2021 Fishery-independent video survey of commercial scallop (*Pecten fumatus)* densities in Tasmanian Scallop Fishery Area 5

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Executive Summary

A towed underwater video camera survey was undertaken in the region referred to as 'White Rock' within Area 5 of the Tasmanian commercial Scallop (*Pecten fumatus*) Fishery (TSF) in June 2021. Forty-nine video tows were randomly allocated within the area of interest and the resultant video was analysed to examine the size structure of the scallop population and the density and biomass of scallops across the survey area.

The mean total scallop density was 0.48 scallops/m^2 and, to facilitate comparison with previous dredge surveys, the legal-size scallop density (30.4 kg/1000 m^2) was calculated. Higher density sites were highly spatially restricted, i.e. patchy. Size structure from video transects showed strong representation of sub-legal scallops (30.5% at the 90 mm legal-size) and a mean size of 96 mm.

Along with the discreet patches of higher densities, the high proportion of sub-legal scallops throughout the survey area, clearly demonstrates that there has been recruitment during the closure of Area 5 (and the entire TSF) since the 2015 fishing season. Furthermore, there are potential good signs for the future, with clear evidence of new recruits.

Biomass across the nearly 200 km^2 survey area was estimated at approximately 5093 t for the legal-sized biomass.

The sites sampled for the video survey generally aligned with the sites sampled in the pre-season dredge survey, allowing for some comparison of the results between the two methods. In the dredge survey, tows in White Rock yielded a mean and median density of legal-sized ($\geqslant$ 90 mm) scallops of 15.6 and 14.2 kg/1000 m^2, respectively, with a sub-legal proportion (discard rate) of 5.7%. In the video survey, a very different mean density (30.4 kg/1000 m^2) to that of the dredge survey was found for legal-sized scallops.

Some of the scallops observed in the video survey transects were below the 90 mm minimum legal-size, leading to a sub-legal proportion of 30.5%, which was an approximate 5-fold increase over that of the dredge survey. This difference in the size frequency between the two methods is not unexpected, as a scallop dredge is designed to be size selective for legal-sized scallops and allow smaller scallops to pass through. Similar disparities have been previously reported in other fisheries when camera and dredge surveys were compared.

Video surveys offer an advantage over dredge surveys due to: (i) lower costs for data collection; (ii) enhanced precision of size structure; (iii) information on recruitment in recent years; (iv) minimal impact on the seafloor and benthic biota and (v) no mortality of sub-legal scallops. Their continued use is recommended for providing data for management of the TSF. However, adoption of video surveys will require review of the criteria for closures in the fishery to account for the difference in selectivity of dredge surveys compared to video surveys. Dredge surveys, both industry standard and modified to account for recruits, could be conducted in parallel with video surveys for a pre-determined period to correctly calibrate closure criteria of the latter. It is also recommended that concurrent with this use of the technique, further development of the video survey method is

undertaken, such as methods to reduce the processing costs of video analysis through techniques such as machine learning.

Background

Developing a robust understanding of the population dynamics of valuable fishery species, such as biomass and size structure of the population, plays a critical role in fishery management. In scallop fisheries around the world, the method of collection of these data has been moving away from solely utilising the dredge fishing method to conduct surveys to also incorporating camera (digital video and/or still images) surveys (Stokesbury 2002; Rosenkranz & Byersdorfer 2004; Taylor et al. 2008). Camera surveying is now routinely used in the United States, Canada, and Iceland, with the latter exclusively using cameras to survey since 2014, and has been trialled for use in various fisheries in the U.K. (ICES 2018). In Australia, the Queensland Department of Agriculture and Fisheries have recently trialled scallop video surveys and are further developing the method (Wyatt 2019). This shift has been due to a range of issues with relying on the use of dredging alone to examine scallop density, biomass and size structure, such as the catch efficiency (McLoughlin et al 1991; Fifas & Berthou 1999) and size selectivity (McLoughlin et al 1991) of the dredge, along with the labour intensity of dredging, which requires a specialised fishing vessel (Rosenkranz & Byersdorfer 2004; Ewing & Lyle 2017) and the potential impact of dredging on the benthic habitat and fauna (Jenkins et al. 2001).

In comparison, camera surveys, which have been employed in some North American fisheries for nearly two decades (Rosenkranz & Byersdorfer 2004; Stokesbury et al 2004), have been demonstrated to have comparatively high efficiency and precision compared to dredges that enable accurate population estimates, particularly in areas of low abundance or those dominated by sub-legal size classes (Shortis 2015). Camera surveys have a minimal impact on the benthos and are relatively unaffected by bottom type and can provide spatially explicit data on scallop populations as well as relevant information on the sea floor and benthic community (Stokesbury et al 2004). They can also be undertaken relatively quickly and simply, without a specialised fishing vessel. However, analysis of the camera images can be time consuming, with automated image analysis being developed in several fisheries to improve time-efficiency (e.g., Wyatt 2019; NEFSC 2018; Chang et al. 2016).

Based on these potential benefits, in 2017, towed video surveys were used by the Institute for Marine and Antarctic Studies, University of Tasmania (IMAS) to assess queen scallop (*Equichlamys bifrons*) stocks in the D'Entrecasteaux Channel for the Tasmanian recreational scallop fishery (Ewing & Lyle 2017), with the results from the towed video compared to a diver transect survey to ground-truth the methodology. Subsequently, in 2017, White Rock (previously also referred to as Sub-Area 6A), which is within Area 5 of the Tasmanian commercial scallop (*Pecten fumatus*) fishery (TSF) was surveyed using the towed video methodology established in the D'Entrecasteaux Channel, including examining the extent of stocks in a dredge prohibited area adjacent to survey area and comparing video and dredge survey results within the survey area (Ewing et al. 2018). These comparisons showed a substantial difference, with the dredge survey reporting nearly all scallops over the minimum legal-size of 90 mm, whereas the video surveys found a much higher proportion of sub-legal scallops.

Since first opening to fishing in 2006, White Rock has been the most consistent site in the TSF in terms of catches in recent years but has suffered multiple stock collapses following fishing and has been closed multiple times sines since 2006, with the area closed since the last open season in 2015. Following a pre-season dredge survey of White Rock in May 2020, which showed moderate recovery in the scallop stocks in the area, there was interest from the Scallop Fishermen's Association of Tasmania to open the area, given the discard rate (percentage of scallops <90 mm) was less than the 20% threshold required for consideration for opening. As the TSF was categorised as depleted (Semmens et al 2018, 2020) and the stock increase since the closure was not significant, the Tasmanian Department of Primary Industries, Parks, Water and Environment (DPIPWE) commissioned IMAS to undertake a towed video scallop survey of White Rock in May/June 2020. The video survey was conducted at 48 randomly allocated sites in the region of interest to the fishery in White Rock. Compared with the 2020 dredge survey, the 2020 video survey yielded a similar legal-sized scallop density (21 kg/1000 m^2), but a much higher proportion of sub-legal scallops (59% in the video survey and 7.5% in the dredge survey) (Semmens et al . 2020). This difference in the size frequency between the two methods is not unexpected, as a scallop dredge is designed to be size selective for legal-sized scallops and allow smaller scallops to pass through. Similar disparities have been previously reported in other fisheries when camera and dredge surveys were compared.

Due to significant dredge effort expended on scallop beds with high proportions of sub-legal scallops during the 2020 pre-season survey, the rules for participation in the 2021 TSF pre-season dredge survey were reformulated. The 2021 pre-season dredge survey in White Rock consisted of 29 survey dredge tows in May 2021 at a random subset of the 48 video sites randomly allocated in the White Rock region for the 2020 White Rock Video survey. The 2021 pre-season dredge survey of White Rock showed similar results to those encountered in the 2020 pre-season dredge survey with a moderate to low mean density of legal-sized scallops (15.6 kg/1000 m^2), and a low proportion of sub-legal sized scallops (5.7%). Given the depleted status of the fishery and the possibility that the shift upwards in size may indicate reduced stock recruitment, DPIPWE commissioned IMAS to undertake a towed video scallop survey of White Rock in June 2021.

Herein we report the results of the towed video survey and compare them to those of the dredge survey.

