2020 Fishery-independent video survey of commercial scallop (*Pecten fumatus)* densities in scallop survey sub-area 6A of the Tasmanian Scallop Fishery

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Executive Summary

A towed underwater video camera was used to assess scallop densities and size frequency in survey sub-area 6A ('White Rock') of the Tasmanian commercial Scallop (*Pecten fumatus*) Fishery (TSF) in May and June 2020. Forty-nine video tows were randomly allocated within the area of interest and video was scored to determine the abundance of the scallops encountered, the size structure of the scallop population and the density and biomass of scallops across the survey area.

The mean total scallop density was 0.76 scallops/m^2 and, to facilitate comparison with previous dredge surveys, the legal-size scallop density (21.9 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 (58.9% at the 90 mm legal-size) and a mean size <90 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 survey sub-area 6A (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 7691 t for the total biomass and 3161 t for the legal-sized biomass, further highlighting the large biomass of sub-legal scallops that may be available to the fishery in subsequent years.

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 survey sub-area 6A yielded a mean and median density of legal-sized (≥ 90 mm) scallops of 21 and 16.6 kg/1000m^2, respectively, with a sub-legal proportion (discard rate) of 7.5%. In the video survey, a very similar mean density (21.9 kg/1000m^2) to that of the dredge survey was found for legal-sized scallops. However, the median density from the video survey was significantly lower (8. 5 kg/1000 m^2) than that of the dredge survey with a much higher sub-legal proportion (58.9%), reflecting the difference in size selectivity of the two methods as well as the sampling of a number of sites with low legal sized densities in the video survey. For both surveys, median density was substantially lower than mean density due to the influence of a small number of high-density sites on the overall mean density, whereas the lower median value reflected the predominantly patchy nature of most sites, which suggests that caution must be taken when extrapolating mean density values across the whole fishery.

Most of the scallops observed in the video survey transects were below the 90 mm minimum legal-size, leading to a sub-legal proportion of 58.9%, which was an approximate 8-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, survey sub-area 6A (often referred to as 'White Rock') 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, survey sub-area 6A 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 sub-area 6A 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. However, as the TSF is currently 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 sub-area 6A in May/June 2020. Herein we report the results of the towed video survey and compare them to those of the dredge survey.

Methods

Video tows were conducted in survey sub-area 6A of the TSF over the 26th, 28th and 29th of May and the 1st and 2nd of June 2020. Forty-nine sites were randomly assigned using the Create Random Points tool in the software package ArcGIS 10.4. Assignment of random points was constrained within a 199 km^2 polygon (perimeter 72 km) provided by DPIPWE that defined the area of interest to management within sub-area 6A, and with a minimum allowable separation of 500m (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 500m, approximately 1m above the seafloor, and at around 1.5 knots by the IMAS research vessel Morana. 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.

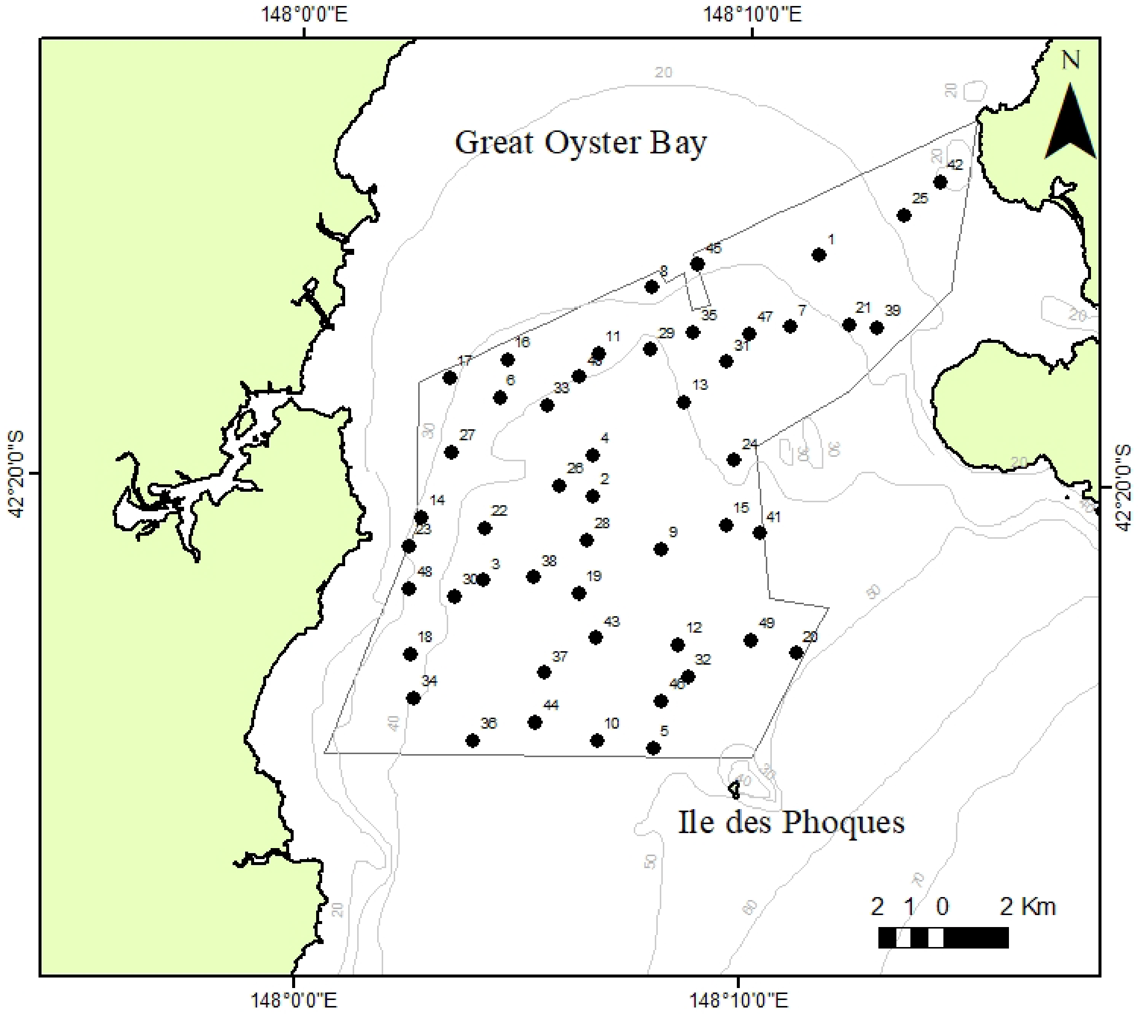

Figure 1. Commercial Scallop (*Pecten fumatus*) video survey sites (with site numbers) conducted in the survey polygon (solid line) in sub-area 6A in May/June 2020. Contours lines indicate depth in meters.

