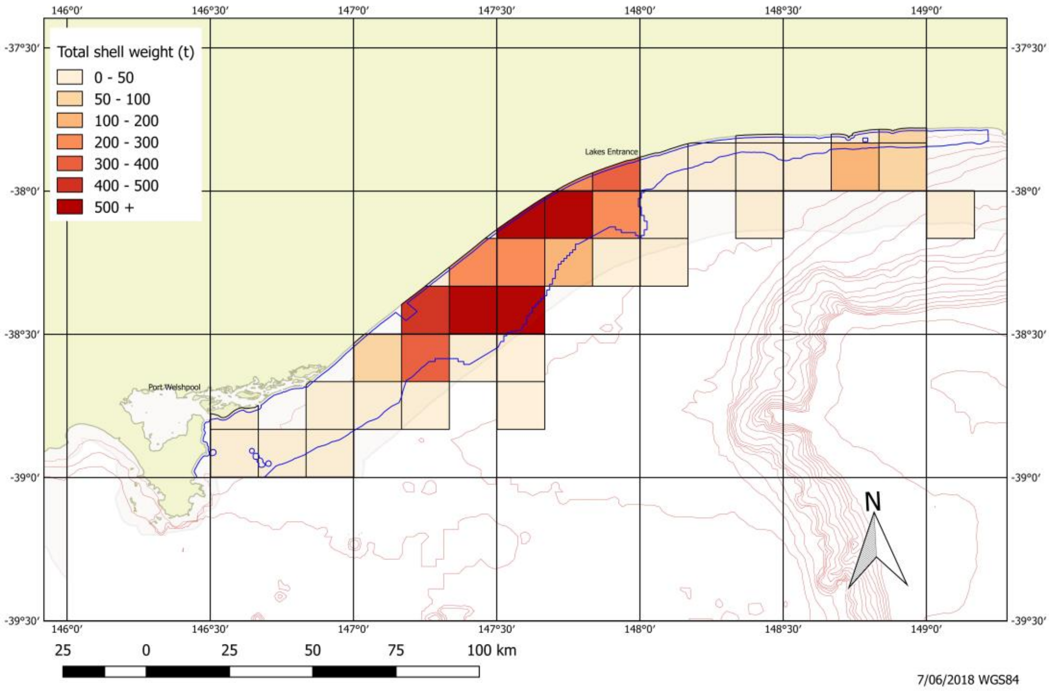

Figure 3. Wide area survey overlayed on commercial catch (t) from 2001–2016 by reporting grid. Note that data has been filtered to maintain confidentiality in line with the "5 boat rule".

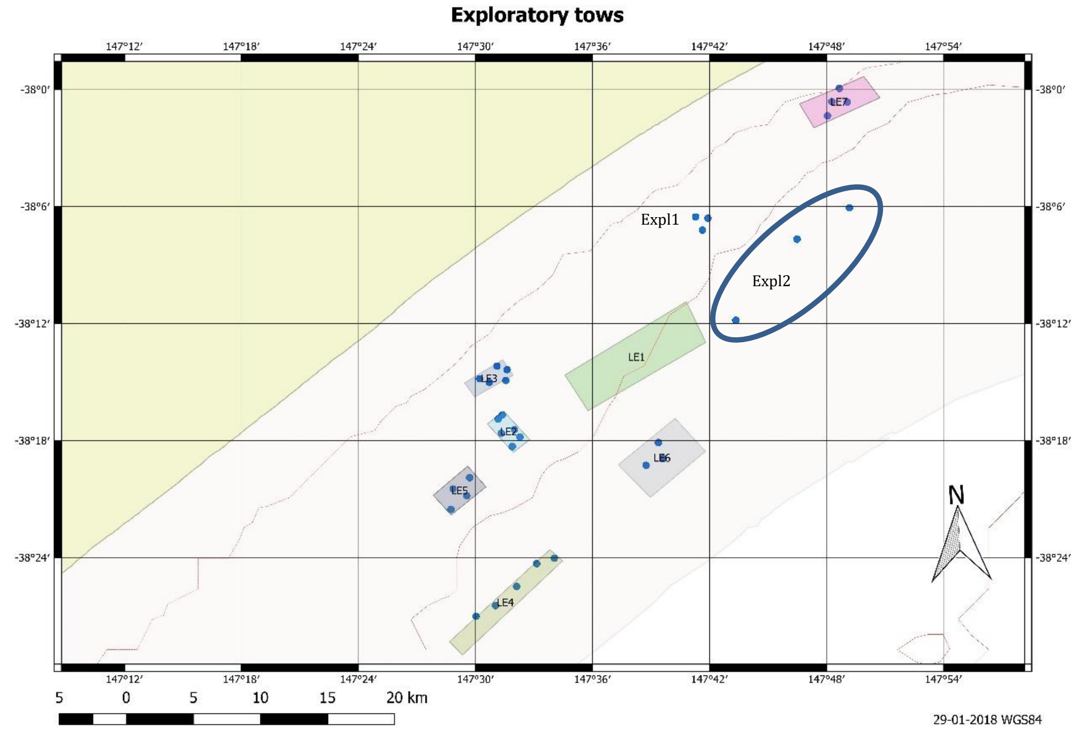

Figure 4. Areas that were targeted by exploratory fishing to identify intensive survey beds. Blue dots show start-tow locations of exploratory tows. Note that exploratory tows made to define the final LE1 Bed are not shown.

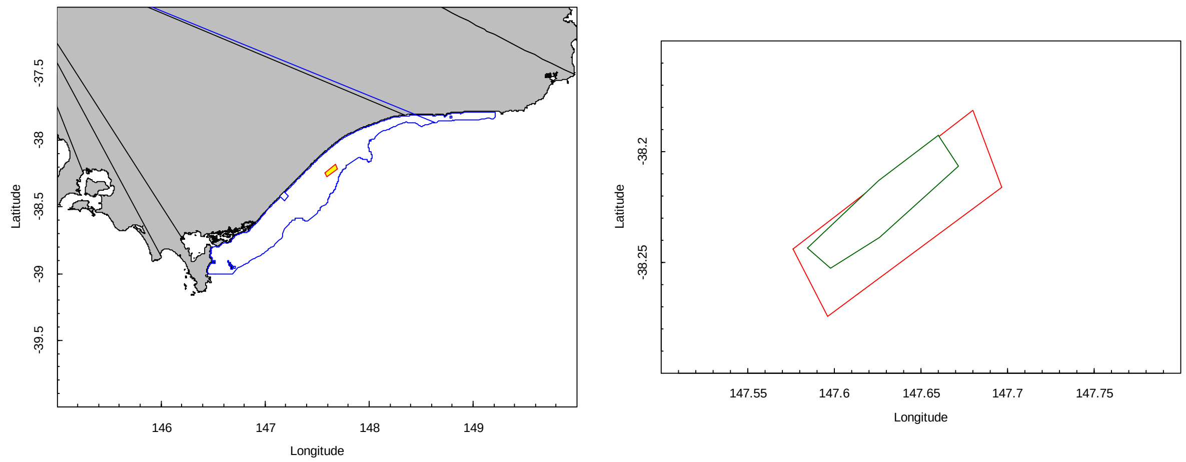

Figure 5. Location of LE1 bed (red polygon in left panel) that was refined through exploratory fishing (green polygon in right panel) and intensively surveyed.

Table 1. Summary of comments from areas where exploratory tows were undertaken. Note that catch composition is not recorded during exploratory tows, most dead scallop shell observed were "old singles".

Stratum	Commercial Scallop catches	Comments
LE1	Averaged about 30 kg per shot	Most promising site
LE2	0-3 kg (Scallops present in only 1 tow)	Dead scallop shell
LE3	0 kg	Rocks
LE4	0 kg	Lots (up to 400 kg) of dead scallop shell on old fishing marks
LE5	0.2–1 kg	Some dead scallop shell
LE6	0 kg	Dead scallop shell
LE7	0 kg	Lots (up to 400 kg) of dead scallop shell
Expl1	0-2 kg	Heavy bottom, lots of sponge
Expl2	0 kg	Lots (up to 300 kg) of dead scallop shell

Sampling methods

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

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

For each shot, estimates of weight were made for: total live scallop catch, dead scallop shell and all bycatch by species / species group. Dead scallop shells were further categorised as:

- 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 being discarded. The observer measured the length of those scallops using an electronic Scielex Shellfish Measuring Board. Either the first or last (or both) scallop from each shot measured using the measuring board was also measured by hand using 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. The orientation of the length measurement used in this report is shown in (see Appendix 1, Figure 33).

From every fifth shot, an additional 10 random scallops were taken before passing through the tumbler to collect biological information and for age estimation. First, the whole scallop was weighed, then split and the gonad condition staged according to the scale in Table 12 and Table 13 based on (Harrington *et al.*, 2010) (see Appendix 1). Adductor meat and gonad were removed from the shell and weighed together to calculate number of meats per kg. Shell height and width (see Appendix 1, Figure 33) were also measured for morphometric analyses. Shell were individually labelled to enable matching up with shot, catch and biological data, and stored in a way so as to maintain the structural integrity of the hinge of the shell.

Data analysis

All data processing and analysis was undertaken in R (R Core Team, 2017), and density plots were created using the package QGIS (version 2.18.15). Estimates of biomass followed the methods of Semmens and Jones (2014).

Biomass

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

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

$$S = L \times W$$

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

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

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

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

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

$$B = meanD * A * 3.03 / 1000$$

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

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

Were meanD is the mean density (kg) of scallops per m^2 swept, t_{n-1} is the t –value for the number of shots (n) -1, SE_{meanD} is the standard error of meanD and A is the total stratum area (m^2). The area of each bed was calculated using the the package QGIS (version 2.18.15).

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

$$B_{>80mm} = B * (1\text{-discard rate})$$

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

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

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

Densities of Commercial Scallops in the broad-area survey were heavily positively skewed, and so bias-corrected 95% CL were calculated using the boot.ci function of the R package “boot” (Cantly and Ripley, 2017) using 1000 bootstrap replicates.

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

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

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

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

Biologicals

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

Age estimation

The preliminary age estimation of *P. fumatus* was conducted by FAS in two phases. The first phase of this project was to conduct a review of international literature relating to scallop ageing, and apply these methods to Commercial Scallops collected during the survey. The aim of the literature review was to identify a preferred ageing method which produced the greatest confidence in ageing readability rating for age estimation of Commercial Scallops. The second stage of the project was to apply the preferred ageing estimation technique to the samples collected from the survey.

In order to investigate whether annual ageing of Commercial Scallops could be estimated, FAS deployed the three methods outlined below on 41 trial samples:

i. External Shell Zones;
ii. Hinge Ligament Zones; and
iii. Internal Shell Zones.

Each method was investigated using a number of trail techniques. Results detailing the outcomes from these trail techniques are provided below.

FAS applied a rating of zone readability for each of the three methods, using the scale detailed in Table 2, to assist in identifying the level of confidence in age estimation.

Table 2. Zone Readability Rating

Rating	Definition
1	102% confidence
2	90% confidence (approx. 1± zones)
3	75% confidence (approx. 1-2± zones)
4	50% confidence
5	poor confidence - disregard sample

<u>External shell zones</u>

Counting the external zones on the shell surface from the umbo (mid-shell base) to the ventral margin has been a well-accepted method to age bivalve molluscs for over 60 years (Stevenson & Dickie, 1954; MacDonald & Thompson, 1988). Both dorsal and ventral shells (i.e. valves) of trial samples were examined to explore and interpret the zones visible on the surface of both the dorsal and ventral shell. The dorsal shell was chosen for age estimation based on information in the literature, and because zone clarity was typically noted to be strongest. Contact between the ventral shell and the seabed reportedly results in poor zone clarity due to excessive wear; in addition, the ventral shell lacks colour band characteristics required for identification of annuli (Fairbridge, 1952; Siddon *et al.*, 2017).

In attempt to improve external shell zone clarity, samples were dried using one of the three preparation methods listed below:

1. Dried in ambient air temperature (approx. 21C°) for a minimum of 12 hours;
2. Dried at 180°C for 1 hour; or
3. Dried at 200°C for 30 minutes.

Drying method 2 and 3 resulted in the complete loss of shell colour, impairing zone clarity on the shells. And so, method 1 was selected as the preferred preparation method for external shell zone investigation. Examples of each of the above drying methods are provided below (Figure 6).

Figure 6: Drying methods, (1) Ambient air for minimum 12 hours, (2) 180°C for 1 hour, (3) 200°C for 30 minutes.

Annuli on dorsal shell surface

Upon examination of the external surface of the dorsal shell, colour bands (light and dark paired zones) and/or texture (raised) bands were observed which resembled annuli described from other scallop species (i.e. weathervane scallops, *Patinopecten caurinus*, Siddon *et al.*, 2017). These zones, considered as 'annuli', were used to estimate age by counting the number of bands of different colour and/or texture (e.g. Figure 7).

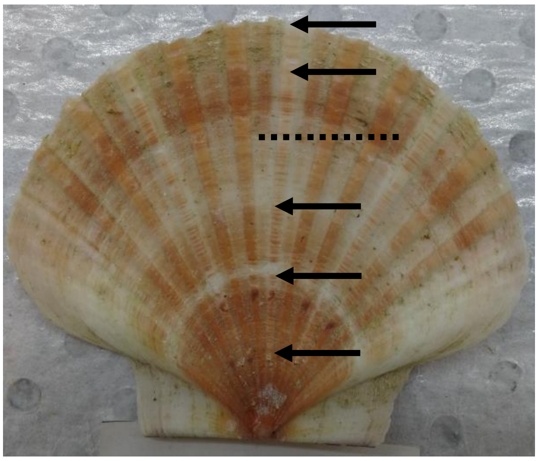

Figure 7: Scallop age estimated by colour band pair and annuli method at 5 years. Arrows point to annuli. Dotted-line marks a false zone.

False zones

Scallops are described to be sensitive to environmental stressors (i.e. dredging and storm events) (Hattersley and Brickle, 2006). As a result, false annuli zones (i.e. stress-marks) are commonly observed when examining the external surface of scallop shells for age estimations (Merril *et al.*, 1965; Stevenson and Dickie, 1954). False zones were disregarded when observed throughout our preliminarily ageing estimations because they do not indicate a one-year age progression.

Annuli on dorsal shell auricle

The auricle, a triangular shell feature located on either side of the umbo (Figure 8), was also used to estimate age. The auricle has previously been used to assist in age estimation when the colour band and texture band methods proved ineffective on the external shell surface, such as those that are heavily worn (Siddon *et al.*, 2017).