Methods

Video tows for the 2021 survey were conducted in the White Rock region of Area 5 of the TSF in June 2021. Survey sites for the 2021 survey were the same as those used in the previous year (Semmens et al. 2020, Fig. 1).

The IMAS towed video camera unit (Fig. 2) was deployed at each site and towed from the site position in a straight line transect for at least 500 m, approximately 1 m above the seafloor, and at around 1.0 - 1.5 knots by the IMAS research vessel Taroona. The direction of the transect at each site was predicated by current and sea-state conditions and fell within the range of 120° to 225°. Each transect was recorded as a track on the vessel GPS unit.

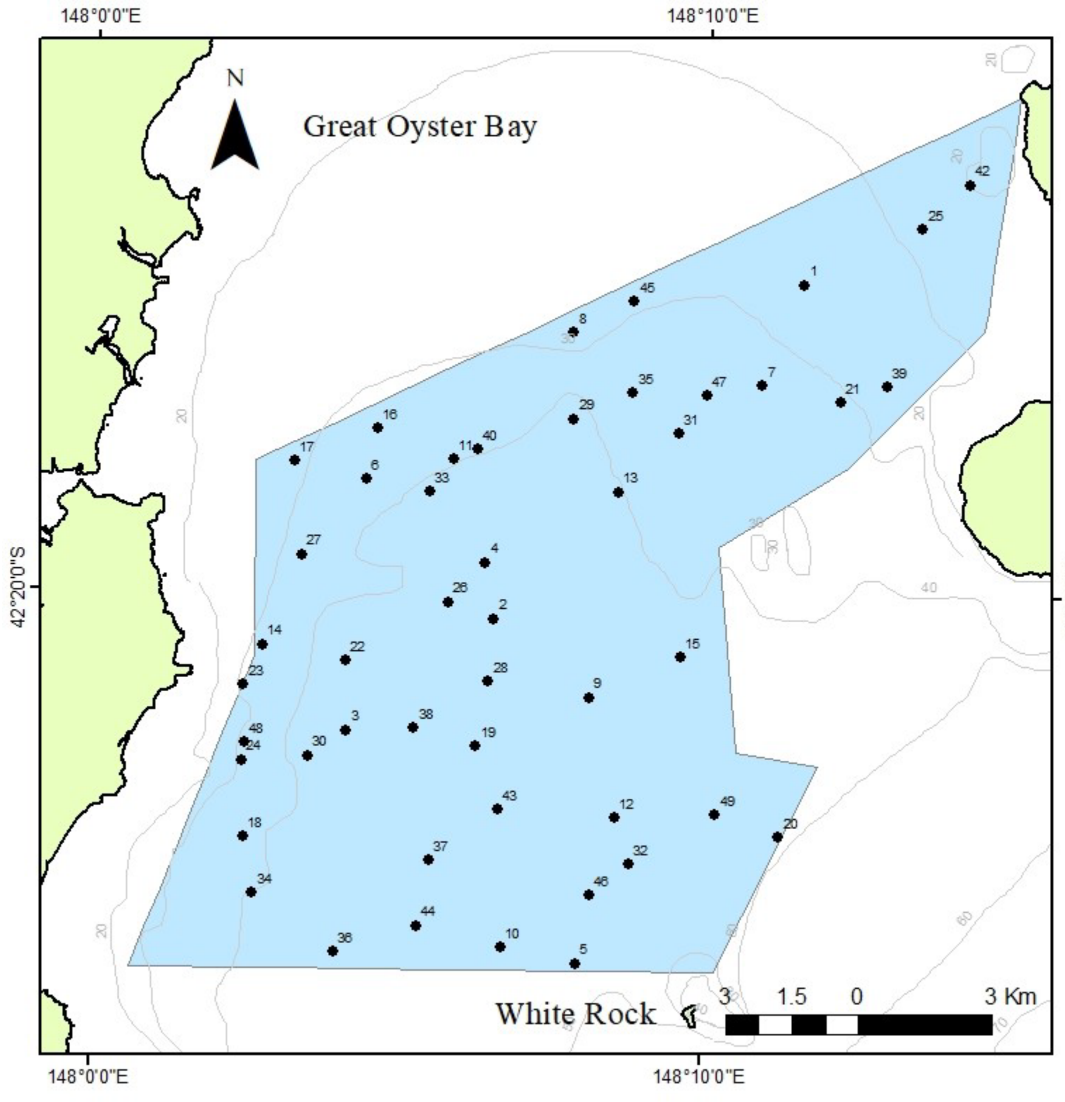


Figure 1. Video survey sites (with site numbers) randomly allocated within the survey polygon (solid line) defined by DPIPWE as the region of interest in TSF Area 5. Contours lines indicate depth in meters.

Figure 2. IMAS towed video camera unit.

The camera unit incorporated a high-definition (GoPro Hero 6) video camera and two parallel scaling lasers at a separation of 150 mm, whose beams contact the seafloor in the centre of the video field (Fig. 3). The separation of the scaling lasers was measured before each transect. The angle of incidence of the camera to the seafloor varied with tow speed and current and was generally in the range of 30° to 60°. In addition to the high-definition footage, a second standard-definition video camera transmitted footage to the surface via an umbilical where it was viewed in real-time to facilitate control of the camera unit.

Once the survey was completed, high-definition video footage from the GoPro video camera from each site was viewed and analysed using video analysis software Transect Measure (SeaGIS) which allowed frame-by-frame analysis of the video footage. Within any video frame, a pixel-to-millimetre calibration could be made using a known distance (the separation of scaling lasers), allowing objects within that frame to be measured in mm. The software also incorporates annotation of the position and time sequence of objects and measurements within any frame. By matching the frame time sequence with vessel GPS track time sequence data, the geographic position of any video frame could be determined. These features of the software were used to ascertain the start and finish positions of the analysed segment/s of each transect, the number of commercial scallops, their size, and their geographic position within a transect.

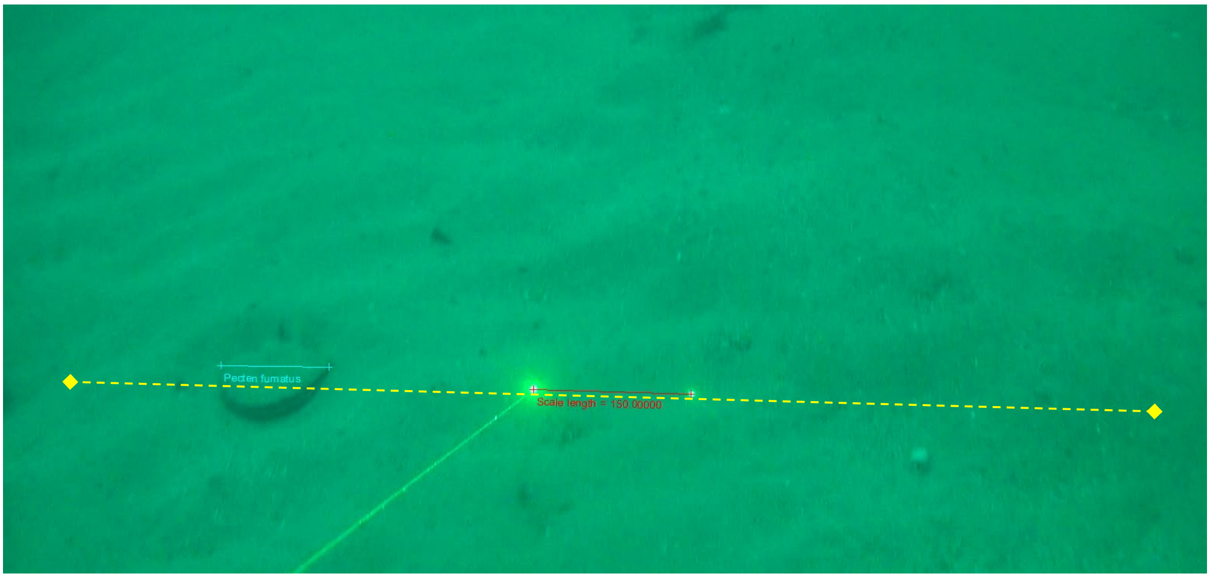


Figure 3. A frame from the video survey footage showing scaling lasers (green dots), pixel to mm calibration (red line), video centre line (dashed yellow line), transect width (dashed yellow line is 1 m long and centred at the centroid of the scaling lasers), and a commercial Scallop (*Pecten fumatus*) with a shell length (mm) measurement (blue line) orientated parallel to the centre line.