Figure 2. IMAS towed video camera unit.

The camera unit incorporated a high definition internet protocol video camera, LED lighting and two parallel scaling lasers at a separation of 150mm, whose beams contact the seafloor in the centre of the video field (Fig. 3). The separation of the scaling lasers was re-checked 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°. The video signal was transmitted to the surface via an umbilical where it was both viewed in real-time to facilitate control of the camera unit and recorded for subsequent analysis.

Once the survey was completed, video footage 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 frame a pixel-to-millimetre calibration was made using a known distance (e.g. the separation of scaling lasers) allowing objects within that frame to be measured in mm. The software also incorporated 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 objects in a frame was determined. These features of the software were used to ascertain the number of commercial scallops, their size, and their geographic position within the analysed segment of each video transect.

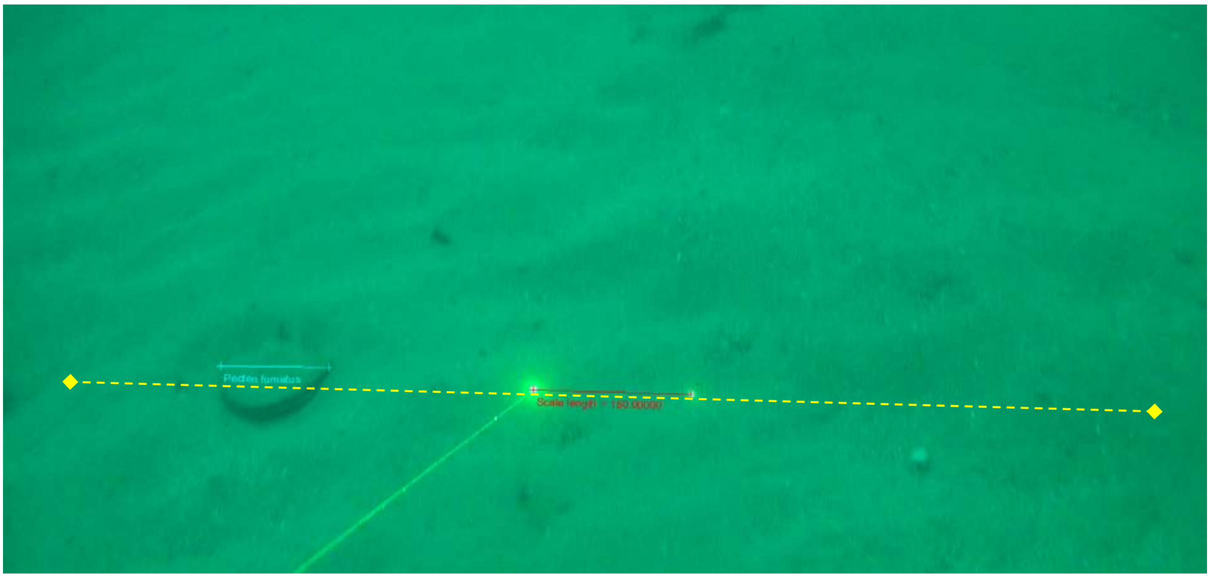

Figure 3. A frame from the video survey footage showing scaling lasers (green dots), pixel to mm calibration (red line), video centre line (dashed yellow line), transect width (dashed yellow line is 1 m long and centred at the centroid of the scaling lasers), and a commercial Scallop (*Pecten fumatus*) 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 250 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 survey sub-area 6A (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).

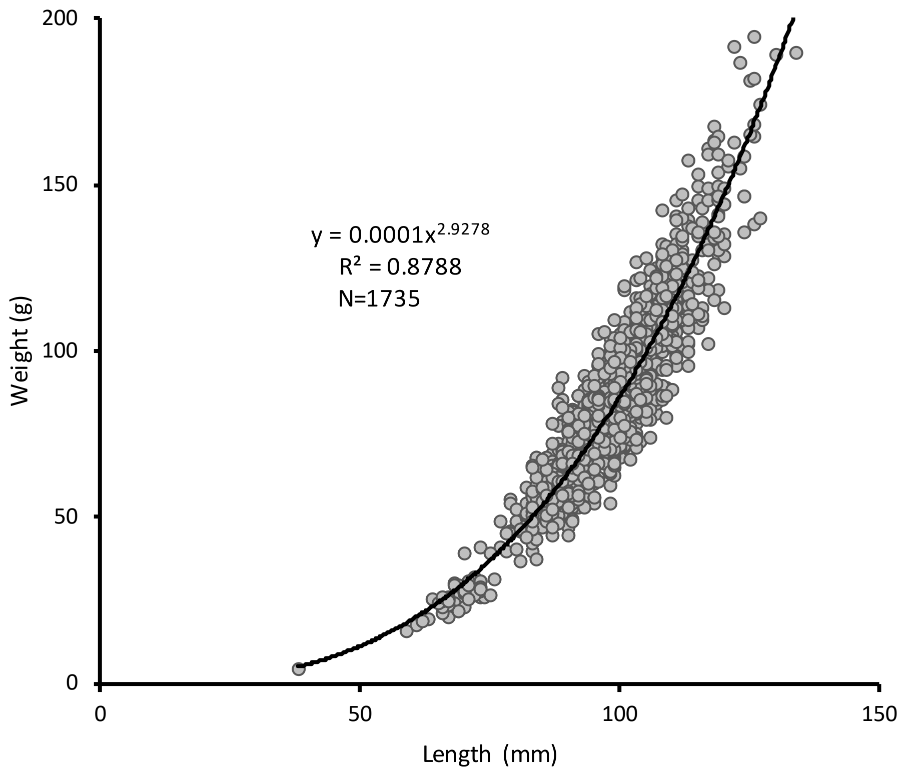

Figure 4. Length-weight relationship for commercial Scallop (*Pecten fumatus*) from previous surveys in sub-area 6A (Semmens et al. 2015). Black line indicates the fitted regression (y = $0.0001x^{2.978}$), where y = scallop weight (g) and x = scallop shell length (mm). The coefficient of determination (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 sub-area 6A in May 2020, 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 sub-area 6A 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 (199.06 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:

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

where sl is the sub-legal proportion (58.9%).

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

The estimated legal-sized scallop density (kg/1000 m^2) for each site was used to generate a modelled density map of the sub-area 6A survey polygon. Densities were estimated using a bivariate gaussian kernel assuming isotropic diffusion with individual scallops assumed to be randomly distributed along each linear transect line. The sub-area 6A survey polygon was partitioned into 100 m^2 cells and biomass was calculated for each cell using equation 7 (see Figure 7).