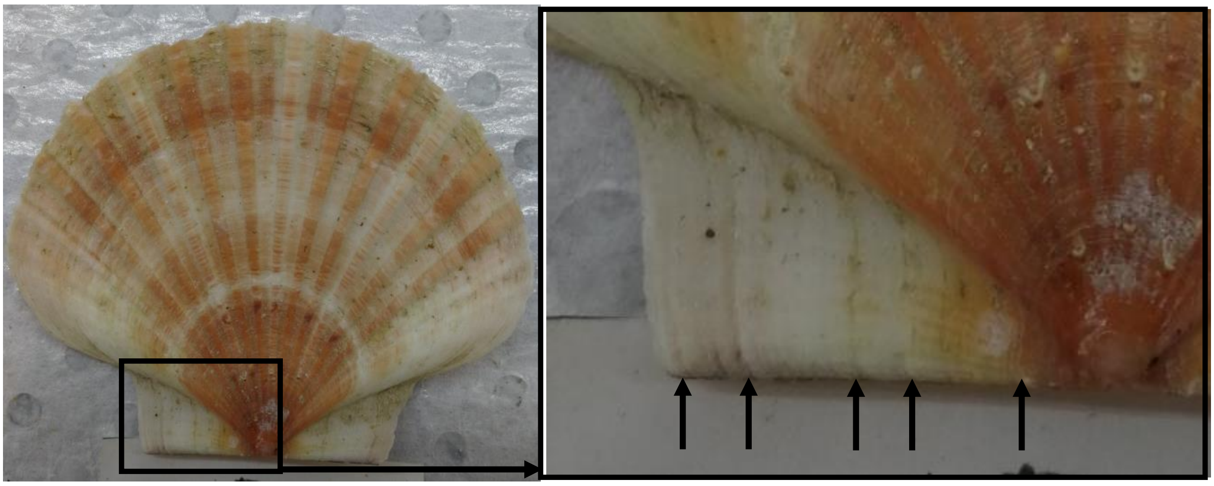

Figure 8. Example of annuli on dorsal shell auricle. Arrows point to annuli.

Hinge Ligament Zones

The resilium, pyramid-shaped calcareous portion of the shell hinge ligament (Figure 9), herein referred to as the 'hinge ligament'), was examined from Phase 1 samples in attempt to interpret visible zones. The hinge ligament has commonly been used to age bivalve molluscs in previous studies (Trueman, 1953; Merrill *et al.*, 1966; Johannessen, 1973).

Hinge ligaments were prepared and read as per Hattersley and Brickle (2006). Following removal of the hinge ligament from shells, each sample was mounted on a slide (Figure 9) and ground back to expose a longitudinal section of the calcareous plate. Upon examination, zones visible on the hinge ligaments appeared to include a high number of false zones. Poor readability was also described from Hattersley and Brickle's (2006) work, wherein 15% of hinge ligament samples were considered impossible to read due to the bands not being visible or stress marks making the bands illegible.

In addition to stress marks impairing readability, FAS observed that the visibility of zones varied with the change of reflected light angle (Figure 10), as well as between the ventral and dorsal hinge ligaments (e.g. Figure 11). These variations noted pose the risk of inaccurate zone interpretation and therefore age estimations.

Figure 9: Hinge ligament mounted on slide

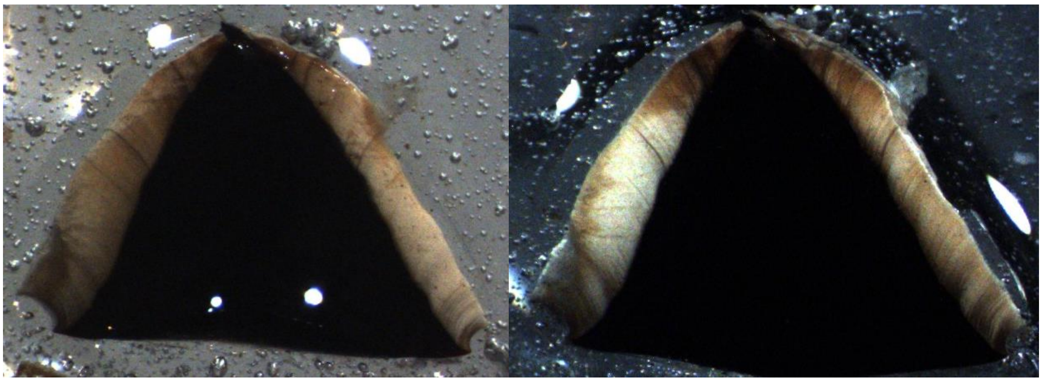

Figure 10: Sample #225, hinge ligament zone visibility varying with the change of reflected light angle.

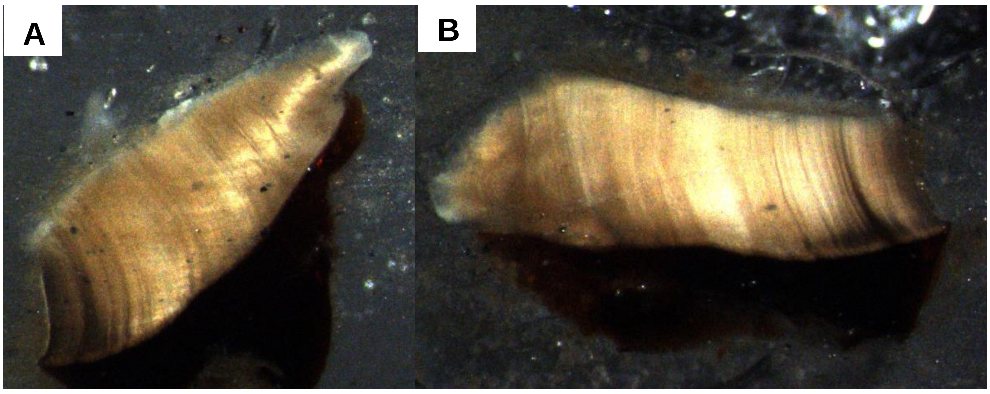

Figure 11: Sample #228, hinge ligament zone variation between ventral (A) and dorsal (B).

The following techniques were investigated in an attempt to produce a more reliable hinge ligament age estimation method by reducing both false zone visibility and variation in zone counts:

i. Hinge ligament mounted on 45° angle (as hinge ligament sits naturally on slide) or flat (e.g. Figure 12);
ii. Magnification power (i.e. 10x vs 20x) (e.g. Figure 13);
iii. Hinge ligament viewed pre-grind (e.g. Figure 14);
iv. Superficial grind vs deeper grind (e.g. Figure 15);
v. Using immersion oil with hinge ligament reads; and,
vi. Adjusting camera setting (i.e. exposure and gamma) to enhance zone count visibility.

None of the above methods proved successful in producing hinge ligament age estimations in which either false zones were less conspicuous or annuli zones could be discerned with greater confidence. And so, the hinge ligament was disregarded as a preferred method for age estimation of *P. fumatus* in Phase 2.

Further hinge ligament age estimation technique investigations (i.e. examine a greater sample size) may aid in producing a more reliable method to discriminate false zones from annuli.

Figure 12: Hinge ligament mounted for a flat grind.

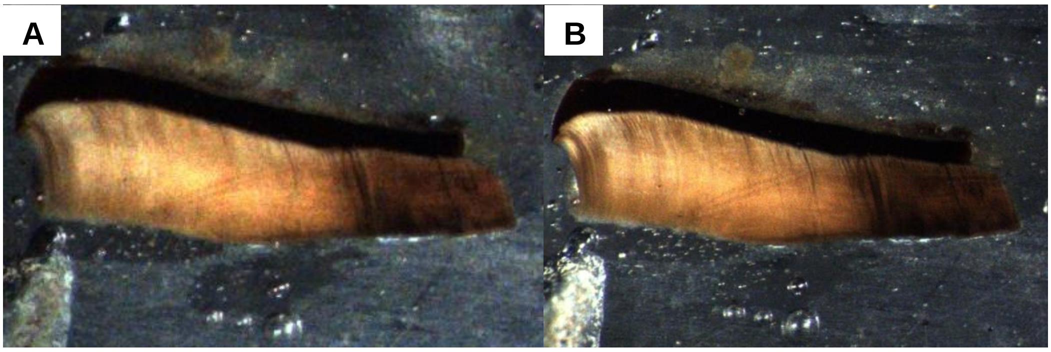

Figure 13: Sample #230, 10x magnification (A) and 20x magnification (B).

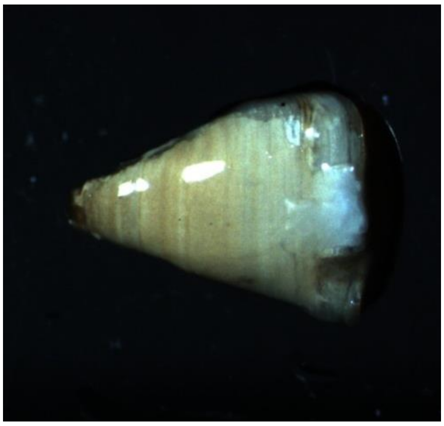

Figure 14: Hinge ligament pre-grind.

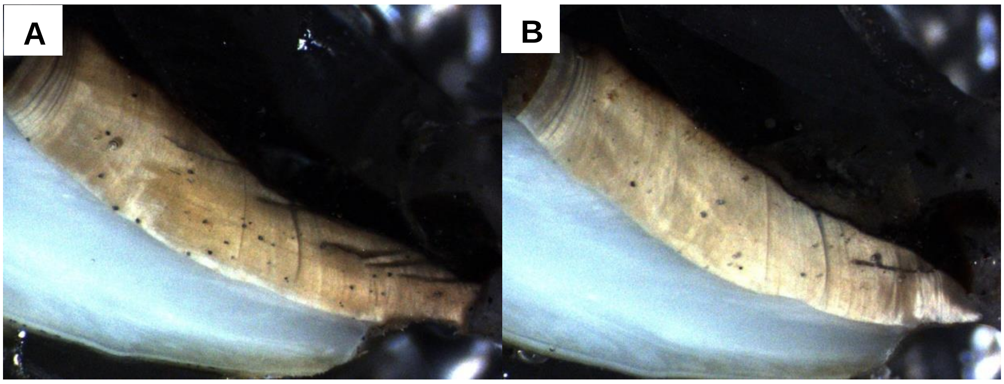

Figure 15: Sample #222, superficial grind (A) and deeper grind (B).

<u>Internal Shell Zones</u>
Previous work on other scallop species has identified internal shell zones as a reliable age estimation method (MacDonald & Thomas, 1980; Arneri *et al.*, 1998; Liu *et al.*, 2017). FAS investigated this ageing technique by examining both the dorsal and ventral shells of *P. fumatus*.

The internal shell zones were examined using a series of transverse section (TS) cuts taken from different locations and angles, prepared as per Liu *et al.* (2017). The following TS trails were performed to investigate the presence of internal shell zones:

a) Diagonal TS of shell ear region (dorsal and ventral) (Figure 16-A);
b) Horizontal TS of shell hinge region (dorsal and ventral) (Figure 16-B)
c) Vertical TS of shell height (Figure 16-C); and
d) Vertical TS of shell auricle (dorsal and ventral) (Figure 16-D).

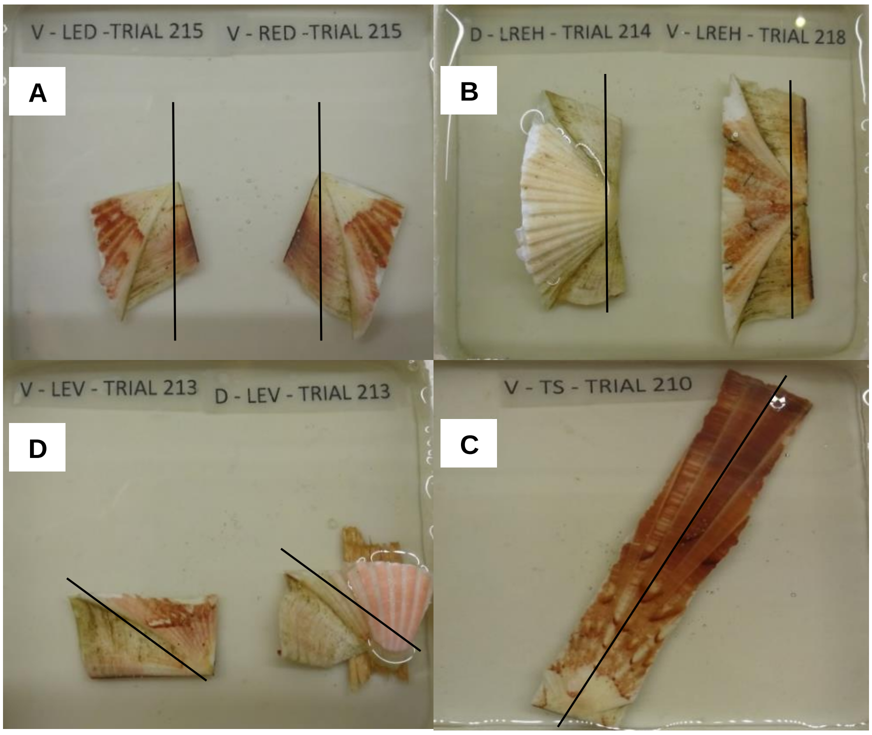

Figure 16: Internal shell zone transverse section cuts (A-D).

Examination of TS samples for presence of internal zones provided limited confidence in using this method for age estimation. Internal zones were observed from a number of diagonal TS (Figure 17) and horizontal TS samples (Figure 18). However, as false zones visible were indistinguishable from annuli, internal shell zone was disregarded as a preferred method for age estimation in Phase 2.