The video footage began and ended on the deck of the vessel, so a subset of the video from each site was used for analysis. The start point of analysis was chosen as the point at which the video unit stabilised at about 1m above the seafloor (generally within the first minute or two of footage). The end point of the segment analysed within a transect was predicated by either the ascent of the video unit (at around 500 m transect length), or at the point where the number of size measurements of commercial scallops exceeded 100. Time sequencing was used to determine the geographic position of the analysis start and end points within each transect. The analysed segment of each transect was assumed to be a straight line between the analysis start point to the analysis end point.

<u>Abundance</u>

Within the analysed segment of each transect, commercial scallops were counted if they crossed the centre line of the video frame (i.e. a horizontal line passing through both laser points) within 500 mm on either side of the centre point between the two scaling laser points (i.e. 1 m transect width; Fig. 3).

<u>Size Structure</u>

a) Size structure

The shell lengths (widest point of the shell, parallel to the hinge) of up to 100 scallops were measured at each site from the video transect footage. Each scallop counted for abundance was assessed for its suitability for size determination. A scallop was sized if it met the following criteria:

1. The margins of the scallop were clearly visible;
2. The scallop was orientated such that plane of the scallop's length was within 30^0 of the horizontal axis, to minimise undersize bias from the angle of incidence of the camera;
3. The scallop was within 150 mm of the centre of the transect, to minimise biases from camera lens distortion.

For every frame in which a scallop was counted, a pixel to mm calibration was applied using the scaling lasers (150 mm) and the length of the scallop was measured in mm.

Every eligible scallop on the analysed segment of the video transect was measured to create a scallop length frequency distribution. This distribution was standardised to allow comparison between sites using the following equation:

$$\text{Equation 1: } LFD_{Std} = LFD \times Count$$

where LFD_{Std} is the standardised scallop length frequency distribution, LFD is the scallop length frequency distribution and count is the number of scallops counted at each site.

b) Sub-legal proportion

The sub-legal proportion (% scallops <the 90 mm legal size) was calculated using the LFD_{Std} for each site and for all sites combined for the total sub-legal proportion (TSL).

<u>Total Density</u>

a) Scallop abundance

The density of scallops (legal [≥ 90 mm] and sub-legal [<90 mm] sizes) at each site was calculated as the number of scallops per m^2, using the following equation:

$$\text{Equation 2: } D = \frac{count}{transect\ area\ (m^2)}$$

where D is scallop density (scallops/m^2), count is the number of scallops counted at each site and transect area (m^2) is the length of the transect multiplied by the width of the transect (1 m).

b) Scallop weight

The standardised length frequency distribution was used to estimate the total (legal and sub-legal) scallop abundance at each site. This abundance was then converted to total scallop weight (kg) for each site using a pre-established relationship between scallop length and weight created using 1735 scallops from White Rock (Semmens et al. 2015; Fig. 4):

$$\text{Equation 3: } W = 0.0001 \times L^{2.978}$$

where W is the shell weight (g), and L is the length (mm) of an individual scallop.

The density of all scallops at each site was calculated as the total scallop weight (kg) per 1000 m^2, using the following equation:

$$\text{Equation 4: } D = \frac{total\ weight\ (kg)}{transect\ area\ (m^2) \times 1000}$$

where D is the estimated total scallop density (kg/1000 m^2), total weight is the total scallop weight from the site in kg and transect area (m^2) is the length of the transect multiplied by the width of the transect (1 m).

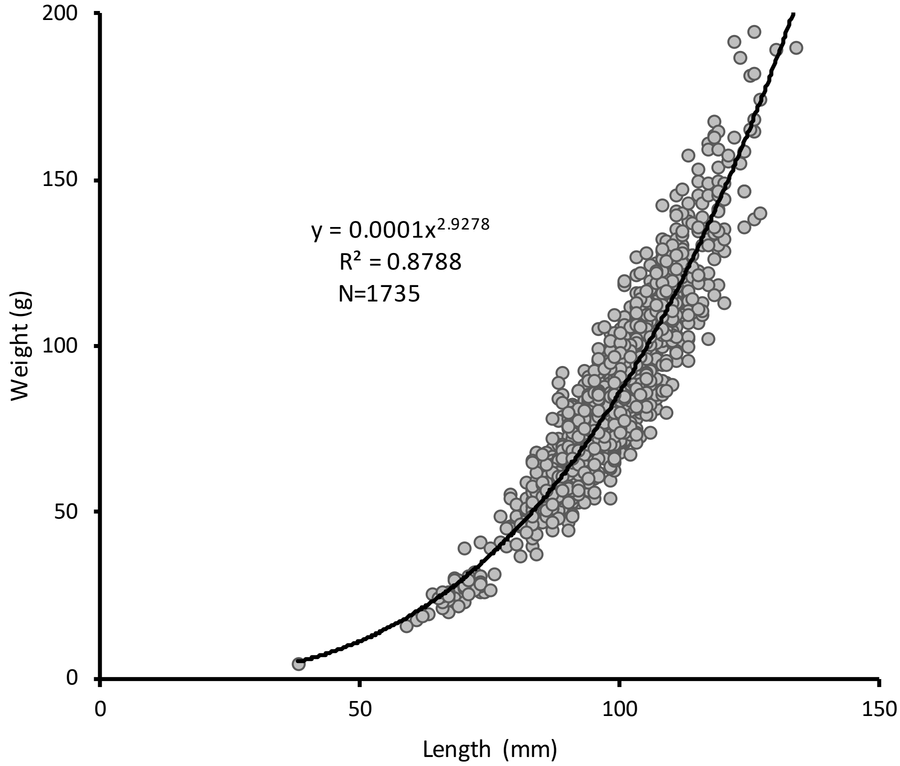


Figure 4. Length-weight relationship for commercial Scallop (*Pecten fumatus*) from previous surveys in White Rock (Semmens et al. 2015). Black line indicates the fitted regression ($y = 0.0001x^{2.978}$), where y = scallop weight (g) and x = scallop shell length (mm). The coefficient of determination (R^2) = 0.8788. N (number of scallops measured and weighed) = 1735.

Legal-Size Density

To enable comparison with the pre-season dredge survey conducted by IMAS in White Rock in May 2021, the standardised length frequency distribution was used to estimate the legal-sized scallop abundance (number of scallops ≥ 90 mm) for each site.

This abundance was then converted to total legal-sized scallop weight (kg) for each site using Equation 3.

The density of legal-sized scallops (D ≥ 90 mm) at each site was calculated as the total legal-sized scallop weight (kg) per 1000 m^2, using equation 4.

Biomass

The total (legal and sub-legal sizes) biomass (t) for the White Rock survey polygon was estimated using the equation:

$$\text{Equation 5: } B = \frac{meanD \times A}{1000}$$

where B is total biomass in t, meanD is the mean density of scallops in kg per m^2 swept, calculated by taking the mean of the density for each site determined using equation 4, and A is the total bed area (200.13 km^2). Efficiency of the survey was assumed to be 100% for this estimate, which was supported by the 2017 diver scallop survey ground-truthing of the video scallop survey methodology (Ewing et al. 2018).

To determine the 95% confidence interval for the biomass estimate, the following equation was used:

$$\text{Equation 6: } 95\%\ CI = \frac{\left(meanD \pm (t_{n-1} \times SE)\right) \times A}{1000}$$

where t_{n-1} is the t value for sample size (n-1).

The legal-size (≥ 90 mm) biomass was calculated using the equation:

$$\text{Equation 7: } B_{\geq 90mm} = B \times (1 - \left(\frac{sl}{100}\right))$$

where sl is the sub-legal proportion (30.5%).

The 95% confidence interval for the legal-size biomass estimate was calculated using equation 6.

Note that only legal size biomass is presented in this report. Also to note, there were six sites which did have scallops present, but none were suitable for measurement due to the low water clarity. For these sites we assumed that the legal-size density was zero. The six sites in question did not have very high abundances (see Table 2), so even though they are not real zeroes, this approach is a conservative one and will result in a slight under-estimate rather than other methods which could result in an over-estimate.