Results

Scallops (*Pecten fumatus*) were encountered at every site in the sub-area 6A survey polygon except for Site 41, which was comprised entirely of low-profile reef habitat. Scallops were the most abundant taxa observed in video footage (Table 1). In total, 9,813 scallops were counted and 2,943 scallops were sized (Fig. 5, Table 2). The mean and median total scallop density was 0.76 and 0.39 scallops/m^2, respectively. Across the survey area, total density was generally higher through the centre of the polygon and in six transects exceeded 2 scallops per 1 m^2 (Fig. 5).

Table 1. Abundance of taxa encountered on video transects.

Category	**Common Name**	**Scientific name**	**Abundance**
Bivalves	Commercial scallop	*Pecten fumatus*	9,813
	Queen Scallop	*Equichlamys bifrons*	10
Crustaceans	Spider Crab	*Leptomithrax gaimardii*	48
Seastars	11-Arm Seastar	*Coscinasterias muricata*	37
Fish	Sand flathead	*Platycephalus bassensis*	8
	Lachet	*Lepidotrigla vanessa*	1
Sharks skates and rays	Carpet shark	*Parascyllium sp.*	1
	Melbourne skate	*Dipturus whitleyi*	1
Marine mammals	Aus. fur seal	*Arctocephalus pusillus*	2

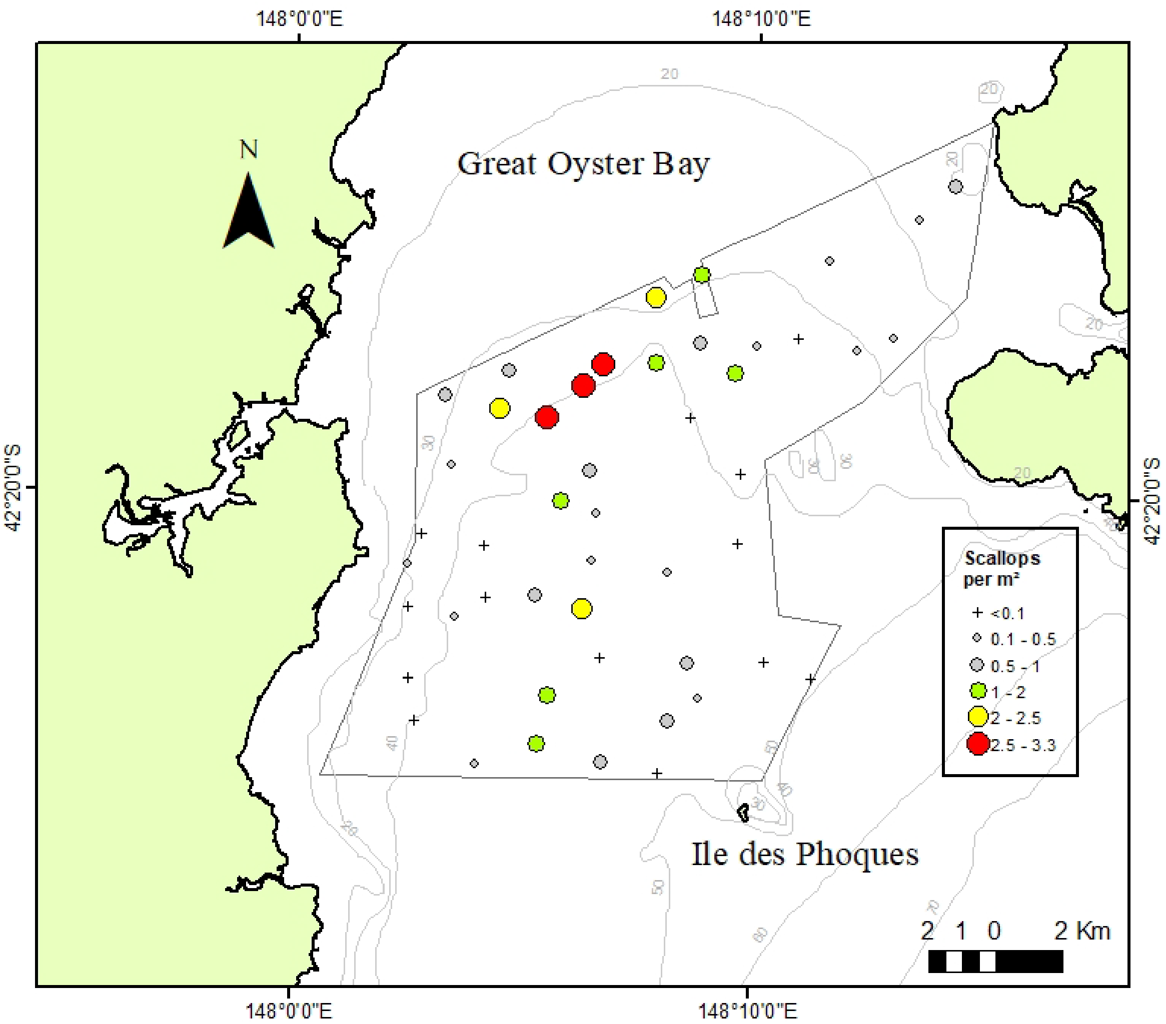

Figure 5. Density (scallops/m^2) of commercial scallop (*Pecten fumatus*) observed in video transects within the sub-area 6A video survey area. Contours lines indicate depth in meters.

The mean and median legal-sized scallop density was 21.9 and 8.5 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. 7). Although the higher densities were only present in discreet patches, this is still a positive sign that recruitment has occurred in survey sub-area 6A, despite very low densities (as determined by dredge surveys) preceding and during the current TSF closure (see Table 3).