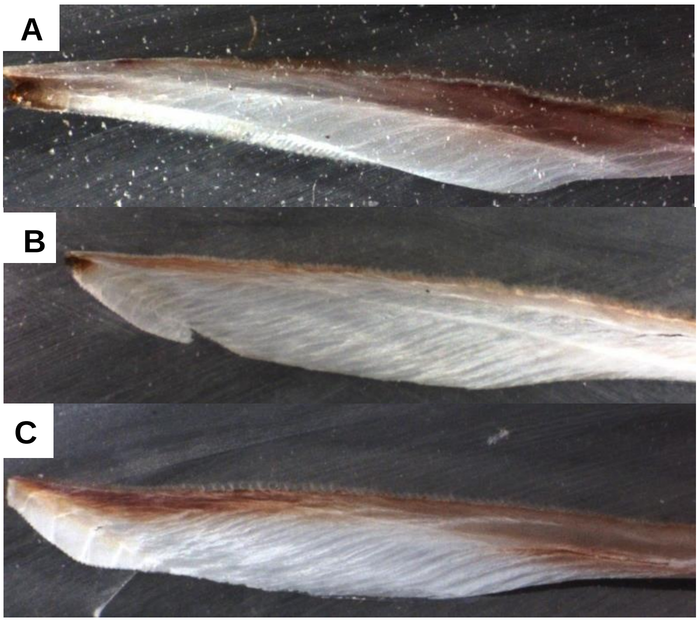

Figure 17: Diagonal TS Samples #215 (A), # 209 (B) and #207 (C).

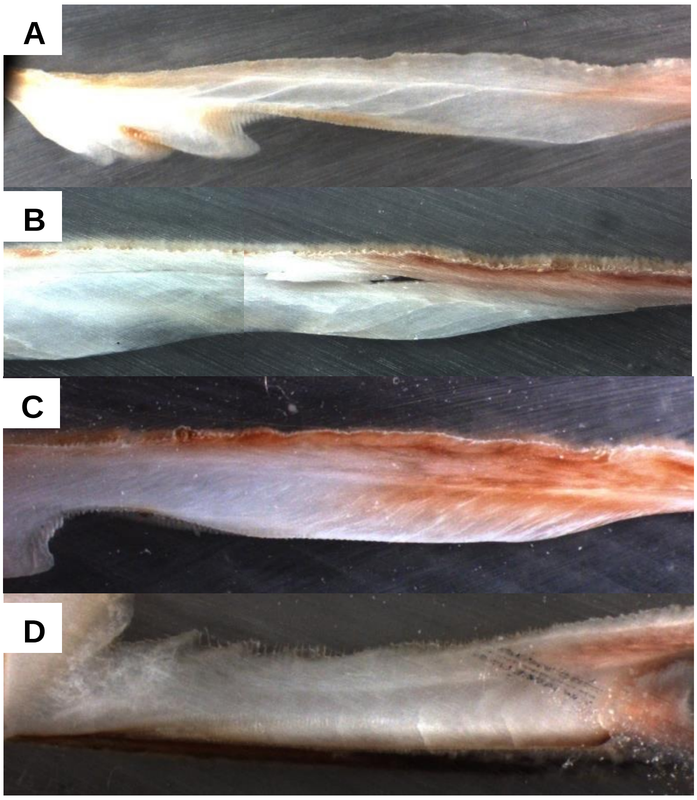

Figure 18: Horizontal TS Samples #205 (A), #208 (B), #218 (C) and #214 (D).

Upon completion of Phase 1, literature review and application of each three trial age estimation techniques, the external (dorsal) shell zone methods were chosen as the preferred technique to apply for Phase 2 age estimations of 101 *P. fumatus* samples from the survey.

Quality Assurance

The survey was undertaken following Standard Operating Procedures. All tow and scallop catch data were recorded in ORLAC Dynamic Data Logger (DDL), which includes quality assurance protocols including automatic data capture (time, date and position), field restrictions, range checks, mandatory fields and lookup tables. All data were manually error checked against data sheets. This database is regularly backed up and is used to extract data for analyses. Data analyses were undertaken using R (R Core Team, 2017), and a subset of outputs were reproduced and compared using an alternative software package. Scallops were measured using an electronic Scielex Shellfish Measuring Board. 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 VFA managers. Where required, comments were addressed in preparation of the final report.

Results

Broad-areas survey shots

The broad-area survey was conducted over two trips from 18/12/2017 – 23/12/2017 and 4/1/2018–7/1/2018 (Table 3). During those trips 148 valid survey tows were undertaken (Table 4, Figure 19). Tows averaged 496 m length and bottom temperatures generally decreased with depth, averaging about 19.1˚C at 20 m depth and 17.2˚C and 45 m depth. Catches of Commercial Scallop ranged 0 kg to 45 kg per tow (Table 4, Figure 19). Zero catches were much more common north of 38^{o} 30′, however in tows south of that line where scallops were caught, they were mostly caught in very small (<4 kg) quantities, with only two tows catching more than 10 kg (Table 4).

Density of scallops in the broad-area stratum was 1.1 kg/1000m^2 based on all tows, or 0.06 individuals per square metre based on non-zero tows only (Table 6). With a total area of 4859 km^2, total scallop biomass was estimated to be 5,107 t. As predicted, however, this estimate is very uncertain, and 95% confidence intervals range 2,226 t–14,372 t. 89.0% of the Commercial Scallop biomass was greater than 80 mm in length, and the estimated biomass greater than that length is 4,545 t (95% CI 1,980 t–12,791 t).

A total of 790 Commercial Scallops were measured in the broad-area stratum. Length measurements from that stratum ranged 31 mm–118 mm, with a mean of 84.5 mm and a median of 86.3 mm (Figure 20, Table 8). There were two small peaks in the length frequency distribution at 70 mm and 77 mm, and most scallops were between 80 mm and 95 mm.

Of all the Commercial Scallop shell caught, “Old single shell” was by far caught in the greatest quantity (94%) in the broad-area survey (Figure 21). Live Commercial Scallops and “New single shell” each comprised about 3% of the Commercial Scallop shell caught, while only 4.2 kg of clappers were recorded. A total catch of 23 t was caught in the 148 survey tows conducted in the broad-area stratum (Table 9). Dead shell (32% by weight), substrate (26%) and sponge (17%) were caught in the greatest quantities in the broad-area stratum (Figure 22), reflecting the fishing in random locations largely outside of usual fishing grounds. Of particular interest to VFA with regards to bycatch, no Northern Pacific Seastars (*Asterias amurensis*) were observed, and one Syngnathid — a Widebody Pipefish (*Stigmatopora nigra*) — was caught during the broad-area survey (Table 9).

Intensive survey of beds

LE1 was surveyed over two trips from 8/1/2018–9/1/2018 and 17/1/2018–18/1/2018 (Table 3). 25 valid random tows were conducted in LE1 with catches ranging 0–48 kg (Table 4, Figure 28). A total of 469 kg of Commercial Scallops were caught, and zero catches were recorded in two tows, both on the deeper side of the stratum area.

The mean density was 27.7 kg/1000 m^2 from all tows, or 0.51 individuals per m^2 based on non-zero tows only (Table 6). The estimated total biomass in the 16.5 km^2 area is 456 t with 95% CIs of 332 t–581 t. 84.6% of the weight of scallops measured was greater than 80 mm (Table 7), resulting in a biomass greater than 80 mm of 386 t (281 t–491 t).

A total of 879 Commercial Scallops were measured from LE1, with a mean length of 84.3 mm and a median of 84.2 mm (Table 8). The length distribution was much narrower compared to the broad-area survey, ranging 71 mm to 96 mm (Figure 20).

Of the Commercial Scallop shell caught, "Old single shell" dominated the catches (60% by weight), but to a lesser extent than in the broad-area survey (Figure 21). "Live Commercial Scallops" and "New single" comprised 18% and 20% of the Commercial Scallop shell catch respectively, while Clappers comprised 2%. Overall, 4.3 t was caught from LE1, most of which was Old single shell (35%), dead shell (33%), live Commercial Scallop (11%) and New Single shell (11%) (Figure 22).

Of particular interest to VFA regarding bycatch, no Northern Pacific Seastars were observed, and one Syngnathid — a Spiny Pipehorse (*Solegnathus spinosissimus*) — was caught during the intensive survey (Table 9).

Biologicals

Biologicals were recorded for 134 and 66 Commercial Scallops from the broad-area survey and LE1 and respectively (Table 10). Comparison of length-weight regressions revealed that the interaction term was significant ($p=0.007$), indicating that there is a difference in slopes in the length-weight relationship between areas (Figure 23, Figure 24). The p-value for the indicator variable ($p<0.0001$) suggests that there is a difference in intercepts, and that there are differences in length-weight relationships between Strata. However, because of the small sample size and the lack of range in length of Commercial Scallops from LE1, results should be treated cautiously. Parameters of the length-weight relationships are shown in Table 10.

Keeping in mind that the survey was conducted outside of the spawning season, meat weights averaged 103 meats per kg in LE1 and 92 meats per kg in the broad-area survey (Figure 23). Most meats (including gonads) weighted 8–10 g in both strata (Figure 25). Gonads in the broad-area survey ranged in maturity from Stage 1–8, with the majority at 5.1 and 5.2 (Figure 26). There was less diversity in the gonad stage from LE1 ranging 4–5.3, with most either stage 5.1 or 5.2.

Scatterplots of each combination of size measurements (including total weight) shown in Figure 23 reveal a linear relationship between measurements (except for those with total weight). The difference in the range of sizes between strata make comparison of size characteristics difficult. The relationship between height and length was similar between beds (Figure 24B) and ANCOVA results imply that the gradients are not significantly different ($F=0.336$, $p=0.56$). However, both height and length were larger at a given width at LE1 than the broad-area survey ($F=9.290$, $p=<0.01$ and $F=8.599$, $p=<0.01$ respectively), however this is likely due to the smaller size range in LE1 samples, and especially low sample sizes at the smaller size range.

Principle Component Analysis revealed that ratios between different measurements of scallops from LE1 largely overlap with those from the broad-area survey (Figure 27), with the main differences being related to the weight ratios and elongation (reflecting differences in size distribution in the samples), but also in the differences in convexity and compacity that are reflected in PC2, and can be seen in Figure 24B and D.

Table 3. Trip summaries showing start and end times and dates, duration and number of survey tows.

Trip	Start date	Start time	End date	End time	Number of valid survey tows
1	18/12/2017	22:41:51	23/12/2017	03:34:30	65
2	4/1/2018	06:10:12	7/1/2018	05:42:14	83
3	8/1/2018	19:11:04	9/1/2018	19:37:59	12
4	17/1/2018	03:16:03	18/1/2018	20:51:43	13
Total					173

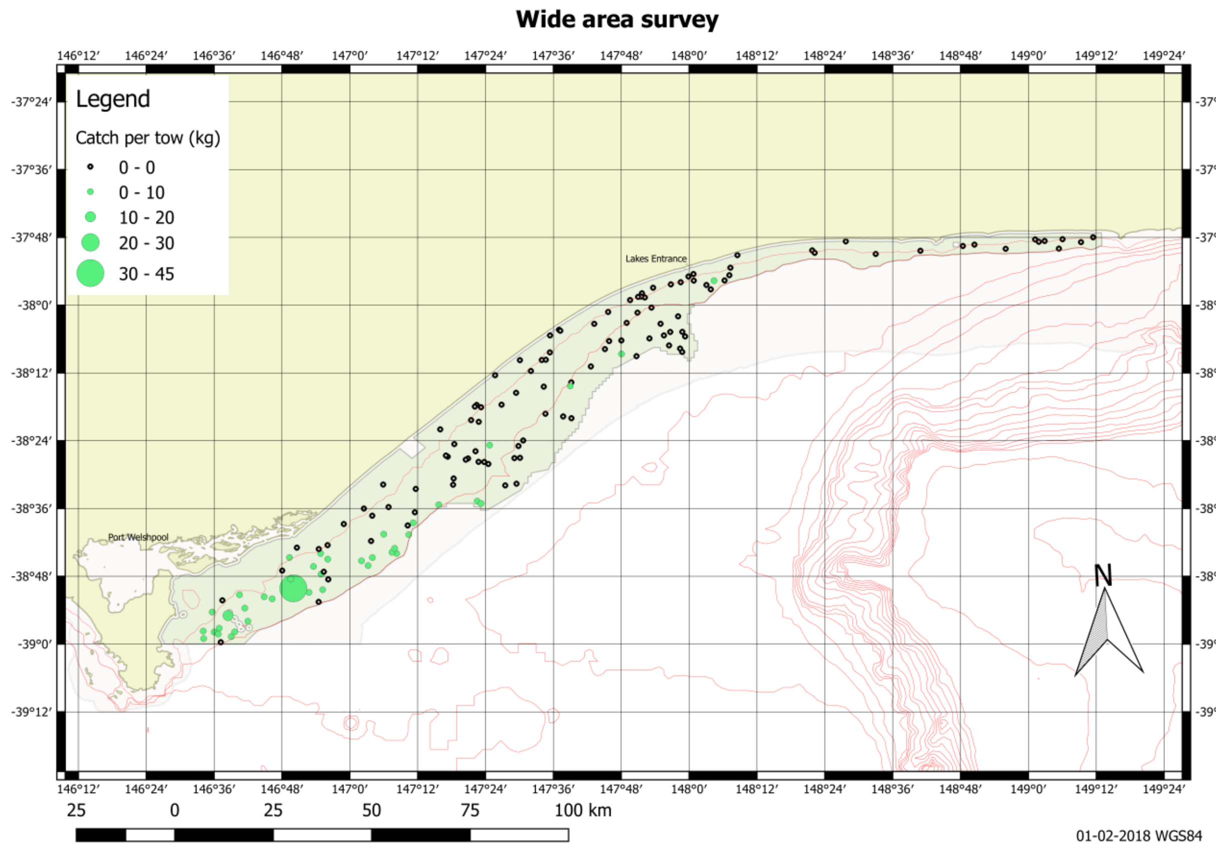

Figure 19. Tows undertaken in the broad-area survey. Open circles with bold boundaries denote 0 kg catches.

Table 4. Catch of Commercial Scallop by shot, shot details and stratum.