Results

Scallops (*Pecten fumatus*) were the most abundant taxa observed in video footage (Table 1). In total, 7,199 scallops were counted, and 1,220 scallops were sized (Fig. 5, Table 2). The mean and median total scallop density was 0.48 and 0.24 scallops/m^2, respectively. Across the survey area, total density was generally higher through the centre of the polygon and in six transects exceeded 1 scallop per 1 m^2 (Fig. 5).

Scallops were encountered at every site that was able to be analysed in the White Rock survey polygon. However, twelve of the 49 survey sites were unable to be analysed due to either very poor visibility (8 sites), or unsuitable habitat (4 sites were on reef) (Table 2). Moderate visibility at 6 sites allowed counts of scallop abundance but precluded measurements of scallop size due to unclear scallop margins (Table 2).

Table 1. Abundance of taxa encountered on the 2021 video transects.

Category	Common Name	Scientific name	Abundance
Bivalves	Commercial scallop	*Pecten fumatus*	7199
Crustaceans	Hermit Crab	*Sp. Diogenidae*	5
Seastars	11-Arm Seastar	*Coscinasterias muricata*	5
Fish	Sand flathead	*Platycephalus bassensis*	20
	Cowfish	*Arcana aurita*	2
	Unknown fish		2
Sharks, skates and rays	Banded Stingaree	*Urolophus cruciatus*	7
	Sparsely spotted Stingaree	*Urolophus paucimaculatus*	23
	Melbourne skate	*Dipturus whitleyi*	1
	Numbfish	*Narcone tasmaniensis*	3
Cephalopods	Octopus	*Octopus pallidus*	3

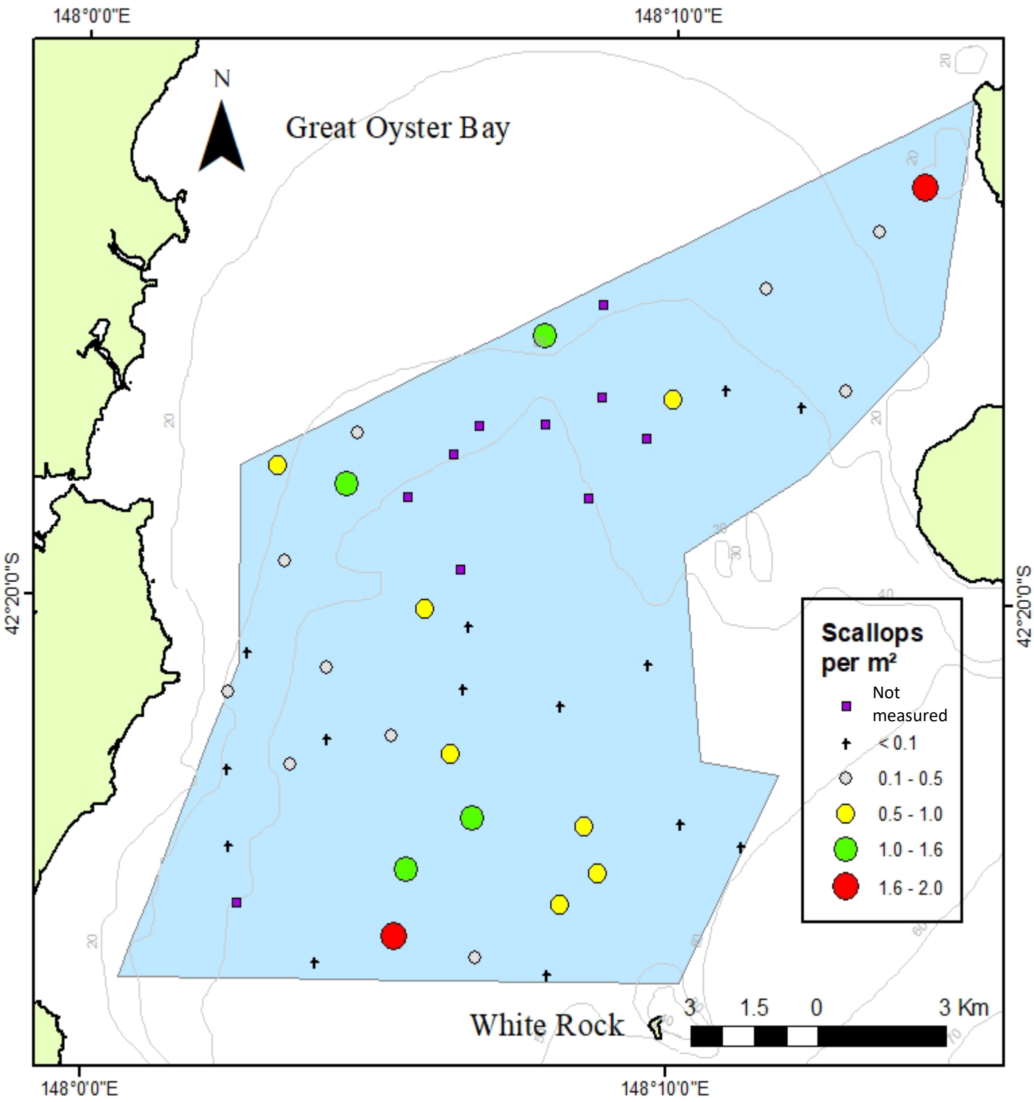


Figure 5. Density (scallops/m^2) of commercial scallop (*Pecten fumatus*) observed in video transects within the TSF Area 5 video survey area. Contours lines indicate depth in meters. Purple squares indicate sites that were not scored due to low visibility that precluded a count of scallops on the transect.

The mean and median legal-sized scallop density was 30.4 and 27.2 Kg/1000 m^2, respectively. The density of legal-sized scallops was generally higher at sites of high total (legal and sub-legal) density (Table 2; Figs. 5 and 6), despite higher sub-legal proportions at these sites. These higher density sites were highly spatially restricted, i.e. patchy (Fig. 6). Although the higher densities were only present in discreet patches, this is still a positive sign that recruitment has occurred in White Rock, despite very low densities (as determined by dredge surveys) preceding and during the current TSF closure (see Table 3).