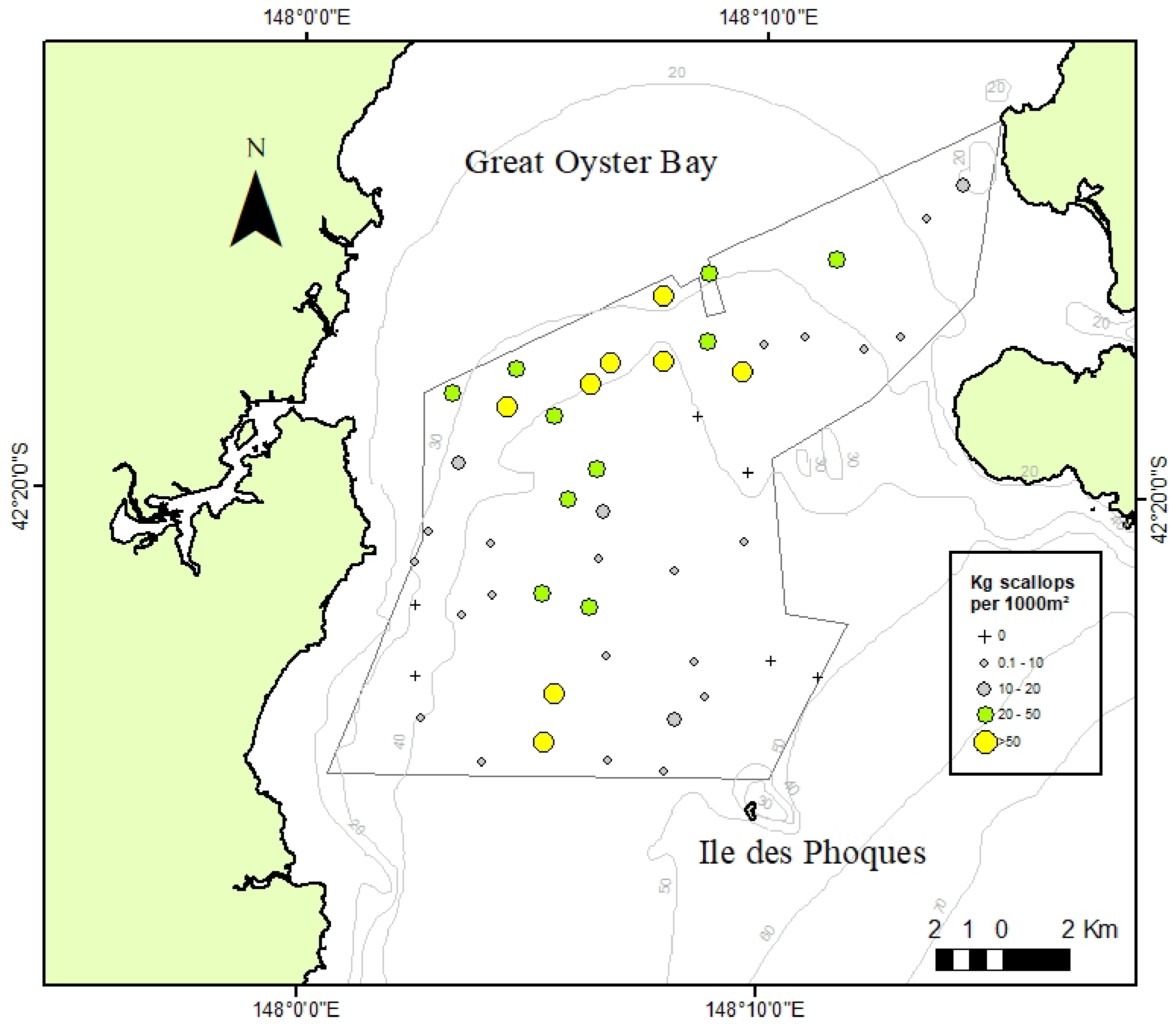

Figure 6. Density (kg/1000 m^2) of legal-sized commercial scallop (*Pecten fumatus*) observed on video transects within the sub-area 6A video survey area (solid line). Contours lines indicate depth in meters.

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 sub-area 6A video survey area. TSL is the total sub-legal proportion for all sites combined.

Site	Depth (m)	Transect Area (m^2)	Scallop density (scallops/m^2)	Proportion measured (%)	Sub-legal % at 90mm	Legal scallop density (Kg/1000m^2)
1	26	586.4	0.287	45	12.0	20.0
2	41	335.2	0.474	28	46.7	17.4
3	42	528.3	0.091	15	85.7	0.9
4	41	219.2	0.844	17	59.4	21.5
5	47	476.9	0.044	43	77.8	0.7
6	35	220.7	2.248	16	59.0	63.2
7	32	545.5	0.020	55	50.0	0.7
8	29	158.7	2.483	31	58.2	79.3
9	42	459.8	0.372	36	72.6	6.4
10	45	332.7	0.640	50	77.6	8.8
11	37	107.3	3.188	27	56.4	92.5
12	44	506.6	0.630	34	81.5	7.3
13	44	337.9	0.015	-		0.0
14	34	457.5	0.092	31	30.8	4.1
15	41	488.7	0.002	100	0.0	0.2
16	31	372.6	0.722	29	46.8	29.1
17	29	627.0	0.818	30	50.6	29.9
18	38	450.1	0.029	23	100.0	0.0
19	41	150.4	2.155	45	84.9	21.5
20	48	527.8	0.004	50	100.0	0.0
21	28	431.1	0.111	50	50.0	4.3
22	40	428.4	0.093	25	50.0	3.3
23	33	419.4	0.100	31	76.9	1.3
24	35	536.6	0.002	-		0.0
25	17	532.5	0.235	34	50.0	8.9
26	40	359.8	1.576	17	59.6	45.3
27	35	389.2	0.434	25	61.9	10.5
28	42	508.2	0.417	42	73.0	7.3
29	36	165.7	1.810	30	38.9	80.2
30	40	433.7	0.115	22	72.7	1.9
31	34	254.9	1.659	25	27.4	84.6
32	44	518.9	0.368	30	71.9	8.2
33	40	128.4	3.248	24	80.6	42.9
34	40	181.5	0.039	14	0.0	3.5
35	33	300.9	0.897	31	49.4	30.8
36	44	436.7	0.192	15	53.8	7.6
37	44	232.1	1.637	26	26.3	91.8
38	43	259.3	0.991	25	59.4	24.5
39	20	515.4	0.204	36	50.0	7.3
40	38	231.8	2.546	24	58.3	71.3
41	42	-	-	-	-	-
42	19	567.0	0.700	23	64.9	18.5
43	43	302.1	0.040	29	67.3	0.8
44	44	177.5	1.915	35	54.0	56.6
45	29	541.6	1.200	18	74.7	20.5
46	43	484.3	0.549	29	69.4	10.9
47	31	508.2	0.331	100	77.6	5.0
48	36	113.7	0.009	-	100.0	0.0
49	50	494.6	0.010	45	-	0.0
Mean	37	382.1	0.762	33.6		21.9
Median	40	429.7	0.394	29.5		8.5
TSL					58.9	

Table 3. Commercial scallop (*Pecten fumatus*) density, mean size, and sub-legal proportion (discard rate) for survey sub-area 6A from recent pre-season dredge surveys.