Date	Start Time	Start Lat	Start Long	Tow Speed (kts)	Set Num ber	Shot Duration (mins)	Distance Towed (m)	Area Swept (sqm)	Catch Weight (kg)	Stratum
19/12/2017	10:28	-38.994	146.620	3.8	1	0:05:44	652	2623	0	WideArea
19/12/2017	10:55	-38.984	146.569	3.7	2	0:03:24	404	1625	0.5	WideArea
19/12/2017	11:28	-38.978	146.495	3.7	3	0:05:58	674	2708	0	WideArea
19/12/2017	12:10	-38.962	146.568	3.5	4	0:04:32	504	2025	0.15	WideArea
19/12/2017	12:29	-38.964	146.600	3.5	5	0:05:11	579	2329	2.4	WideArea
19/12/2017	12:51	-38.953	146.615	3.5	6	0:04:39	540	2172	2.1	WideArea
19/12/2017	13:12	-38.970	146.612	3.5	7	0:04:46	516	2072	0.4	WideArea
19/12/2017	13:37	-38.978	146.650	3.5	8	0:05:38	632	2542	0.1	WideArea
19/12/2017	13:57	-38.964	146.661	3.5	9	0:04:57	639	2569	6.9	WideArea
19/12/2017	16:10	-38.916	146.641	3.5	10	0:04:53	528	2121	13	WideArea
19/12/2017	16:39	-38.905	146.594	3.5	11	0:05:05	519	2086	0.5	WideArea
19/12/2017	17:54	-38.871	146.624	3.5	12	0:05:18	603	2424	0	WideArea
19/12/2017	18:23	-38.855	146.675	3.5	13	0:05:08	600	2412	0.23	WideArea
19/12/2017	19:14	-38.894	146.690	3.5	14	0:04:41	515	2072	1.4	WideArea
19/12/2017	19:42	-38.933	146.699	3.5	15	0:04:36	536	2153	0.34	WideArea
19/12/2017	20:26	-38.866	146.771	3.5	16	0:04:50	544	2189	9.9	WideArea
19/12/2017	20:56	-38.860	146.748	3.5	17	0:04:29	501	2013	3.6	WideArea
21/12/2017	04:26	-38.847	146.880	3.2	18	0:04:39	518	2082	2.1	WideArea
21/12/2017	04:47	-38.840	146.920	3.2	19	0:04:18	474	1906	3.2	WideArea
21/12/2017	05:24	-38.876	146.908	3.2	20	0:05:13	474	1904	0	WideArea
21/12/2017	06:10	-38.836	146.833	3.5	21	0:04:52	484	1946	45	WideArea
21/12/2017	07:12	-38.808	146.826	3.5	22	0:04:32	443	1782	0.4	WideArea
21/12/2017	07:39	-38.783	146.801	3.2	23	0:04:46	530	2131	0	WideArea
21/12/2017	08:07	-38.745	146.822	3.5	24	0:05:03	524	2107	0.1	WideArea
21/12/2017	08:43	-38.715	146.844	3.5	25	0:02:46	239	962	0	WideArea
21/12/2017	09:22	-38.771	146.893	3.2	26	0:04:55	443	1783	0.8	WideArea
21/12/2017	09:50	-38.794	146.915	3.2	27	0:05:01	508	2042	0.05	WideArea
21/12/2017	10:00	-38.787	146.923	3.2	28	0:04:33	488	1962	0	WideArea
21/12/2017	10:27	-38.809	146.936	3.2	29	0:04:48	468	1880	0	WideArea
21/12/2017	11:05	-38.749	146.935	3.2	30	0:03:00	296	1191	1	WideArea
21/12/2017	11:27	-38.733	146.914	3.2	31	0:04:40	466	1872	0.45	WideArea
21/12/2017	11:38	-38.720	146.909	3.2	32	0:05:12	553	2222	0	WideArea
21/12/2017	11:59	-38.708	146.934	3.2	33	0:05:18	596	2395	0	WideArea
21/12/2017	13:03	-38.754	147.034	3.2	34	0:04:28	501	2015	0.05	WideArea
21/12/2017	13:21	-38.768	147.054	3.2	35	0:04:38	507	2038	0.2	WideArea
21/12/2017	13:55	-38.745	147.067	3.2	36	0:04:41	433	1742	1.3	WideArea
21/12/2017	14:32	-38.733	147.138	3.2	37	0:04:51	576	2315	2.1	WideArea
21/12/2017	14:56	-38.729	147.124	3.2	38	0:04:49	530	2132	0.1	WideArea
21/12/2017	15:11	-38.717	147.132	3.2	39	0:05:01	454	1826	0.05	WideArea
21/12/2017	15:56	-38.696	147.063	3.2	40	0:04:38	542	2180	0	WideArea
21/12/2017	16:21	-38.676	147.100	3.2	41	0:04:21	503	2022	0.4	WideArea
22/12/2017	04:24	-38.646	146.982	3.2	42	0:04:45	473	1902	0	WideArea
22/12/2017	05:03	-38.600	147.042	3.2	43	0:03:00	361	1451	0	WideArea
22/12/2017	05:23	-38.621	147.066	3.2	44	0:05:24	648	2606	0	WideArea
22/12/2017	06:02	-38.596	147.114	3.2	45	0:05:14	384	1542	0	WideArea
22/12/2017	07:01	-38.677	147.174	3.2	46	0:04:35	478	1921	0.23	WideArea
22/12/2017	07:27	-38.642	147.187	3.2	47	0:05:40	623	2506	0.46	WideArea
22/12/2017	07:51	-38.650	147.171	3.2	48	0:04:39	442	1776	0	WideArea
22/12/2017	08:18	-38.611	147.192	3.2	49	0:04:42	515	2070	0	WideArea
22/12/2017	08:55	-38.589	147.262	3.2	50	0:04:52	508	2042	0.41	WideArea
22/12/2017	09:39	-38.578	147.375	3.2	51	0:04:38	507	2037	0.16	WideArea
22/12/2017	09:56	-38.585	147.387	3.2	52	0:04:50	441	1774	2.6	WideArea
22/12/2017	10:54	-38.527	147.491	3.2	53	0:04:31	532	2137	0	WideArea
22/12/2017	11:19	-38.532	147.458	3.3	54	0:05:15	565	2271	0	WideArea
22/12/2017	12:35	-38.530	147.304	3.2	55	0:04:28	546	2196	0	WideArea
22/12/2017	13:20	-38.511	147.306	3.2	56	0:04:52	535	2149	0	WideArea
22/12/2017	14:12	-38.542	147.194	3.2	57	0:02:42	294	1183	0	WideArea
22/12/2017	15:30	-38.529	147.098	3.2	59	0:02:15	207	834	0	WideArea
22/12/2017	17:35	-38.452	147.349	3.2	60	0:04:57	442	1777	0	WideArea
22/12/2017	17:59	-38.462	147.379	3.2	61	0:04:13	424	1705	0	WideArea
22/12/2017	18:14	-38.463	147.396	3.2	62	0:05:32	487	1958	0	WideArea
22/12/2017	19:00	-38.451	147.485	3.2	63	0:05:13	579	2328	0	WideArea
22/12/2017	19:57	-38.450	147.502	3.2	64	0:01:39	149	599	0	WideArea
22/12/2017	21:01	-38.416	147.497	3.2	66	0:05:14	662	2660	0	WideArea
22/12/2017	21:18	-38.399	147.511	3.2	67	0:04:37	474	1907	0	WideArea
4/01/2018	07:55	-37.939	147.946	3.5	1	0:04:21	496	1994	0	WideArea
4/01/2018	08:24	-37.932	147.975	3.5	2	0:04:22	478	1922	0	WideArea
4/01/2018	08:42	-37.927	148.014	3.5	3	0:04:24	465	1869	0	WideArea
4/01/2018	09:05	-37.915	147.998	3.5	4	0:03:03	329	1323	0	WideArea
4/01/2018	09:15	-37.908	148.013	3.5	5	0:05:04	551	2214	0	WideArea
4/01/2018	09:41	-37.940	148.051	3.5	6	0:04:31	482	1939	0	WideArea
4/01/2018	10:04	-37.953	148.064	3.5	7	0:04:50	466	1872	0	WideArea
4/01/2018	10:28	-37.928	148.074	3.5	8	0:05:00	579	2328	1.2	WideArea
4/01/2018	10:59	-37.927	148.105	3.5	9	0:04:44	486	1952	0	WideArea

Date	Start Time	Start Lat	Start Long	Tow Speed (kts)	Set Num ber	Shot Duration (mins)	Distance Towed (m)	Area Swept (sqm)	Catch Weight (kg)	Stratum
4/01/2018	11:15	-37.912	148.119	3.5	10	0:04:35	457	1838	0	WideArea
4/01/2018	11:32	-37.889	148.122	3.5	11	0:05:01	464	1867	0	WideArea
4/01/2018	11:57	-37.852	148.142	3.5	12	0:04:42	433	1742	0	WideArea
4/01/2018	13:37	-37.838	148.363	3.5	13	0:05:01	504	2025	0	WideArea
4/01/2018	13:54	-37.846	148.370	3.5	14	0:04:27	411	1652	0	WideArea
4/01/2018	14:34	-37.812	148.462	3.5	15	0:05:28	528	2123	0	WideArea
4/01/2018	15:17	-37.849	148.550	3.5	16	0:04:51	452	1818	0	WideArea
4/01/2018	16:36	-37.839	148.682	3.5	17	0:04:51	493	1983	0	WideArea
4/01/2018	17:31	-37.825	148.807	3.5	18	0:02:21	218	878	0	WideArea
4/01/2018	17:48	-37.821	148.841	3.5	19	0:05:37	489	1966	0	WideArea
4/01/2018	18:27	-37.834	148.933	3.5	20	0:04:52	523	2102	0	WideArea
4/01/2018	19:03	-37.806	149.020	3.5	21	0:04:41	478	1922	0	WideArea
4/01/2018	19:14	-37.813	149.031	3.5	22	0:04:41	485	1948	0	WideArea
4/01/2018	19:28	-37.811	149.048	3.5	23	0:04:38	498	2002	0	WideArea
4/01/2018	20:02	-37.833	149.090	3.5	24	0:04:43	515	2069	0	WideArea
4/01/2018	20:27	-37.805	149.101	3.5	25	0:04:46	523	2103	0	WideArea
4/01/2018	20:50	-37.814	149.155	3.5	26	0:04:58	437	1755	0	WideArea
4/01/2018	21:09	-37.800	149.191	3.5	27	0:04:37	527	2118	0	WideArea
5/01/2018	07:00	-37.949	147.894	3.5	28	0:04:31	479	1926	0	WideArea
5/01/2018	07:48	-37.965	147.861	3.5	29	0:04:45	489	1964	0	WideArea
5/01/2018	08:02	-37.977	147.870	3.5	30	0:04:40	557	2239	0	WideArea
5/01/2018	08:21	-37.975	147.859	3.5	31	0:04:53	474	1905	0	WideArea
5/01/2018	08:32	-37.975	147.850	3.5	32	0:04:48	462	1855	0	WideArea
5/01/2018	08:49	-37.985	147.826	3.5	33	0:04:41	467	1876	0	WideArea
5/01/2018	09:28	-38.022	147.848	3.5	34	0:04:38	480	1931	0	WideArea
5/01/2018	09:55	-38.007	147.889	3.5	35	0:05:01	505	2029	0	WideArea
5/01/2018	10:33	-38.033	147.968	3.5	36	0:04:54	499	2007	0	WideArea
5/01/2018	11:27	-38.055	147.916	3.5	37	0:04:41	479	1926	0	WideArea
5/01/2018	11:53	-38.079	147.944	3.5	38	0:04:47	516	2076	0	WideArea
5/01/2018	12:15	-38.089	147.926	3.5	39	0:04:49	558	2243	0	WideArea
5/01/2018	12:40	-38.079	147.980	3.5	40	0:04:33	476	1914	0	WideArea
5/01/2018	12:55	-38.092	147.988	3.5	41	0:04:52	451	1813	0	WideArea
5/01/2018	13:34	-38.138	147.980	3.5	42	0:04:04	673	2706	0	WideArea
5/01/2018	13:49	-38.128	147.974	3.5	43	0:05:00	528	2121	0	WideArea
5/01/2018	14:07	-38.119	147.941	3.5	44	0:04:50	529	2127	0	WideArea
5/01/2018	14:33	-38.098	147.883	3.5	45	0:04:56	574	2306	0	WideArea
5/01/2018	15:09	-38.052	147.816	3.5	46	0:04:47	488	1962	0	WideArea
5/01/2018	15:37	-38.020	147.761	3.5	47	0:04:49	448	1800	0	WideArea
5/01/2018	16:08	-38.055	147.720	3.5	48	0:04:55	482	1938	0	WideArea
5/01/2018	16:43	-38.106	147.764	3.5	49	0:04:48	487	1957	0	WideArea
5/01/2018	17:05	-38.104	147.800	3.5	50	0:04:50	463	1863	0	WideArea
5/01/2018	17:39	-38.150	147.845	3.5	51	0:04:43	433	1741	0	WideArea
5/01/2018	18:05	-38.144	147.801	3.5	52	0:04:45	518	2083	0.05	WideArea
5/01/2018	18:29	-38.130	147.752	3.5	53	0:05:02	477	1919	0	WideArea
5/01/2018	19:03	-38.181	147.711	3.5	54	0:04:59	557	2241	0	WideArea
5/01/2018	20:13	-38.073	147.617	3.5	55	0:02:29	232	934	0	WideArea
5/01/2018	20:56	-38.075	147.620	3.5	56	0:04:41	481	1934	0	WideArea
5/01/2018	21:13	-38.089	147.590	3.5	57	0:04:50	526	2114	0	WideArea
6/01/2018	06:44	-38.139	147.590	3.5	58	0:05:02	491	1974	0	WideArea
6/01/2018	07:02	-38.161	147.578	3.5	59	0:04:46	522	2100	0	WideArea
6/01/2018	07:13	-38.162	147.566	3.5	60	0:04:43	487	1956	0	WideArea
6/01/2018	07:43	-38.162	147.501	3.5	61	0:04:52	521	2096	0	WideArea
6/01/2018	08:07	-38.194	147.534	3.5	62	0:04:58	537	2158	0	WideArea
6/01/2018	08:38	-38.240	147.572	3.5	63	0:04:53	503	2022	0	WideArea
6/01/2018	09:12	-38.228	147.653	3.5	64	0:04:52	552	2218	0	WideArea
6/01/2018	11:13	-38.238	147.650	3.5	66	0:05:12	570	2292	0.3	WideArea
6/01/2018	12:04	-38.334	147.653	3.5	67	0:04:55	550	2209	0	WideArea
6/01/2018	12:21	-38.328	147.629	3.5	68	0:04:48	499	2005	0	WideArea
6/01/2018	12:45	-38.320	147.577	3.5	69	0:04:56	616	2477	0	WideArea
6/01/2018	13:30	-38.259	147.490	3.5	70	0:04:25	418	1681	0	WideArea
6/01/2018	14:49	-38.207	147.428	3.5	72	0:04:43	451	1814	0	WideArea
6/01/2018	15:38	-38.294	147.374	3.5	73	0:04:41	517	2079	0	WideArea
6/01/2018	15:45	-38.299	147.369	3.5	74	0:05:03	521	2096	0	WideArea
6/01/2018	16:03	-38.301	147.387	3.5	75	0:05:37	586	2357	0	WideArea
6/01/2018	16:32	-38.294	147.447	3.5	76	0:04:47	470	1890	0	WideArea
6/01/2018	17:12	-38.344	147.380	3.5	77	0:05:03	575	2311	0	WideArea
6/01/2018	17:27	-38.339	147.358	3.5	78	0:04:50	520	2089	0	WideArea
6/01/2018	18:08	-38.366	147.267	3.5	79	0:05:29	610	2451	0	WideArea
6/01/2018	18:40	-38.410	147.308	3.5	80	0:04:44	505	2029	0	WideArea
6/01/2018	19:38	-38.413	147.412	3.5	81	0:04:47	537	2161	0.05	WideArea
6/01/2018	20:06	-38.431	147.371	3.5	82	0:04:36	452	1816	0	WideArea
6/01/2018	21:24	-38.469	147.408	3.5	84	0:04:24	490	1970	0	WideArea
6/01/2018	22:20	-38.447	147.289	3.5	85	0:04:43	482	1938	0	WideArea
6/01/2018	22:29	-38.444	147.283	3.5	86	0:05:06	536	2155	0	WideArea