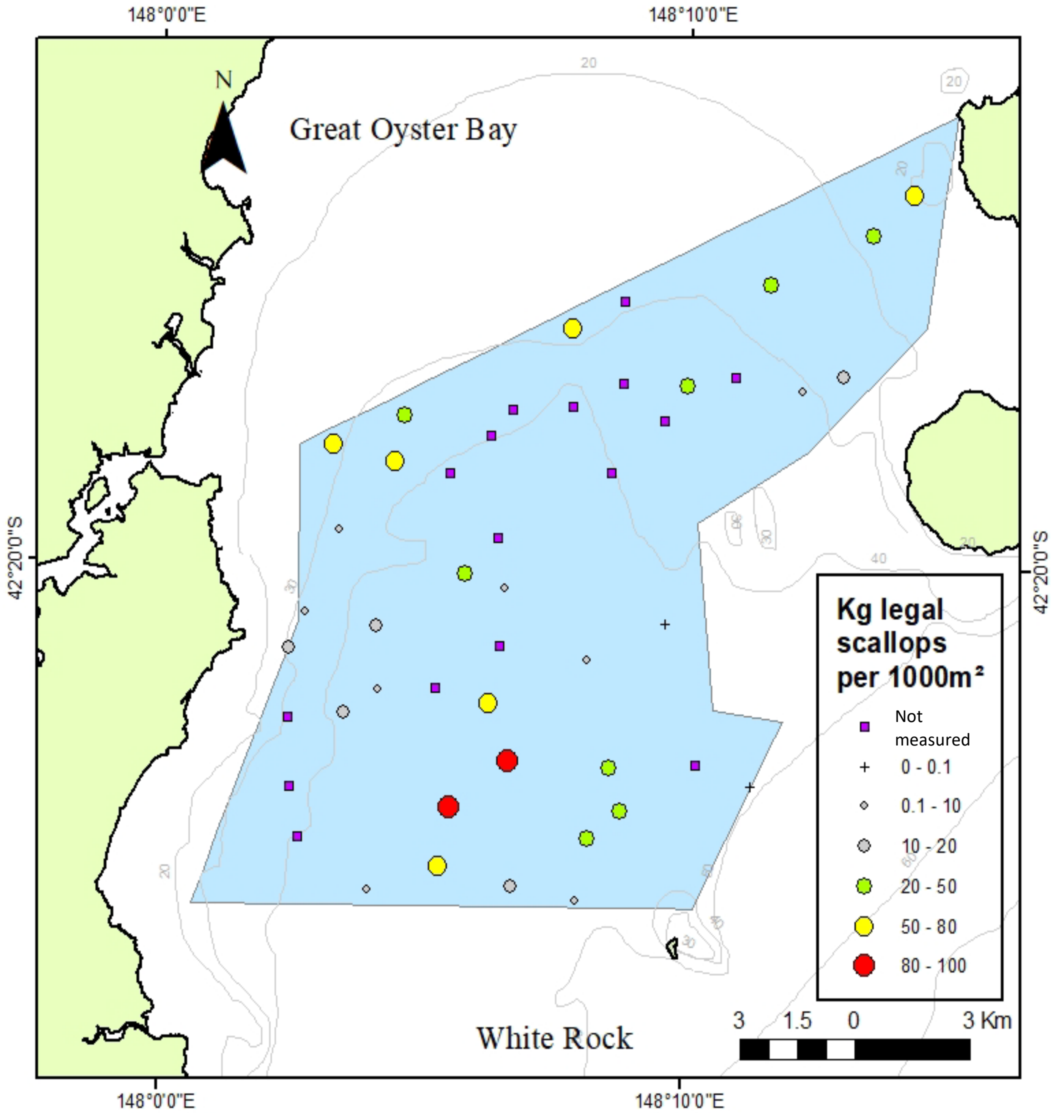


Figure 6. Density (kg/1000 m^2) of legal-sized commercial scallop (*Pecten fumatus*) observed on video transects within the TSF Area 5 video survey area. Contours lines indicate depth in meters. Purple squares indicate sites at which a legal-sized density could not be calculated either due to an inability to score the transect (see purple squares in Fig. 5), or sites at which scallops were able to be counted but were unable to be measured.

Table 2. Commercial scallop (*Pecten fumatus*) density, the proportion of scallops on the transect that were measured for length, and the sub-legal proportion for each survey site within the TSF Area 5 video survey area. TSL is the total sub-legal percentage for all sites combined. Water clarity ratings were: 1=excellent visibility (allowing an abundance count and length measurements), 2=moderate (abundance and length), 3=low (abundance only), 4=poor (not suitable for abundance or length).

Site	Depth (m)	Transect Area (m^2)	Scallop density (scallops/m^2)	Proportion measured (%)	Sub-legal % at 90mm	Legal density (Kg/1000 m^2)	Clarity rating
1	27	504	0.24	10.6	0	27.2	1
2	42	508	0.03	17.6	66.7	0.7	2
3	43	519	0.08	2.5	0	4.4	2
4	43	-	-	-	-	-	4
5	48	543	0.06	9.1	33.3	3.5	1
6	36	120	1.57	19.6	40.5	69.3	2
7	33	152	0.04	0	-	-	3
8	31	409	1.03	16.7	21.4	58.2	2
9	44	249	0.06	50.0	0	5.0	2
10	47	443	0.31	51.5	40.0	14.2	1
11	37	-	-	-	-	-	4
12	45	495	0.83	35.4	59.3	30.2	1
13	45	-	-	-	-	-	4
14	34	449	0.06	22.2	66.7	1.6	1
15	42	519	0.06	3.3	100	0.0	1
16	30	470	0.34	22.8	2.8	32.2	1
17	28	438	0.97	21.0	11.2	70.2	1
18	38	604	0.02	0	-	-	3
19	42	454	0.93	7.6	15.6	66.8	2
20	49	488	0.09	2.2	100	0.0	1
21	29	462	0.09	57.1	8.3	6.8	2
22	41	578	0.13	7.8	16.7	10.1	2
23	33	511	0.18	2.2	0	12.4	2
24	36	301	0.02	0	-	-	3
25	19	512	0.30	20.6	9.4	30.1	1
26	41	312	0.94	13.3	53.8	29.0	2
27	35	529	0.14	44.6	33.3	7.5	1
28	43	173	0.10	0	-	-	3
29	36	-	-	-	-	-	4
30	42	509	0.18	7.8	28.6	11.6	1
31	36	-	-	-	-	-	4
32	45	523	0.54	16.7	17.0	40.2	1
33	44	-	-	-	-	-	4
34	41	504	-	-	-	-	4
35	38			Reef habitat			
36	44	484	0.03	13.3	0	3.2	1
37	45	517	1.55	6.5	11.5	99.6	1
38	44	142	0.34	0	-	-	3
39	25	505	0.41	20.1	50.0	18.1	1
40	40	-	-	-	-	-	4
41	30			Reef habitat			
42	18	577	1.60	15.7	55.9	63.6	1
43	40	505	1.50	6.4	22.4	89.4	2
44	45	243	1.65	26.5	50.0	59.7	1
45	29			Reef habitat			
46	44	379	0.62	44.0	28.2	35.7	1
47	33	267	0.55	11.0	12.5	41.0	2

Table 2. continued.

Site	Depth (m)	Transect Area (m²)	Scallop density (scallops/m²)	Proportion measured (%)	Sub-legal % at 90mm	Legal density (Kg/1000 m²)	Clarity rating
48	36			Reef habitat			
49	47	467	0.04	0	-	-	1
Median	41	470	0.24	13.3	16.13	27.2	
Mean	38	419	0.48	16.4	25.38	30.4	
TSL					30.5%		

Table 3. Commercial scallop (*Pecten fumatus*) density, mean size, and sub-legal proportion (discard rate) for White Rock from recent pre-season dredge surveys.

Year	**Density (kg/1000 m²)**		**Mean scallop size (mm ± SE)**	**Discard rate (% <90 mm)**
	Mean	Median		
2021	15.6	14.2	102.2 ± 0.2	5.7
2020	20.9	16.6	97.9 ± 0.2	7.5
2017	4.7	3.9	100.5 ± 0.1	2.2
2016	4.4	3.5	96.8 ± 0.2	22.5
2015	19.7	15.8	99.1 ± 7.7	3.9
2014	8.6	7.2	98.2 ± 8.2	7.3
2013	6.2	-	93.9 ± 11.1	18.2
2011	>30	-	-	7.5

Across all sites, 19.5% of the scallops encountered on transects met the criteria for size measurement. This proportion varied between transects from 0% to 57%. The size frequency histogram (Fig. 7) shows the presence of juvenile scallops as small as 50 mm, which may be underrepresented due to small scallops potentially not being as easily identified in the video as larger scallops. Generally, size structure from video transects showed strong representation of sub-legal scallops with a high sub-legal proportion at 90 mm (30.5% by abundance and 19.3% by scallop weight) and mean size of 96mm; Fig. 8). As with scallop density, beds with larger scallops were in a patchy distribution across White Rock (Figs. 8 and 9).