Year	Sub-Area 6A			
	Density (kg/1000 m²)		Mean scallop size (mm ± SE)	Discard rate (% <90 mm)
	Mean	Median		
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

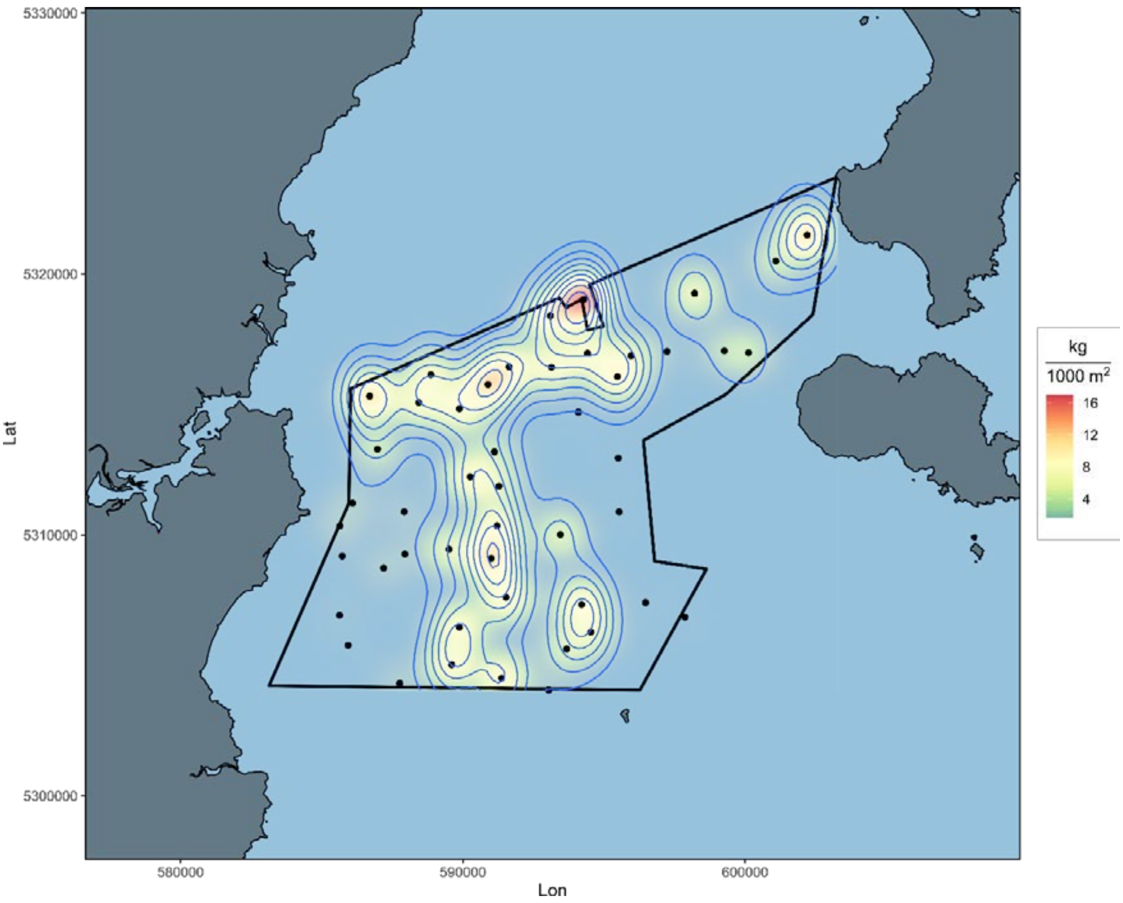

Figure 7. Modelled biomass of legal-sized commercial scallops (*Pecten fumatus*) across the survey area (solid line) in sub-area 6A, as determined by the 2020 video survey. Each blue contour line indicates a 10% decrease in biomass density from the central point.

Across all sites, 30% of the scallops encountered on transects met the criteria for size measurement. This proportion varied between transects from 14% to 100% due to factors such as swell conditions and underwater visibility (Table 2). Scallop size varied between sites with the higher density sites generally composed of sub-legal scallops (Figs. 8-10). Size structure from video transects showed strong representation of sub-legal scallops with a very high sub-legal proportion at 90 mm (58.9% by abundance and 55% by scallop weight) and mean size <90 mm (85.6 mm; Fig. 8).

Along with the discreet patches of higher densities, the high proportion of sub-legal scallops throughout the survey area (Figs. 8-10), clearly demonstrate that there has been recruitment during the closure of survey sub-area 6A (and the entire TSF) since the 2015 fishing season. Furthermore, there are potential good signs for the future, with clear evidence of new recruits, although survey densities of these recruits are low. The size frequency histogram (Fig. 8) shows the presence of juvenile scallops as small as 34 mm, which may be underrepresented due to small scallops potentially not being as easily identified in the video as larger scallops.

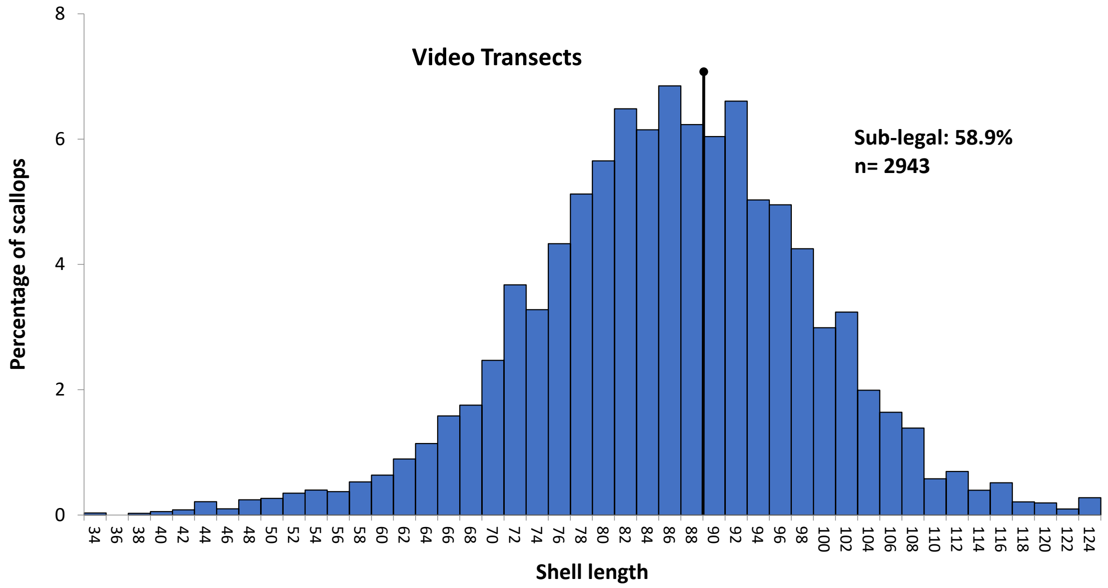

Figure 8. Standardised commercial scallop (*Pecten fumatus*) length frequency distribution pooled for all video transects within the sub-area 6A video survey area. Sub-legal proportion (% <90 mm legal-size by abundance) was 58.9% for the 2943 scallops measured. Mean size ± se: 85.6 ± 0.4 mm. The vertical line shows the 90 mm minimum length.