Date	Start Time	Start Lat	Start Long	Tow Speed (kts)	Set Num ber	Shot Duration (mins)	Distance Towed (m)	Area Swept (sqm)	Catch Weight (kg)	Stratum
9/01/2018	10:18	-38.223	147.650	3.5	1	0:05:15	567	2280	1.6	LE1
9/01/2018	10:56	-38.211	147.645	3.5	2	0:04:54	521	2093	18	LE1
9/01/2018	11:17	-38.207	147.649	3.5	3	0:04:33	650	2615	17	LE1
9/01/2018	11:33	-38.211	147.655	3.5	4	0:04:24	704	2830	30	LE1
9/01/2018	11:56	-38.211	147.660	3.5	5	0:05:35	513	2061	0	LE1
9/01/2018	12:17	-38.208	147.661	3.5	6	0:03:45	381	1531	5	LE1
9/01/2018	12:34	-38.198	147.657	3.5	7	0:04:31	564	2269	11	LE1
9/01/2018	12:50	-38.200	147.653	3.5	8	0:04:43	440	1769	27	LE1
9/01/2018	13:13	-38.206	147.641	3.5	9	0:04:46	435	1750	10	LE1
9/01/2018	13:53	-38.212	147.633	3.5	10	0:06:17	645	2594	29	LE1
9/01/2018	14:19	-38.218	147.640	3.5	11	0:04:32	593	2386	48	LE1
9/01/2018	14:56	-38.215	147.651	3.5	12	0:04:19	395	1587	16	LE1
17/01/2018	09:13	-38.244	147.587	3.5	1	0:05:02	583	2346	7	LE1
17/01/2018	09:26	-38.248	147.595	3.5	2	0:04:53	514	2066	16	LE1
17/01/2018	09:45	-38.246	147.603	3.5	3	0:04:53	488	1964	32	LE1
17/01/2018	10:08	-38.248	147.605	3.5	4	0:04:52	422	1695	33	LE1
17/01/2018	10:44	-38.240	147.607	3.4	5	0:04:58	521	2094	32	LE1
17/01/2018	11:28	-38.236	147.609	3.3	6	0:05:10	514	2068	25	LE1
17/01/2018	12:06	-38.234	147.611	3.3	7	0:04:54	461	1855	24	LE1
17/01/2018	13:07	-38.235	147.630	3.2	8	0:04:51	504	2028	0.3	LE1
17/01/2018	13:25	-38.228	147.640	3.5	9	0:04:49	591	2375	0	LE1
17/01/2018	13:38	-38.226	147.628	3.3	10	0:04:46	497	1998	29	LE1
17/01/2018	14:12	-38.221	147.626	3.5	11	0:04:41	460	1851	22	LE1
17/01/2018	14:44	-38.225	147.620	3.3	12	0:04:43	481	1936	24	LE1
17/01/2018	15:13	-38.227	147.616	3.4	13	0:04:54	505	2028	12	LE1

Table 5. Tow summaries and catch of Commercial Scallop by stratum.

Stratum	Number of Tows	Minimum distance (m)	Maximum distance (m)	Mean distance (m)	Minimum total weight (kg)	Maximum total weight (kg)	Total catch (kg)
LE1	25	381	704	518	0	48	468.9
WideArea	148	149	674	496	0	45	104.28

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

Stratum	Stratum area	No. of tows	Mean density (kg / 1000m^2)	Standard deviation (kg / 1000m^2)	Lower 95% CL (t)	Estimated biomass (t)	Upper 95% CL (t)	Density (ind/m^2)
LE1	16.5	25	27.7	18.29	331.9	456.4	580.8	0.51
Wide-Area	4858.7	148	1.1	6.1	2225.5*	5106.5	14371.8*	0.06

Table 7. Percent weight of scallops > 80 mm (catch weighted by weight), and biomass estimates 95% confidence limits for scallops greater than 80 mm calculated using the straight-line method.

Stratum	% weight > 80 mm	Lower 95% CI (t)	Estimated Biomass (t)	Upper 95% CI (t)
LE1	84.6	280.8	386.1	491.4
WideArea	89.0	1980.7	4544.8	12790.9

Table 8. Number of length measurements (N), median, mean and standard error (SE) of scallops measured, and % of scallops measured (catch weighted by weight) less than and greater than 80 mm and mean number of meats per kg of scallops greater than 80 mm from each bed.

		Length (mm)			80 mm		Meats / kg
Bed	N	Median	Mean	SE	%<	%>	Mean
LE1	879	84.2	84.3	0.2	15.4	84.6	103
WideArea	790	86.3	84.5	0.4	11.0	89.0	92

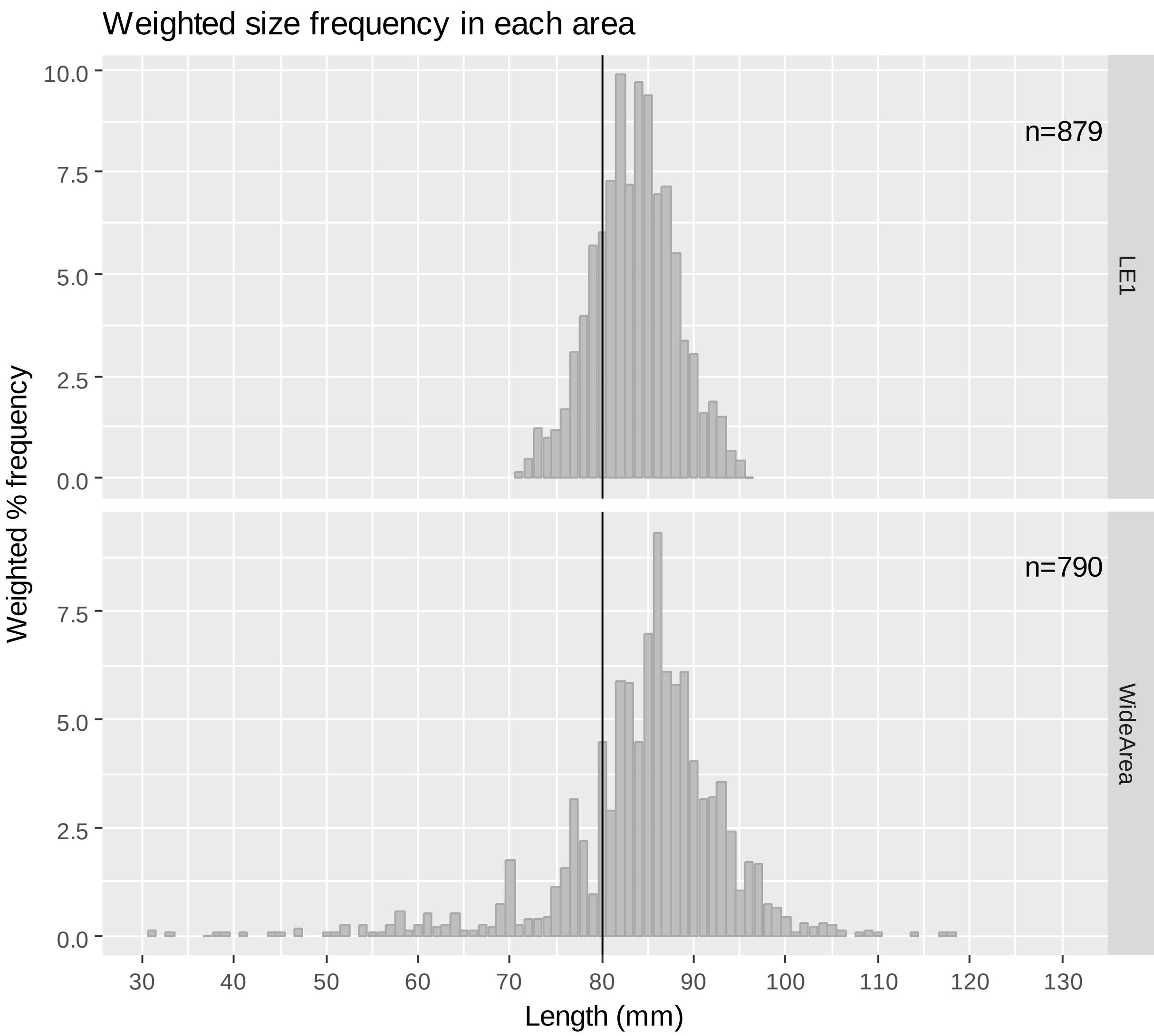

Figure 20. Catch weighted size frequency from shots included in biomass estimates from each stratum. The vertical line is at 80 mm.

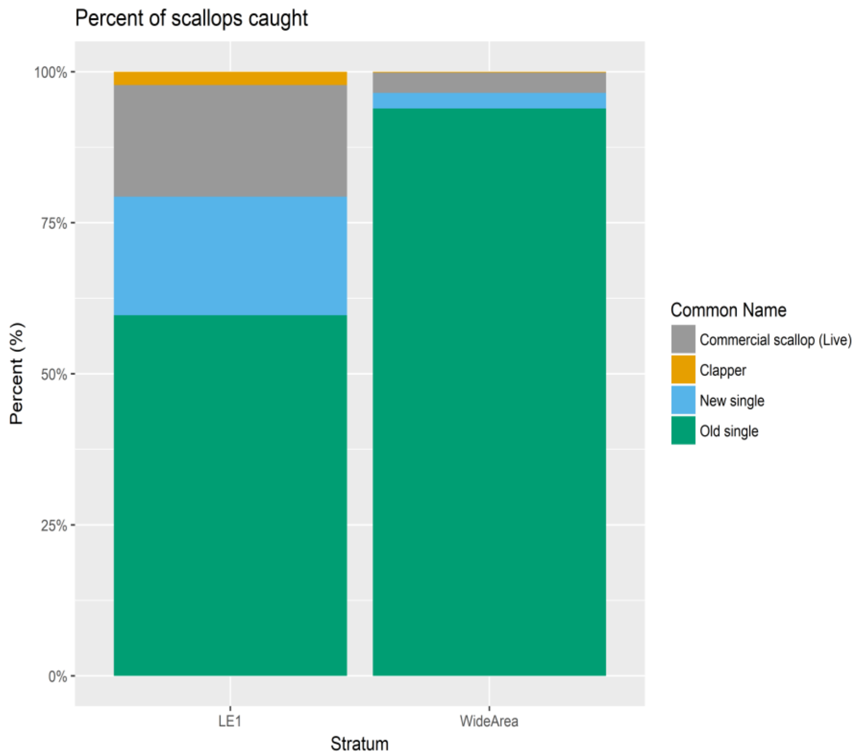

Figure 21. Percent composition (by weight) of Clappers, live Commercial Scallop, New single and Old single shell from each Stratum.

Table 9. Catch (kg) of each species by stratum. "U" denoted undifferentiated species.

	Catch weight (kg)		
Species	LE1	WideArea	Total
Algae (U)		494	494
Angel Shark		2	2
Ascidian (U)	5.5	393	398.5
Banded Stingaree	0.3	9	9.3
Barber Perch		0.2	0.2
Barred Grubfish		0.1	0.1
Bassina Spp.		0.1	0.1
Bighead Gurnard Perch		0.3	0.3
Blacklip Abalone		0.2	0.2
Blacktip Cucumberfish		4.2	4.2
Bluestriped Goatfish		0.1	0.1
Brittlestars (U)	0.1	11.9	12
Bug (U)		0.7	0.7
Cassidae Spp.	0.5	0.5	1
Clapper	56.2	4.2	60.4
Cockle (U)		3	3
Cocky Gurnard		0.4	0.4
Commercial Scallop	468.9	104.28	573.18
Common Gurnard Perch		3.9	3.9
Common Stargazer		4.4	4.4
Conidae Spp.		2.2	2.2
Cowrie (U)	1	1.9	2.9
Crab (U)	0.1	7.85	7.95
Crassatellidae (U)		15.2	15.2
Crustacean (U)		0.2	0.2
Cucumberfish, Greeneye & Flathead Lizardfish (U)		0.2	0.2