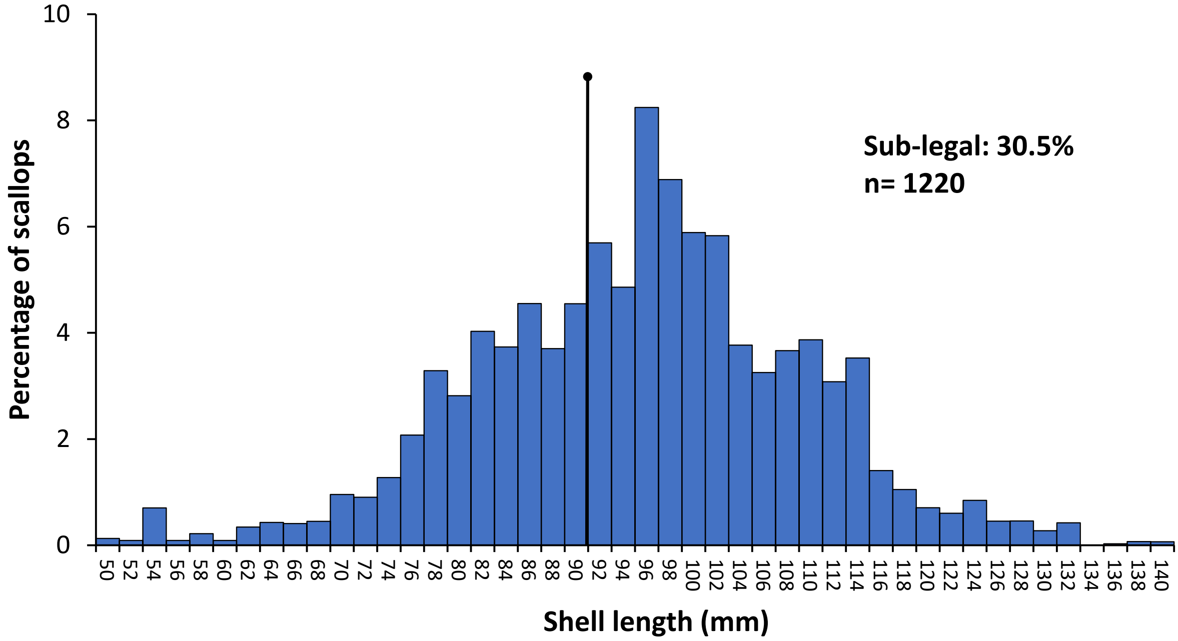


Figure 7. Standardised commercial scallop (*Pecten fumatus*) length frequency distribution pooled for all video transects within the TSF Area 5 video survey area. Sub-legal proportion (% <90 mm legal-size by abundance) was 30.5% for the 1220 scallops measured. Mean size ± se: 96mm ± 0.4 mm. The vertical line shows the 90 mm minimum length.

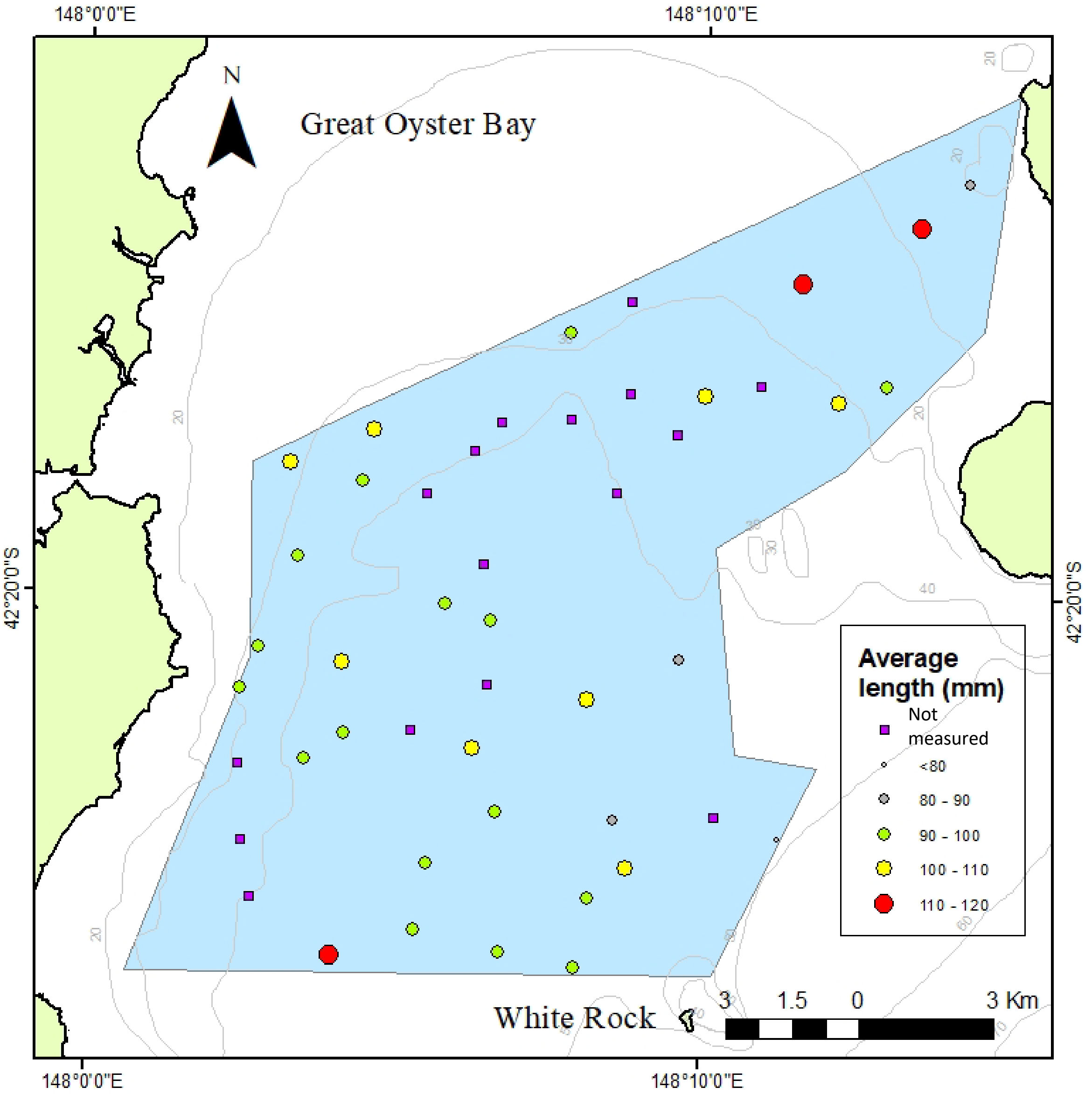


Figure 8. Average length (mm) of commercial scallop (*Pecten fumatus*) observed on video transects within the TSF Area 5 video survey area. Contours lines indicate depth in meters. Purple squares are sites at which average scallop length could not be calculated either due to an inability to score the transect (see purple squares in Fig. 5), or sites at which scallops were able to be counted but were unable to be measured.