Although, the biomass was calculated using the standard method of scaling-up the mean density across the survey area, it is clear that 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. 6 and 7). Biomass across the nearly 200 km^2 polygon was estimated at approximately 7691 t for the total biomass and 3161 t for the legal-sized biomass, further highlighting the large biomass of sub-legal scallops that may be available to the fishery in subsequent years (Table 4; Figs. 9 and 10). Given that this is the first random-sampling design video survey undertaken in the TSF, with the 2017 sub-area 6A survey limited in its spatial coverage and primarily designed to examine a dredge-prohibited area (Ewing et al. 2018), these biomass results cannot be compared to existing video survey data. However, it provides a reference point following extended fishery closure to compare future survey biomass estimates to.

Table 4. Estimated commercial scallop (*Pecten fumatus*) biomass (t), with 95% confidence intervals, within the sub-area 6A video survey area, based on video survey results for all scallops (total) and legal-sized (≥ 90 mm) scallops.

	Lower CI (t)	Biomass (t)	Upper CI (t)
Total	5053.07	7691.83	10330.58
≥ 90 mm	2076.80	3161.34	4245.80

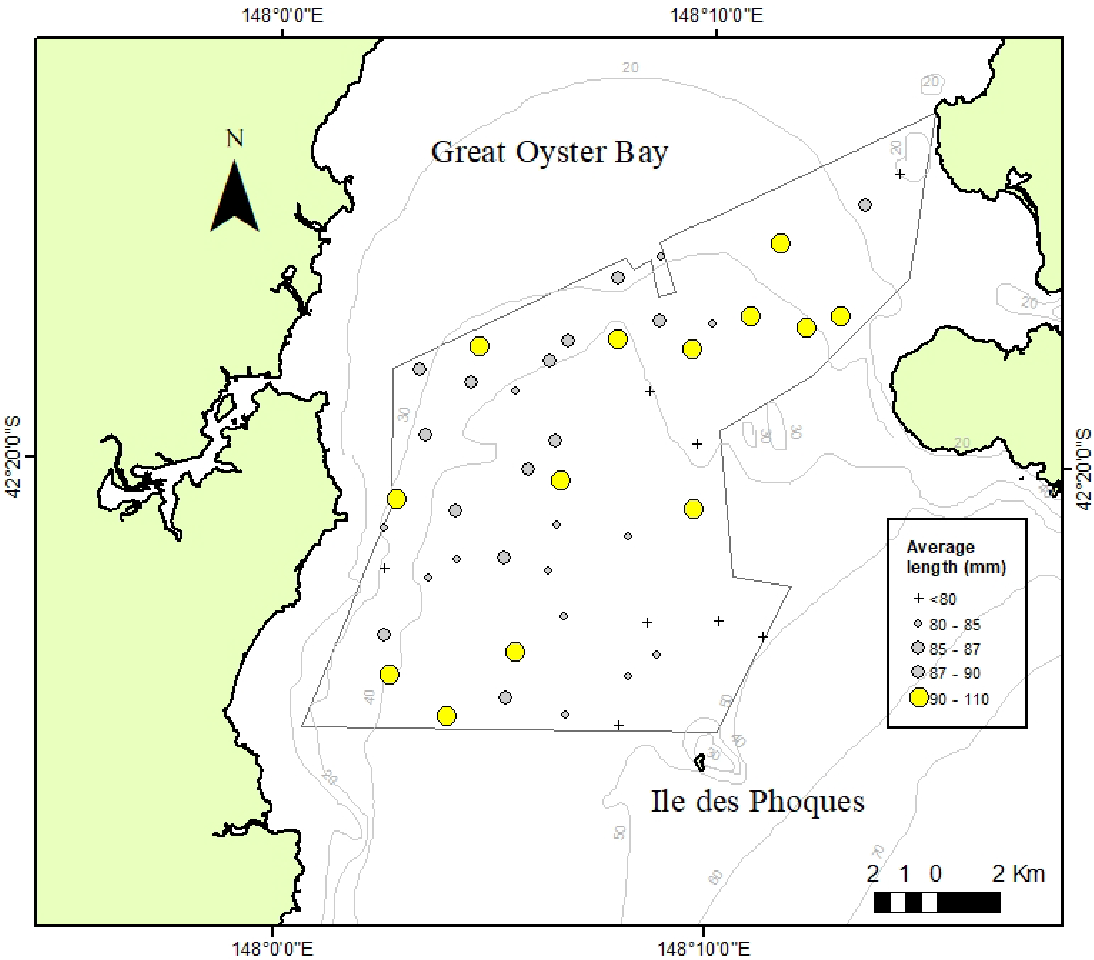

Figure 9. Average size (mm) of commercial scallop (*Pecten fumatus*) observed on video transects within the Sub-Area 6A video survey area. Contours lines indicate depth in meters.