Cuttlefish (U)		1.3	1.3
Deepwater Stargazer		0.2	0.2
Doughboy Scallop	0.1	69.25	69.35
Echinoderm (U)		0.1	0.1
Eleven-Arm Seastar	177	467.9	644.9
Flathead (U)	1.7	0.1	1.8
Flounder (U)	0.7	3	3.7
Globefish		0.3	0.3
Greenback Stingaree		2	2
Hard Coral (U)		252.7	252.7
Hermit Crab (U)	4.9	153.3	158.2
Little Gurnard Perch	0.2		0.2
Mixed Fish		0.3	0.3
Mollusc (U)		4.6	4.6
Moreton Bay Bug (U)		3.8	3.8
Nassarine	4		4
New Single	498	80.1	578.1
Nudibranch (U)		5.7	5.7
Octopus (U)	2.3	17.5	19.8
Old Single	1516	2914.6	4430.6
Oysters (U)		8.5	8.5
Peacock Skate	0.3	1	1.3
Polychaete Worm (U)		4.2	4.2
Pufferfish (U)		1.3	1.3
Ranellidae	19.5	105.3	124.8
Razor Clam	0.8	7.2	8
Red Cod		0.1	0.1
Red Indian Fish		0.2	0.2
Red Mullet		0.1	0.1
Righteye Flounder (U)		0.1	0.1
Sea Grass (U)		42	42
Sea Urchin (U)	0.2	38.6	38.8
Seapen (U)	1.5	3.4	4.9
Seastar (U)		198.3	198.3
Shark Egg (U)		1.6	1.6
Shaw Cowfish		0.1	0.1
Shell (U)	1430	7314.9	8744.9
Silver Cobbler		0.6	0.6
Silver Spot		0.1	0.1
Skipjack Trevally		0.2	0.2
Smooth Stingray		8	8
Snipe Eel (U)		0.2	0.2
Soft Coral (U)		349.5	349.5
Southern Blue-Ringed Octopus		0.5	0.5
Southern Fiddler Ray		5.7	5.7
Southern Rock Lobster		0.2	0.2
Southern Sand Flathead		0.7	0.7
Sparsely-Spotted Stingaree	0.3	12.6	12.9
Spider Crab (U)	11.3	17.1	28.4
Spiny Pipehorse	0.1		0.1
Sponge (U)	140	3924	4064
Sponges (Coral)		1	1
Substrate		5989.5	5989.5
Tasmanian Numbfish	1.1	1.1	2.2
Triggerfish & Leatherjacket (U)		1.8	1.8
Venus Shells		0.5	0.5
Volute (U)	0.5	10.6	11.1
Widebody Pipefish		0.1	0.1
Total (kg)	4343.1	23091.68	27434.78

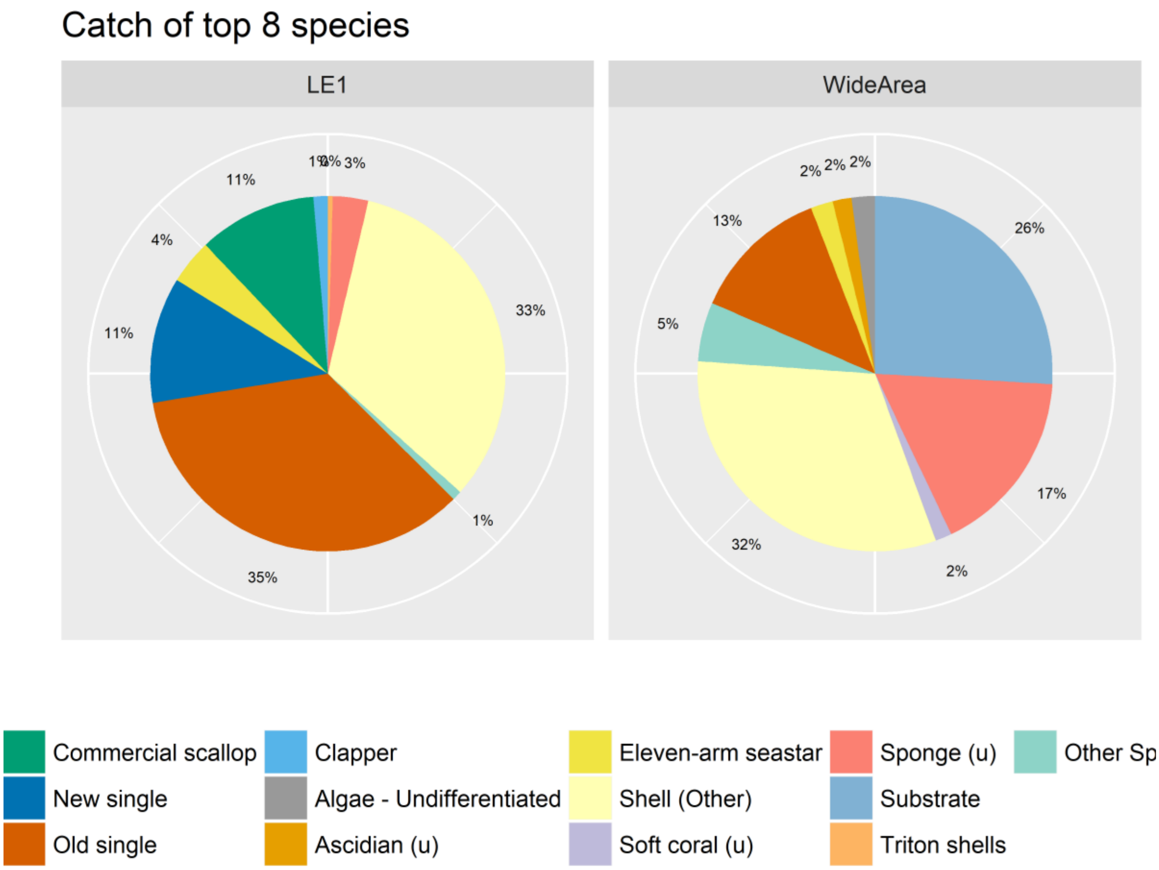

Figure 22. Percent catch composition in each bed sampled by weight from all beds.

Table 10. Number of scallops retained for biological sampling, and parameter estimates for length weight relationships.

Area	N	a	b	Adjusted R^2
LE1	66	-5.632	2.160	0.715
Broad-area	134	-7.908	2.691	0.974
Combined	200	-7.730	2.645	0.961

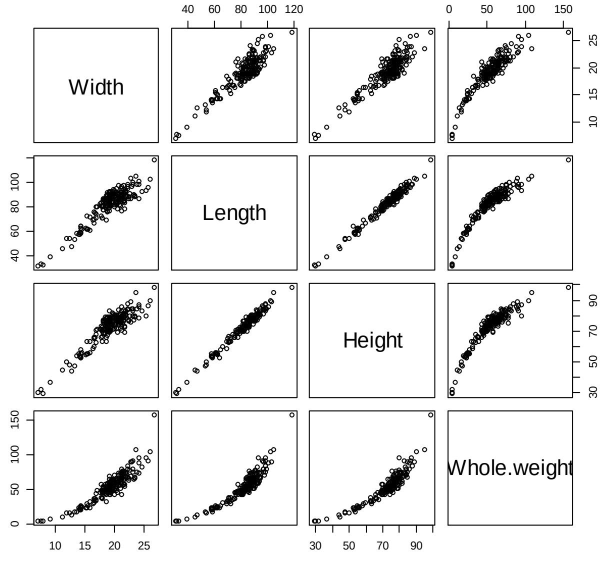

Figure 23. Scatterplot matrix of size measurements and total weight for all samples combined.

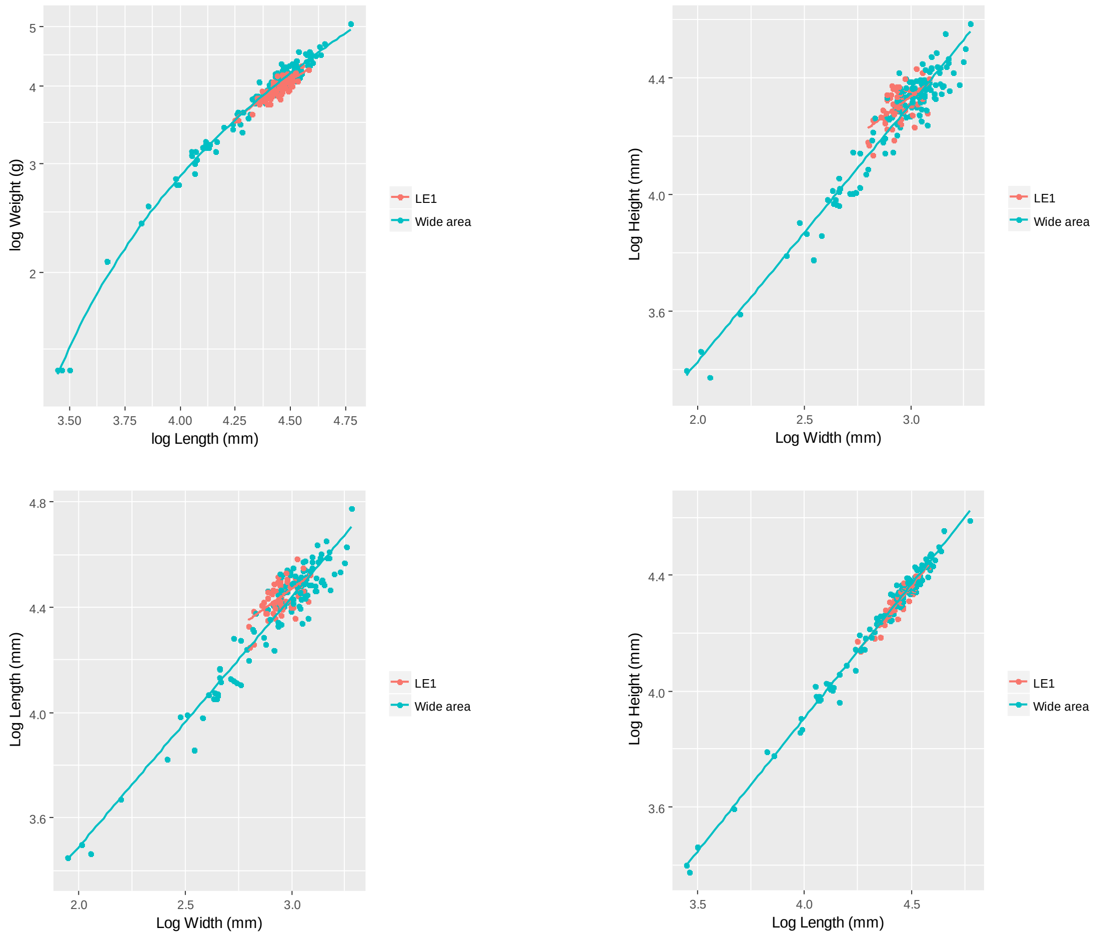

Figure 24. Log transformed A) length and weight, B) height and width, C) length and width and D) height and length from each bed.

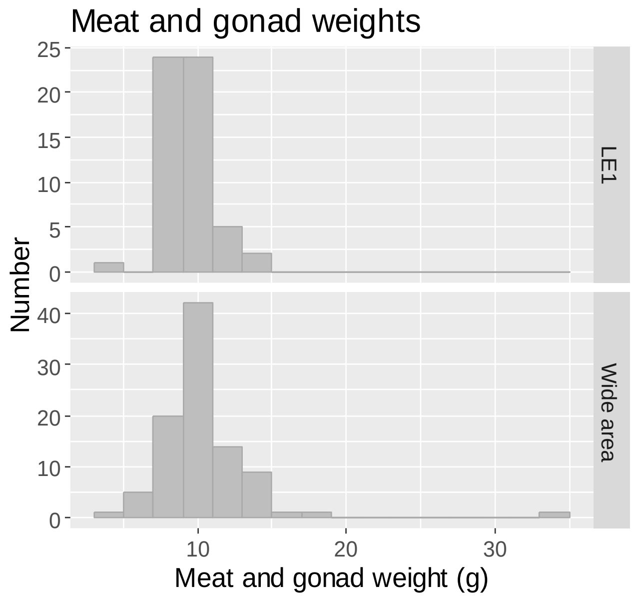

Figure 25. Frequency of combined meat and gonad weights of scallops >80 mm measured from each bed binned into 2 g weight categories.

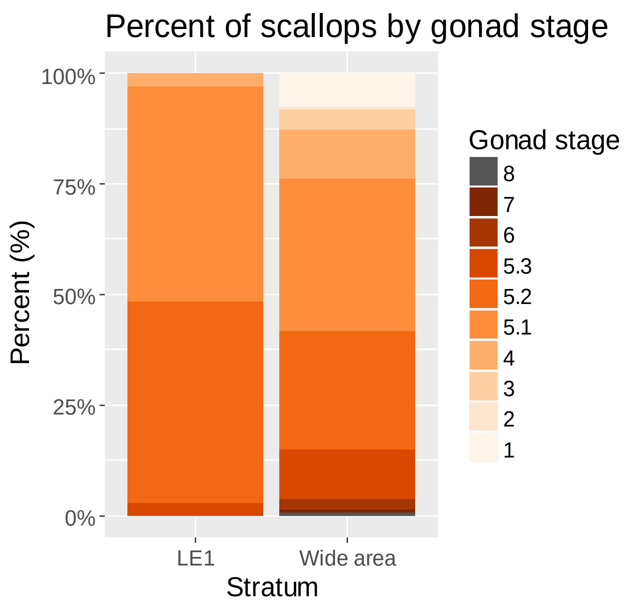

Figure 26. Percent of scallops at each stage from each bed based on macroscopic staging criteria.

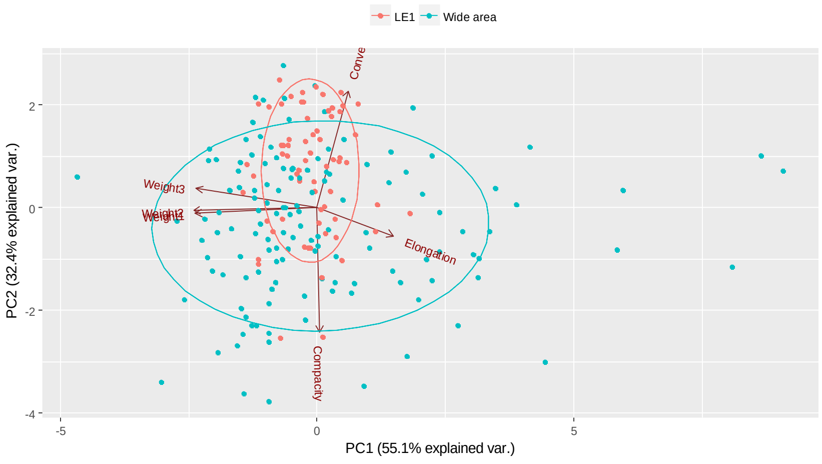

Figure 27. Principle component analysis on ratios of different shell measurements and weight: Elongation – height/length; Convexity – height / width; Compacity - width / length; Weight1 – weight/ length, Weight2 – weight/ height, Weight3– weight/ width.