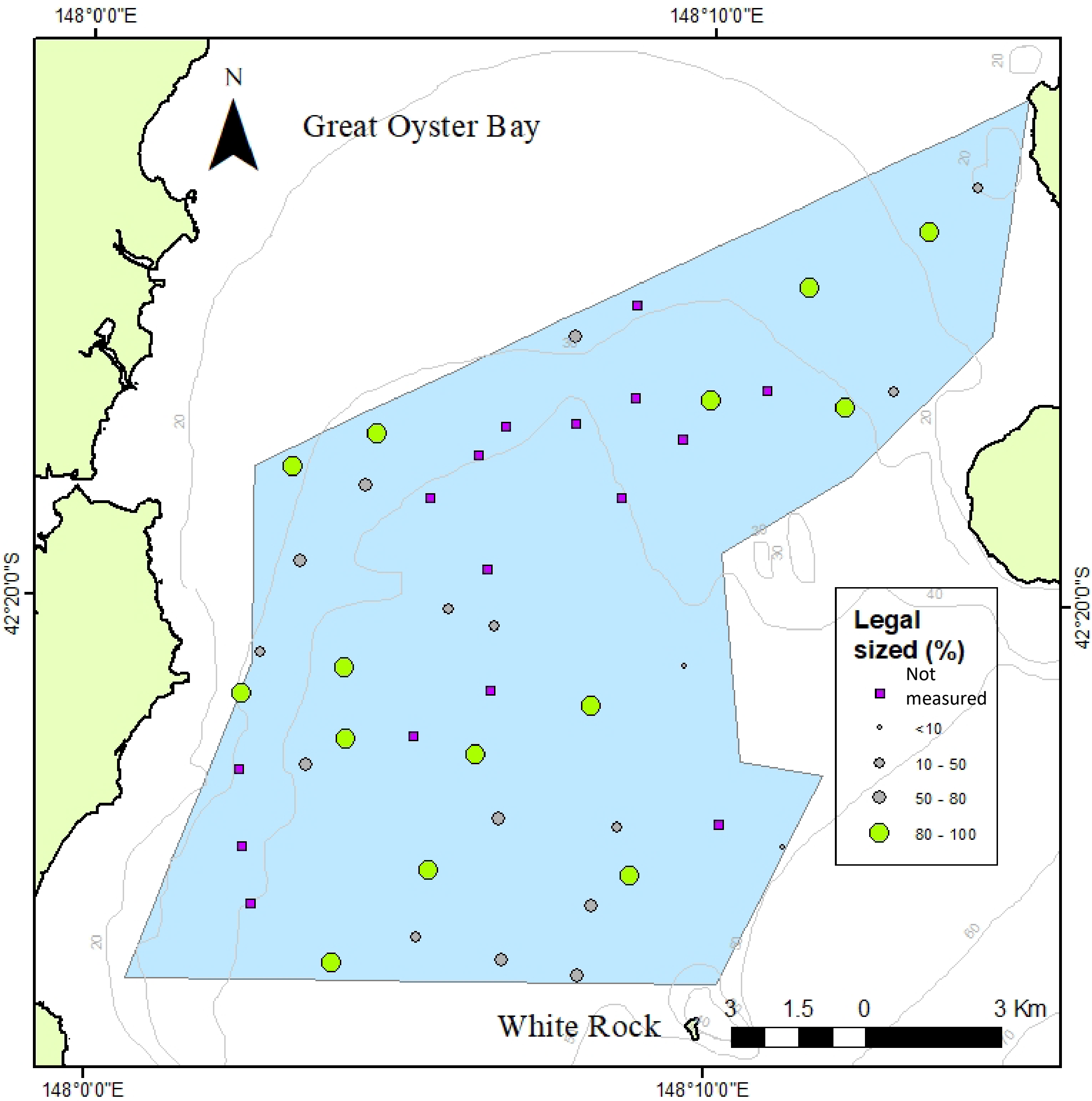


Figure 9. Percentage of commercial scallops (*Pecten fumatus*) more than or equal to the legal size limit (90mm) within the TSF Area 5 video survey area. Contours lines indicate depth in meters. Purple squares are sites at which percentage legal size could not be calculated either due to an inability to score the transect (see purple squares in Fig. 5), or sites at which scallops were able to be counted but were unable to be measured.

Biomass

Although, the biomass was calculated using the standard method of scaling-up the mean density across the survey area, the actual biomass is not evenly distributed across the entirety of the area, as there was a great deal of spatial variability between sites (Table 2; Figs. 5 and 6). Biomass across the 200 km^2 polygon was estimated at approximately 5093 t for the legal-sized biomass (Table 4). Please note only legal-sized biomass is provided below.

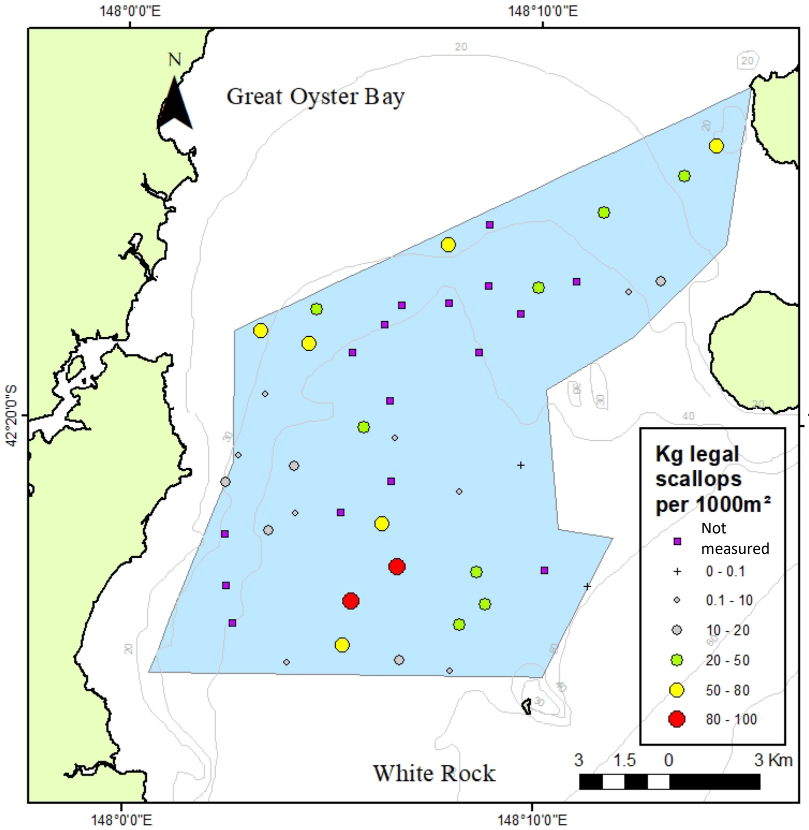
Table 4. Estimated commercial scallop (*Pecten fumatus*) legal-sized (≥ 90 mm) biomass (t), with 95% confidence intervals, within the TSF Area 5 video survey area, based on video survey results, with dredge survey biomass (not adjusted for dredge efficiency) from the same survey area for comparison.

Method	Lower CI (t)	Biomass (t)	Upper CI (t)
Dredge (n = 29)	2024.7	3122.2	4219.8
Video (n = 37)	3191.3	5093.2	6995.1

Comparison between the 2021 video and dredge surveys

Dredge tows in the 2021 White Rock survey yielded a mean and median density of legal-sized (≥ 90 mm) scallops of 15.6 and 14.2 kg/1000 m^2, respectively, with a sub-legal proportion (discard rate) of 5.7% (Table 3; Fig. 11). The video survey yielded a higher mean density (30.4 kg/1000 m^2) to that of the dredge survey was found for legal-sized scallops. There was a notable difference in the sub-legal proportion at the 90 mm legal-size, however, which was 30.5% in the video survey, an approximate 5-fold increase over the dredge survey (see Tables 2 and 3). The basis for this increase can be seen in the comparison of size structure between the two survey methods (Fig. 12). The dredge survey reported that >60% of scallops were in the 94-106 mm range and <6% of the caught scallops were in the 70-90mm range, whereas the video survey found that 94-100 mm range scallops comprised 35% of observations and that sub-legal scallops in the 70-90mm range made up nearly 30% of the population. Legal sized biomass for White Rock was estimated at 5093.2 ± 1901.9 t in the video survey, and 3122.2 ± 1097.5 t in the dredge survey.

An adjustment for dredge efficiency of 33% (Harrington et al. 2008) is applied to dredge biomass estimates when assessing the Tasmanian scallop fishery for potential opening. It should, however, be noted that the comparison between the dredge and video biomass estimates in the White Rock region in the 2021, and 2022 surveys (Semmens et al. 2023) raises questions around the validity of the adjustment applied for dredge efficiency. The dredge estimates of the mean and lower and upper 95% confidence intervals for biomass were 61.3, 63.4 and 60.3% of those for video in 2021, respectively. Similarly, the dredge estimates of the mean and lower and upper 95% confidence intervals for biomass were 58.1, 54.3 and 60.2% of those for video in 2022. This suggests that dredge efficiency, at least in the White Rock region, is significantly higher than 33% and closer to 60%.