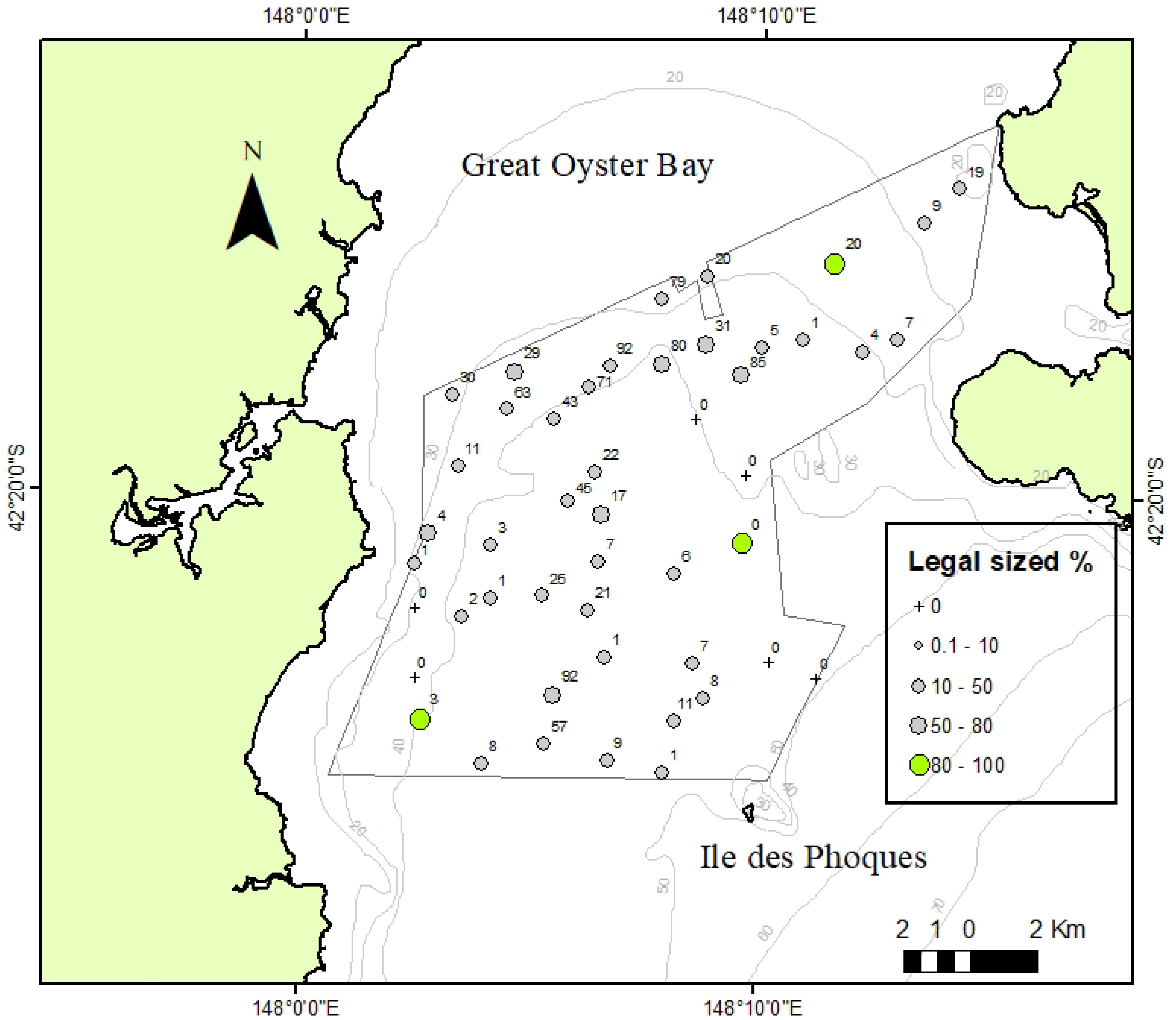

Figure 10. Percentage of commercial scallops (*Pecten fumatus*) ≥ the legal size limit (90mm) within the sub-area 6A video survey area (solid line). Data labels are density of legal-sized scallops observed on video transects expressed as Kg/1000 m^2. Contours lines indicate depth in meters.

Comparison between the sub-area 6A 2020 video survey and 2020 pre-season dredge survey

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 of the two methods. In the dredge survey, tows in survey sub-area 6A yielded a mean and median density of legal-sized (≥ 90 mm) scallops of 21 and 16.6 kg/1000m^2, respectively, with a sub-legal proportion (discard rate) of 7.5% (Table 3; Fig. 11). In the video survey, a very similar mean density (21.9 kg/1000m^2) to that of the dredge survey was found for legal-sized scallops. However, the median density from the video survey was significantly lower (8. 5 kg/1000 m^2) than that of the mean density of both the video and dredge surveys, suggesting that a small number of high-density sites were inflating the mean density from the video survey. Additionally, when individual survey sites were compared (Fig. 11), there was general agreement on the density of legal-sized scallops between the two methods (video and dredge). There was a notable difference in the sub-legal proportion at the 90 mm legal-size, however, which was 58.9% in the video survey, an approximate 8-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 >40% of scallops were in the 94-100 mm range and <10% of the caught scallops were in the 80-90mm range, whereas the video survey found that 94-100 mm range scallops comprised <20% of observations and that sub-legal scallops in the 80-90mm range made up nearly 40% of the population.

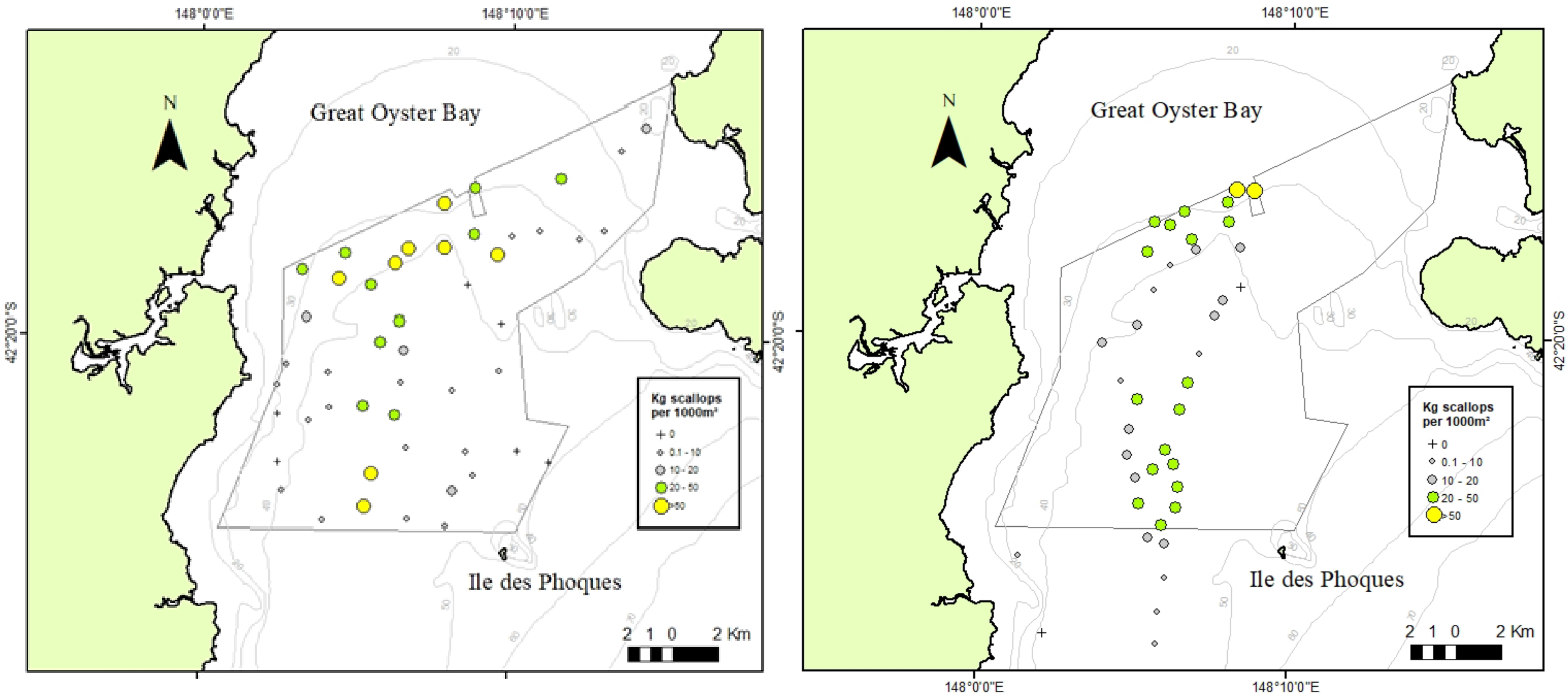

Figure 11. Density of legal-sized (≥90 mm) commercial scallop (*Pecten fumatus*) observed in the 2020 video survey of sub-area 6A video (left panel) and 2020 pre-season dredge (right panel) surveys, expressed as kg/1000m^2. The solid line in both panels denotes the video survey area. Contours lines indicate depth in meters.