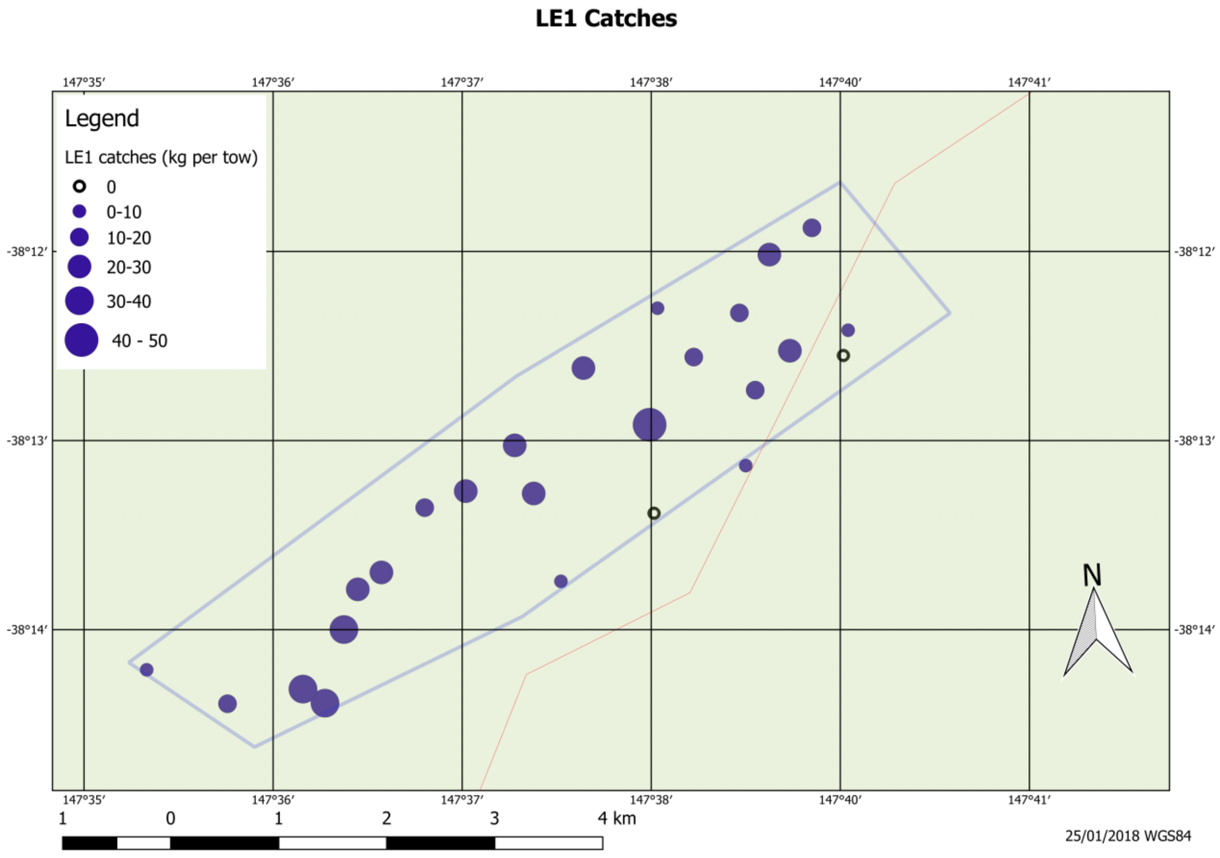

Figure 28. LE1 survey catches. Open circles denote zero catches.

Age estimation

Age estimations of the 101 samples (Table 14) were made from annuli (colour and/or texture bands) on dorsal shell surface and annuli on dorsal shell auricle. Zone readability rating for each age estimation as well as biological data used for analysis has also been provided in Table 14.

Readability was scored one to five, where one was a perfectly readable sample and five was unreadable. Samples with a readability of two have a high confidence that the assigned age is correct, samples with a readability of three might be plus or minus one year. Samples with a readability of four are open to multiple interpretations.

Re-reads (second reads) were performed on a subsample of 65 samples to determine the inter-reader variability for the estimates. Estimates from both first and second reads were compared using IPAE (Beamish and Fournier, 1981) resulted in an average percent error (APE) of 6.74%. The mode of the differences was zero indicating no systematic bias in repeated readings. The maximum difference between readings was ±2 years. Readability was slightly lower (indicating better readability on the surface of the shells compared to the auricle. This is the preferred method to estimate the age of *P. fumatus.*

Readability is a function of zone clarity. The estimates made from the external shell and the auricle was similar. The mean of the readability estimates for the external shell counts and the auricle were 3.47 and 3.49 respectively. This indicated that the estimates were slightly better for the shell surface compared to the auricle. All further estimates of age were made using external shell zone counts

Age composition and age-at-size analysis have been completed using age estimations from surface annuli counts. In cases where shell marginal erosion or fouling prevented readability of annuli on the dorsal shell surface (i.e. readability rating = 5), annuli on the dorsal shell auricle were used for age analysis.

Figure 29 illustrates the age composition of the samples examined for preliminary age estimation. The most frequently occurring age class recorded 4 years (Freq. = 30). Samples from LE1 were generally older than those from the wide area survey, with the most frequent age group of 6 years.

Von Bertalanffy growth curve was fitted to the shell length (Table 11, Figure 30). T zero was set to zero to provide a more biologically plausible mathematical expectation of the parameters.

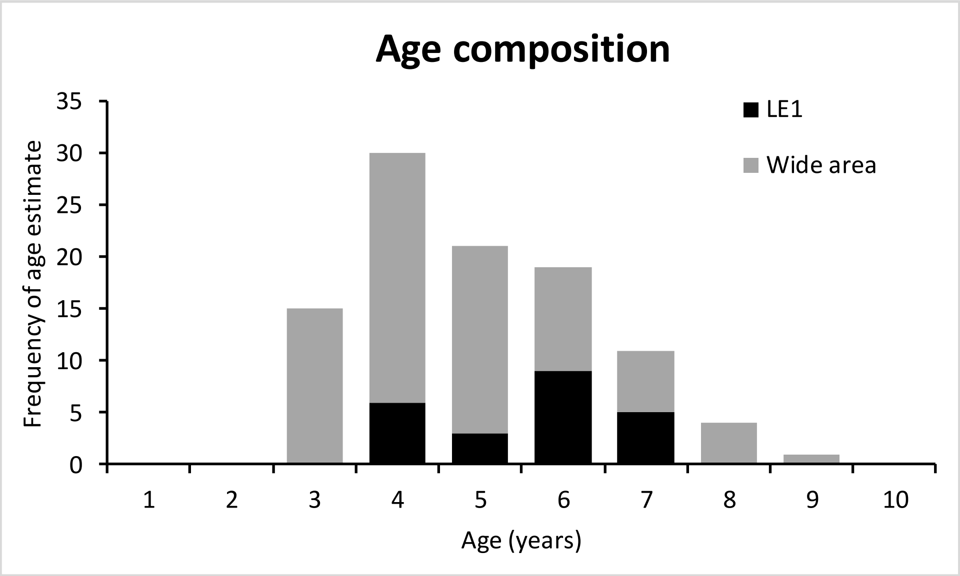

Figure 29. Age composition of *P. fumatus* samples (n=101) from the wide area survey and the LE1 bed.

Table 11. Estimated Von Bertalanffy parameters.

Parameter	Value
L infinity	108.574
K	0.29723
T zero	Not used

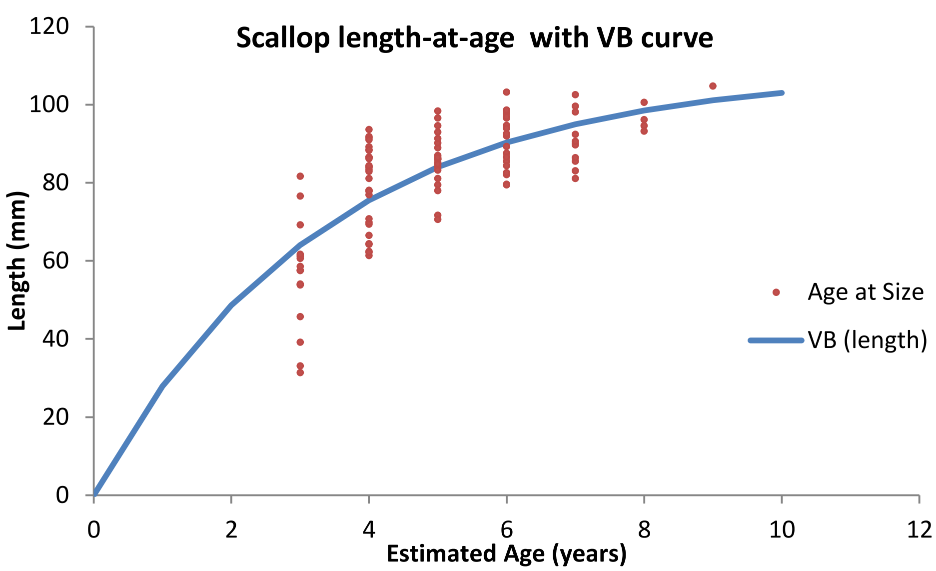

Figure 30. Von Bertalanffy growth curve based on 101 Commercial Scallops.

Discussion

This project addressed the stated need of the VFA to "design and manage the undertaking of a survey that will provide an estimate of scallop biomass out to 20 nautical miles of the Victorian coastline between Wilsons Promontory and Point Hicks and inform the future sustainable management of the fishery". While this was undertaken, it was acknowledged beforehand that there would be a very high degree of uncertainty around the resulting biomass estimate for this broad area, that might be of limited use to management. Therefor we included a provision to include intensive surveys of potential scallop beds as identified.

From the 148 randomly allocated broad-area survey tows conducted, total biomass was estimated to be 5,107 t (95% confidence intervals ranged 2,226 t–14,372 t; Table 6), and with 89% of the scallops greater than 80 mm length, estimated biomass greater than 80 mm was 4,545 t (95% CI 1,980 t–12,791 t; Table 7). Nearly all of the catch during the broad-areas survey was from south of S38˚ 30' (Figure 19). Despite the only two tows containing more than 10 kg of scallops being recorded south of that line, areas around those tows were not considered suitable for intensive surveys because of a lack of scallops in other tows in the vicinity and the prevalence of substrate unsuitable to fishing with a scallop dredge, and the high risk of losing a dredge.

Based on anecdotal information from industry members, exploratory fishing was conducted at 9 areas north of S38˚ 30' (Figure 4), however only one, LE1, was considered suitable for an intensive survey. The area of LE1 was refined through further exploratory fishing, and 25 random tows were allocated and sampled. This resulted in an estimated total biomass of 456 t (95% CIs of 332 t–581 t; Table 6). 84.6% of the weight of scallops measured was greater than 80 mm, resulting in a biomass greater than 80 mm of 386 t (95% CIs of 281 t–491 t; Table 7). It is of note that this biomass estimate is from a general area in the broad-area survey where very few scallops were caught.

The prevalence of old single shell in the catch from the broad-area survey indicates a lack of recent mortality at the sites surveyed (Figure 21). Some "clappers" were observed from LE1, which also had a higher composition of new single shell. Length frequency distribution from the broad-area survey indicated recruitment, possibly across a number of year classes in the broad-area survey, but not in LE1 (Figure 20).

Commercial Scallops are broadcast spawners which can suffer reduced fertilisation success at low densities and poor spawning synchronisation (Mendo *et al.*, 2014). The 2017 Victoria (Ocean) Scallop survey found scallop densities of 0.06 individuals per m^2 in the broad-area survey, and 0.51 individuals per m^2 in LE1. The density for the broad-area survey is based on all data from that stratum, however given the almost complete lack of scallops east of longitude 147˚ 12', densities would be much higher in the south-west if the data from the eastern sites were excluded, however this division was not planned *a priori* and has not been calculated. This is an important consideration given that spawning synchronisation is much less important for very large areas compared to localised beds. Mendo *et al.* (2014) found that at a density of 0.203 individuals per m^2, only 25% of Commercial Scallops in their survey area were within the optimum distance for fertilization success. At 0.51 individuals per m^2, the density calculated from LE1 was higher than 0.203 individuals per m^2, so it is likely that more than 25% of scallops would be within the optimum distance for fertilization success — but the implications of this to future settlement and recruitment of Commercial Scallops is not known.

The last survey of the Victoria (Ocean) Scallop fishery was undertaken in 2012 (Semmens and Jones, 2012). They conducted a broad-area survey, however survey locations were not randomly allocated, but rather, the positioning of the 297 tows were left to the discretion of the skipper, and so a direct comparison of results between surveys cannot be made. Semmens and Jones (2012) reported only three survey tows containing more than 10 kg per 1000 m^2 (40 kg, 16 kg and 12 kg), and an overall mean density of less than 1 kg per 1000 m^2. The 2018 survey recorded three tows containing more than 10 kg per 1000 m^2 (70 kg, 19 kg and 14 kg) from 148 tows, and an overall density of 1.1 kg per 1000 m^2 (Table 6).

Stratified random surveys are undertaken in the Bass Strait Central Zone Scallop Fishery (BSCZSF) (e.g. Knuckey *et al.*, 2015, 2016, 2017). Surveys strata are allocated in a similar way to how they were allocated in this report, focussed on potentially viable or previously surveyed beds. Mean scallop densities during the 2017 survey ranged 6.5 kg/1000 m^2 off Flinders Island to 209 kg/1000 m^2 off King Island (Knuckey *et al.*, 2017). The Flinders Island beds (with densities ranging 6.5–12.7 kg/1000 m^2) are not considered commercially viable, and as such, no commercial fishing has been undertaken there for a number of years. The LE1 stratum in this report had a mean density of 27.7 kg/1000 m^2 over an area of about 16.5 km^2, with an estimated biomass of 456 t. In comparison, two slightly smaller beds (13.93 km^2 and 13.95 km^2) in the 2017 BSCZSF survey (Apollo Bay 1 and 2) had densities of 205 kg/1000 m^2 and 156 kg/1000 m^2 respectfully, with estimated biomasses of 2856 t and 2182 t.

This preliminary study of age composition and method development for ageing Commercial Scallops found that the best way to estimate the age of the samples was to use surface counts on the shell. Other methods used in other species produced results that were not repeatable and showed structure with no patterns of deposition that could be assigned to an annual basis. The modal age for the samples provided using surface counts to estimate the age was four years. The maximum age was nine and the minimum was three. The age composition data presented in this report for has not been validated. Age estimates would benefit from a mark-recapture event, as previously described in scallop ageing studies both locally and internationally (Paul, 1981; Gwyther and McShane, 1987).

The von Bertalanffy growth parameters asymptote was just over 100 mm. Growth starts to slow considerably after approximately 4–5 years where a shell height of approx. 80-90 mm is reached. This is consistent with earlier scallop growth research conducted in Port Phillip Bay (Gwyther and McShane, 1987).