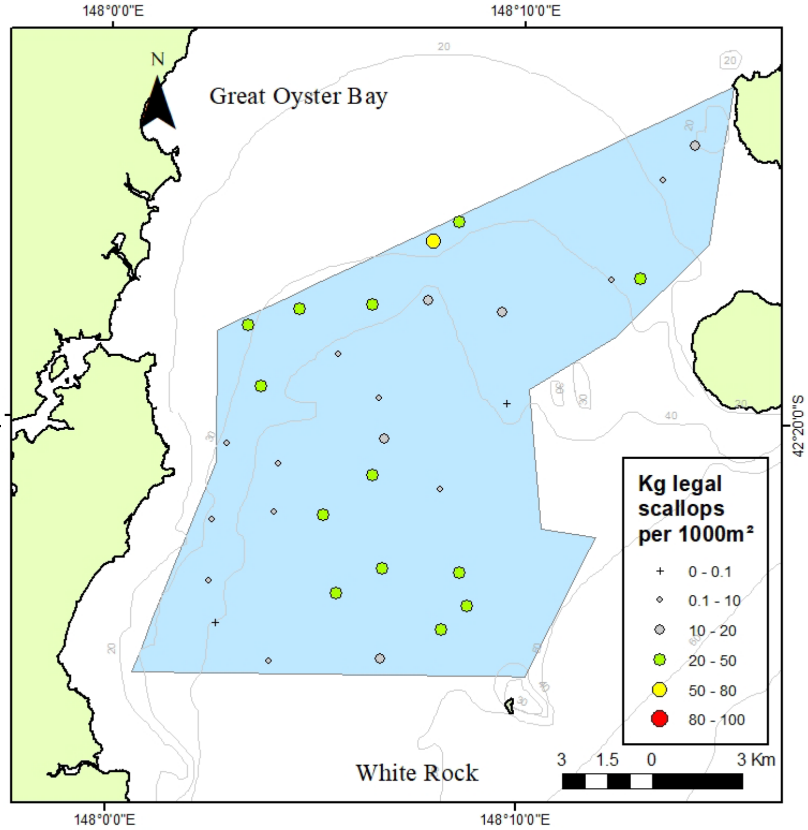


Figure 11. Density of legal-sized (≥90 mm) commercial scallop (*Pecten fumatus*) observed in the 2021 video (left panel) and 2021 pre-season dredge (right panel) surveys of the TSF Area 5 survey area, expressed as kg/1000 m^2. Contours lines indicate depth in meters.

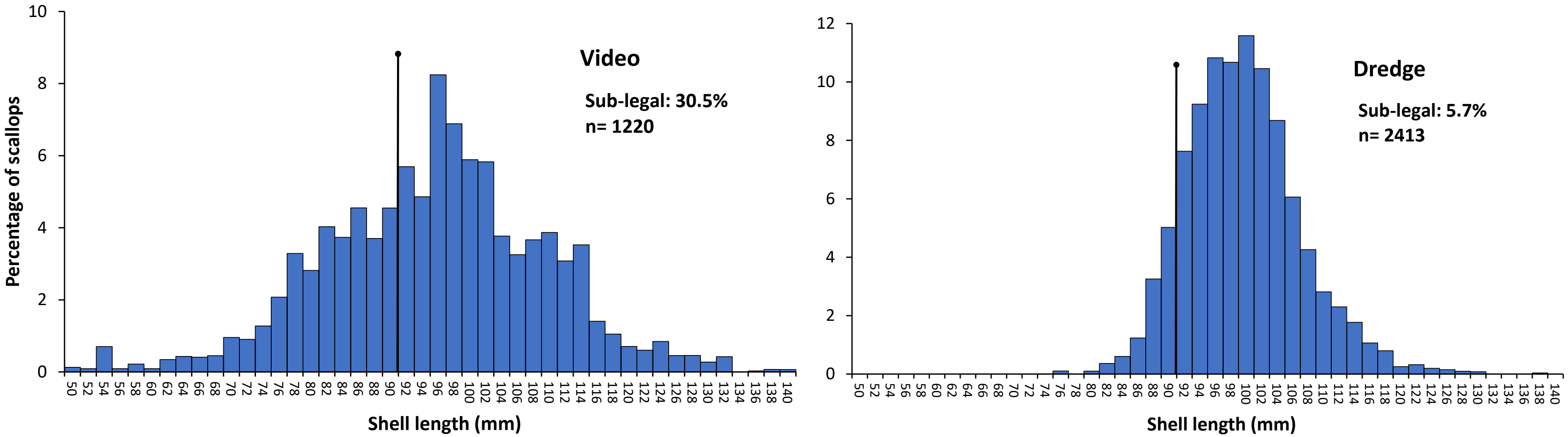


Figure 12. Standardised commercial scallop (*Pecten fumatus*) length frequency distribution for the 2021 TSF Area 5 survey area video transects (left panel) and dredge survey shots (right panel). Sub-legal proportion (% <90 mm) in the video survey was 30.5% for the 1220 scallops measured at 90 mm minimum length and mean size ± se: 96 mm ± 0.4 mm. For the dredge survey, the sub-legal proportion (discard rate) was 5.67% from 2413 scallops measured at 90 mm minimum length and mean size ± se: 102.2 ± 0.2 mm. The vertical lines show the 90 mm minimum length.

Conclusions

The video surveys conducted in 2021 found higher densities of both legal and sub-legal commercial scallops (*Pecten fumatus*) compared to the dredge survey in White Rock. Like the 2020 surveys, the video survey yielded a higher sub-legal density than the dredge in the 2021 survey, however in 2021, this was a 5-fold higher estimate compared to an 8-fold higher estimate in 2020. Unlike the 2020 surveys where video and dredge methods yielded similar legal densities, the video survey yielded a higher (almost double) legal-sized density than the dredge in the 2021 survey. The high proportion of sub-legal commercial scallops throughout the video survey area clearly demonstrates that there has been recruitment in White Rock during the closure of the TSF since the 2015 fishing season. The results from the video survey of White Rock demonstrated, similarly to 2020, that the video survey method can be used to effectively gather abundance and size structure data that can be invaluable for informed management of the TSF, without impacting on the seafloor, the benthic community and sub-legal scallops, particularly the vulnerable newly settled scallops.

Unlike the 2020 survey, the legal-sized scallop density in 2021 did not match between the video and dredge surveys. Legal-sized scallop density estimated from the video survey was 30.4 kg/1000 m^2, compared to the dredge estimate of 15.6 kg/1000 m^2. This difference between years is likely a result of the high percentage of sub-legal scallops in the video survey in 2020 (58.9%) compared to 2021 (36.5%).

In 2021, there were a number of video sites that were unable to be scored due to low visibility. The exclusion of these videos may potentially have introduced a bias in the measurements made of scallops in lower visibility tows, for example smaller scallops that are harder to see and measure. This lower visibility was also not randomly distributed in space and time and so compromises the random sample design (i.e. low visibility occurred in the sampling conducted in late June and was worst at sites in >40m and in the central northern area of the sample region).

Similarly to 2020, there was also a difference in the size-frequency of scallops captured in the surveys. The video survey estimated approximately 30.5% sub-legal proportion (i.e. 30.5% of all scallops <90 mm) and a mean size of 96 mm for the video survey compared to a 5.7% sub-legal proportion and a mean size of 102.2 mm for the dredge survey. This result is similar to that of both the 2017 and 2020 White Rock video surveys, with a marked difference between the video and dredge survey size structures. Additionally, the smallest scallop measured was 50 mm in the video survey, compared to the smallest measurement of 76 mm in the dredge survey. Comparing the 2020 and 2021 video survey scallop measurements has shown that the mean size of scallops has increased in White Rock. The mean size of measured scallops has increased from 85.6 mm in 2020 to 96 mm in 2021 for the video survey, and from 97.9 mm to 102.2 mm for the dredge survey. This indicates the scallops in the area have increased in size as a result of area being closed to fishing.

The difference in the size frequency between the two methods is not unexpected, as a scallop dredge is designed to be size selective for legal-sized scallops and such a difference is also seen in other fisheries that use both camera and dredge surveys (e.g., Atlantic sea scallops *Placopecten magellanicus*; NEFSC 2018).

It should be noted that dredge surveys can be modified to better sample sub-legal scallops, where the dredge is lined with a finer mesh than is standard, however, there has been no-ground-truthing for commercial scallops (*Pecten fumatus*) to quantify the effectiveness of modified dredges. In addition, such modification affects the performance of the dredge (Haddon et al. 2006; Koopman et al. 2019) and most importantly, in areas where there has been new settlement, like standard dredging, it has the potential to impact vulnerable newly settled scallops.

Given the advantage video surveys offer over dredge surveys in terms of time and labour costs for the field component of the survey, enhanced precision of size structure, provision of new information on recruitment in recent years and minimal impact on the seafloor, the benthic biota and sub-legal scallops, it is recommended that they are continued to be used as a tool for providing data for management of the TSF.

However, considering the current TSF closure criteria was developed for data from dredge surveys, e.g. closure for >20% discard rate, implementation of video surveys will require a review of these criteria to determine how data from video surveys may affect these decisions. A potential method for doing so would be to run dredge surveys, using both industry standard methods and modified dredges to better account for recruitment, in parallel with video surveys to more comprehensively understand the differences in size structure reported by these methods.

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