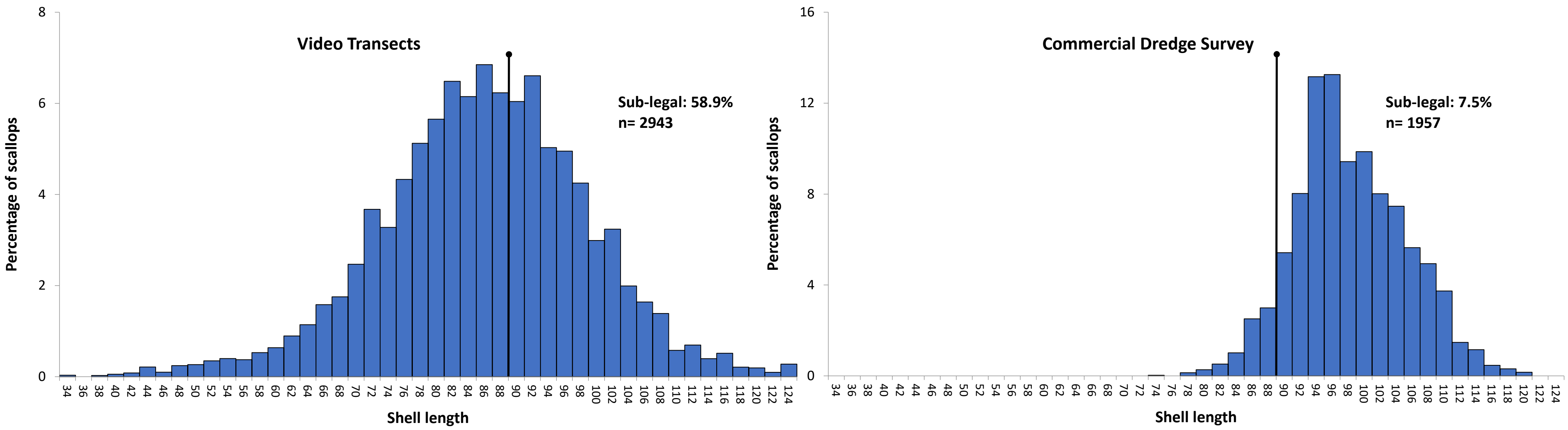

Figure 12. Standardised commercial scallop (*Pecten fumatus*) length frequency distribution for all 2020 survey sub-area 6A video transects (left panel) and dredge survey shots (right panel). Sub-legal proportion (% <90 mm) in the video survey was 58.9% for the 2943 scallops measured at 90 mm minimum length and mean size ± se: 85.6 ± 0.4 mm. For the dredge survey, the sub-legal proportion (discard rate) was 7.5% from 1957 scallops measured at 90 mm minimum length and mean size ± se: 97.9 ± 0.2 mm. The vertical line shows the 90 mm minimum length. Note that the y-axis differs for the two graphs.

Conclusions

The high proportion of sub-legal commercial scallops (*Pecten fumatus*) throughout the video survey area, clearly demonstrates that there has been recruitment in survey sub-area 6A during the closure of the TSF since the 2015 fishing season. Furthermore, there are potential good signs for the future, with clear evidence of new recruits, although survey densities of these recruits are low, potentially as these very small scallops are not as easily identified in the video as larger scallops.

The results from the video survey of survey sub-area 6A demonstrated 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.

The very close match between the legal-size scallop density determined by both the video and dredge survey methods demonstrates that the video method appears to be equally capable as dredging in surveying legal-size scallops, noting that this is the portion of the population that scallop dredges are designed to capture. This result also matches that of the 2017 Sub-Area 6A video survey when compared against the pre-season dredge survey results, with video and dredge surveys reporting similar densities of legal-size scallops (kg per 1000 m^2) across the sampled sites (Ewing et al. 2018).

While both the 2020 survey sub-area 6A video and dredge surveys showed very similar densities, the scallop size frequency distributions were very different between the two methods, with a 58.9% sub-legal proportion (i.e. 58.9% of all scallops <90 mm) and a mean size of 85.6 mm for the video survey compared to a 7.5% sub-legal proportion and a mean size of 97.9 mm for the dredge survey. This result is similar to that of the 2017 Sub-Area 6A video survey, with a marked difference between the video and dredge survey size structures (37% compared to 1.2 % sub-legal proportions, respectively), noting that only a small number of dredge shots and video transects could be compared (Ewing et al. 2018). Importantly in the 2020 video survey, juvenile scallops as small as 34 mm could be counted and measured, indicating recent recruitment, whereas scallops less than 70 mm were not detected in the 2020 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 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. A similar approach has been employed to ground-truth the video survey method using dive surveys on a small scale (Ewing & Lyle 2017) and with asynchronous comparison to a previous dredge survey (Ewing et al 2018). A more comprehensive set of data collected from contemporaneous video and dredge surveys over a pre-determined period would provide a robust basis for interpreting data from subsequent video surveys.

It is also recommended that concurrent with on-going use of the video survey technique, further development of the survey method is undertaken, particularly regarding two major aspects of the analysis of video footage. Firstly, analysis is currently time consuming, as it needs to be done manually. However, with automated image analysis being developed in several scallop fisheries to improve time-efficiency (e.g., Wyatt 2019; Richards et al. 2019; NEFSC 2018; Chang et al. 2016), these techniques could be applied to the Tasmanian camera survey methodologies. To this end, the VIAME application, which is an open-source system for analysis of underwater video and imagery for fisheries stock assessment developed in cooperation with the US National Oceanic and Atmospheric Administration (see Richards et al. 2019), has been assessed by David Moreno (IMAS) as the most appropriate automated image analysis option available and relatively simple to start trialling with the IMAS video surveys. Secondly, the currently used criteria for determining whether a scallop should be measured, developed in the D'Entrecasteaux Channel video scallop survey (Ewing & Lyle 2017) to avoid introducing an under-sizing bias, is quite conservative, leading to the exclusion of a considerable number of scallops. This could potentially influence the quantification of size structure and biomass. Although restricting measurements to scallops well-aligned with the transect line improved the accuracy of identifying the proportion of legal sized scallops, bringing the percentage of legal sized scallops in video surveys from 15% up to 23% compared to the 20% found by divers, the need to routinely exclude scallops from the analysis could be reduced by further developing the towed camera unit's design, with other scallop video surveys having reduced or removed such issues through targeted camera design specifically for scallop surveys (e.g., Habcam system, NEFSC 2018), whereas the current unit that IMAS uses is an off-the-shelf unit.

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