Our approach to the survey was considered appropriate given the VFA requirements and uncertainty in the distribution of Commercial Scallops in the fishery. While the sites containing the greatest densities in the broad-area survey were not intensively surveyed, there was consensus amongst the skipper, observer and vessel owner that those areas were not suitable for an intensive survey because of the foul ground and risk of losing a dredge. Our choice of Broad-area stratum boundaries was based on industry advice, the 40 m depth contour, substrate classifications and results of past surveys. One small area (~74 km^2) representing about 1.5% of the total broad-area survey area that fell outside of the 40 m depth contour and shale sand habitat polygon perhaps should have been included in the broad-area stratum (Figure 31), because Commercial Scallops — albeit in low densities (5–10 kg per 1000 m2) — were reported from that area by Semmens and Jones (2012) from the 2012 survey. Modifying the broad-area stratum to include that area should be considered in future surveys.

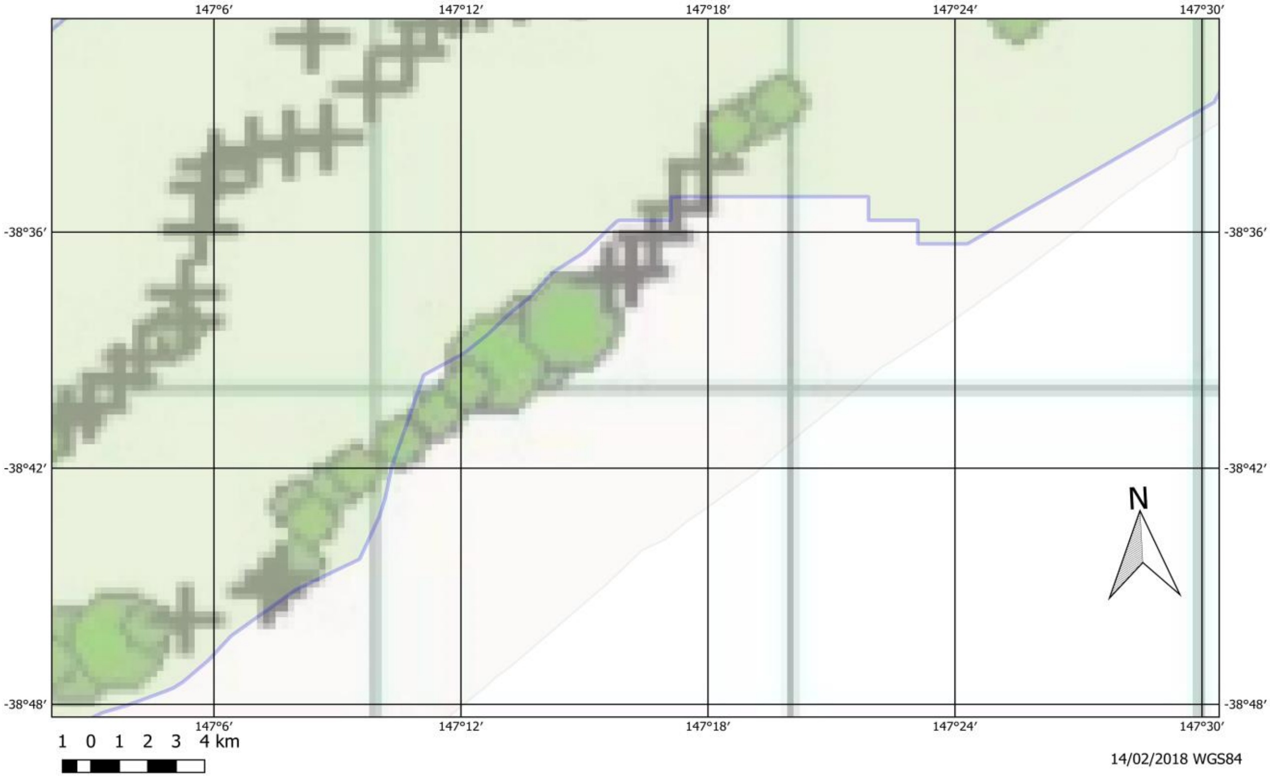

Figure 31. 2012 survey tow locations outside of the 2018 Broad-area survey stratum (green polygon with blue boundary).

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Appendix 1 – Survey methods

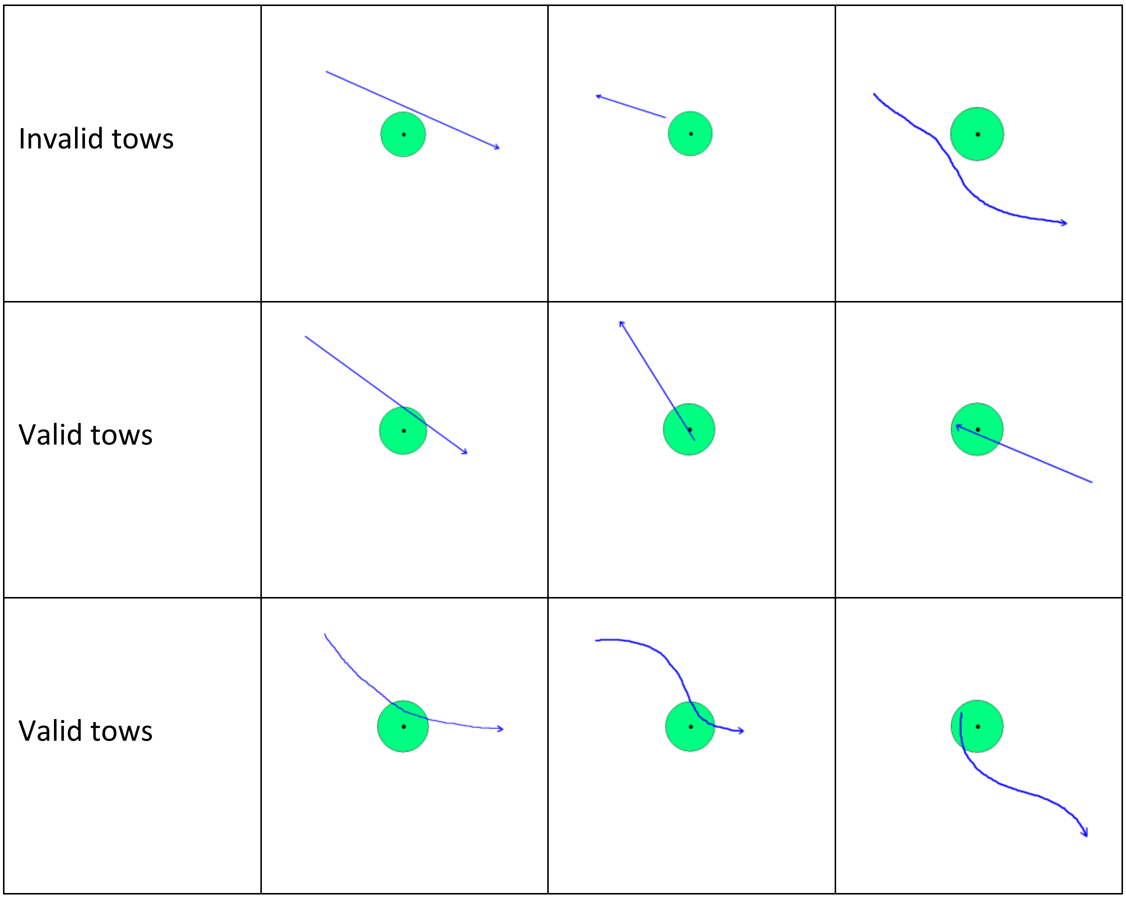

Figure 32. How to conduct a valid survey tow. Green circle is 100 m radius.

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

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

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

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

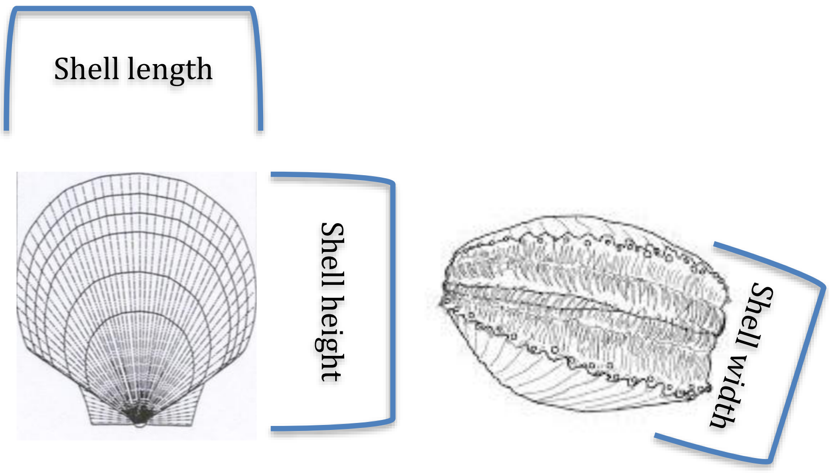

Figure 33. Shell diagram showing measurement of length, height and width used in this report.

Table 14. *P. fumatus* biological and ageing estimation data

***Age estimated using auricle annuli rather than surface annuli**

P. fumatus ID number	Height (mm)	Length (mm)	Weight (g)	Auricle Annuli Count	Auricle Annuli Readability Rating	Surface Annuli Count	Surface Annuli Readability Rating
2	86	100.6	88	8	4	8	4
3	76.3	86.5	50	4	5	4	3
4	75.2	84	63	4	3	4	4
5	79	89.2	66	4	3	4	3
6	84.6	98.3	75	6	4	6	3
7	78.7	91.8	63	4	3	4	3
8	78.8	84.1	66	4	3	4	3
9	80.1	94.6	66	5	4	5	3
10	52.6	64.2	23	3	3	4	3
11	79.5	89	56	5	3	5	3
12	72.4	81.7	48	3	5	3	3
13*	79.1	93.6	68	4	3	4	5
14	58.6	69.4	30	4	3	4	3
16	84	96.6	80	6	3	6	4
18	63	71.7	32	5	4	5	3
19	75	84.1	54	5	3	5	3
20	71.9	81.1	52	6	4	5	3
21	55.9	61.4	25	4	4	4	4
23	71	79.5	49	5	3	5	3
25	69.7	76.9	47	4	3	4	3
26	49.7	53.8	16	3	3	3	3
27	55.3	62.4	25	4	3	4	3
28	75.6	86	57	4	4	5	4
29	69.3	78.1	58	4	3	4	3
30	68.9	78	46	5	3	5	3
31	64.8	69.9	34	4	3	4	3
32	83	94.7	75	6	3	6	4
33	78.7	88.3	58	4	3	4	3
36	72.2	83.2	55	5	3	5	3
38	84	97.7	70	6	3	6	3
39	65.8	78	42	4	4	4	4
44	84.5	94.6	68	7	4	8	4
45	94.9	104.8	108	8	4	9	4
46	80.5	93	60	4	3	5	3
48	85.6	96.6	80	5	3	5	4
50	88.8	103.2	90	6	3	6	4
51	78.8	86.2	63	5	3	5	3
53	69.8	82.1	48	5	4	6	4
54	83	92.4	69	7	4	7	3
55	77.1	90.1	58	6	4	7	4
56	87.6	98.6	84	6	4	6	3
57	77.2	89.3	64	6	4	6	4
58	75.2	86	60	5	2	5	3
59	31.9	33.1	4	3	4	3	4
60	73.9	83.4	51	4	4	4	3
61	54.8	62.2	24	4	4	4	4
62	70.8	77.8	47	4	3	4	3
63	77.1	90.2	64	5	3	5	3
64	78.1	87	74	5	4	5	4
65	78.3	88.5	72	5	4	4	3

***P. fumatus* ID number**	**Height (mm)**	**Length (mm)**	**Weight (g)**	**Auricle Annuli Count**	**Auricle Annuli Readability Rating**	**Surface Annuli Count**	**Surface Annuli Readability Rating**
66	56.1	60.6	24	3	3	3	4
67	55.5	57.5	23	3	2	3	3
68	53.7	57.6	22	4	4	3	3
69	55.1	61.2	26	3	2	3	3
70	47.8	54.1	16	3	3	3	3
71	59.6	66.5	31	4	3	4	4
72	90	102.6	104	6	4	7	4
73	54.9	61.7	24	3	4	3	3
74	52.8	58.6	23	3	3	3	3
75	66.3	70.6	37	5	4	5	3
76	57.8	64.4	26	4	5	4	3
77	70.7	81.1	49	4	4	4	3
78	76.3	86.6	55	4	4	4	4
79	73.9	85.5	55	7	3	7	4
80	69.9	79.6	46	6	3	6	4
81	70	84.4	57	3	5	4	4
82	81.3	92	67	X	5	6	4
83	73	85.5	54	6	3	6	3
84	72.9	86.4	49	7	3	7	3
85	71.1	81.1	48	7	4	7	4
86	78.1	91.3	59	5	4	5	4
87	79	89.7	58	7	3	7	3
88	68.5	79.5	44	6	3	6	4
89	75.6	84.4	51	6	3	6	4
90	74.2	83.1	55	7	4	7	4
91	74	82.6	50	6	3	6	4
92	77.2	87.6	61	6	3	6	4
93	44.3	45.7	11	3	3	3	4
94	76.1	86.5	66	4	3	4	3
95	80.1	94	73	6	3	6	4
96	84.7	96.9	90	6	3	6	4
97*	86.3	96.2	91	8	4	9	5
98	83.9	91.5	72	5	4	4	3
99	73.4	86.2	59	4	4	4	3
100	79.6	93.2	95	7	4	8	4
101	79.5	91	78	4	4	4	3
102	71.3	82.9	51	5	4	4	3
103	78.2	90.6	77	7	4	7	3
104	80.2	92.6	75	5	3	6	3
105	87.2	98.1	95	7	4	7	4
106	36.3	39.2	8	3	3	3	3
107	75.9	86.6	69	6	3	6	3
108	73.1	85.2	64	5	4	5	4
109*	75.4	86.5	77	5	3	5	5
110	82.9	98.4	91	5	4	5	3
111	76.8	84.8	67	5	4	5	3
112	63.1	69.2	32	4	3	3	3
114	62.9	70.8	38	4	3	4	4
115	70.3	76.6	43	4	4	3	4
116	29.9	31.4	4	3	3	3	3
117	84.3	99.6	79	7	4	7	4