UPDATE 1: Characterisation of the water and seabed environment of the recently-developed mussel farm in Jervis Bay.

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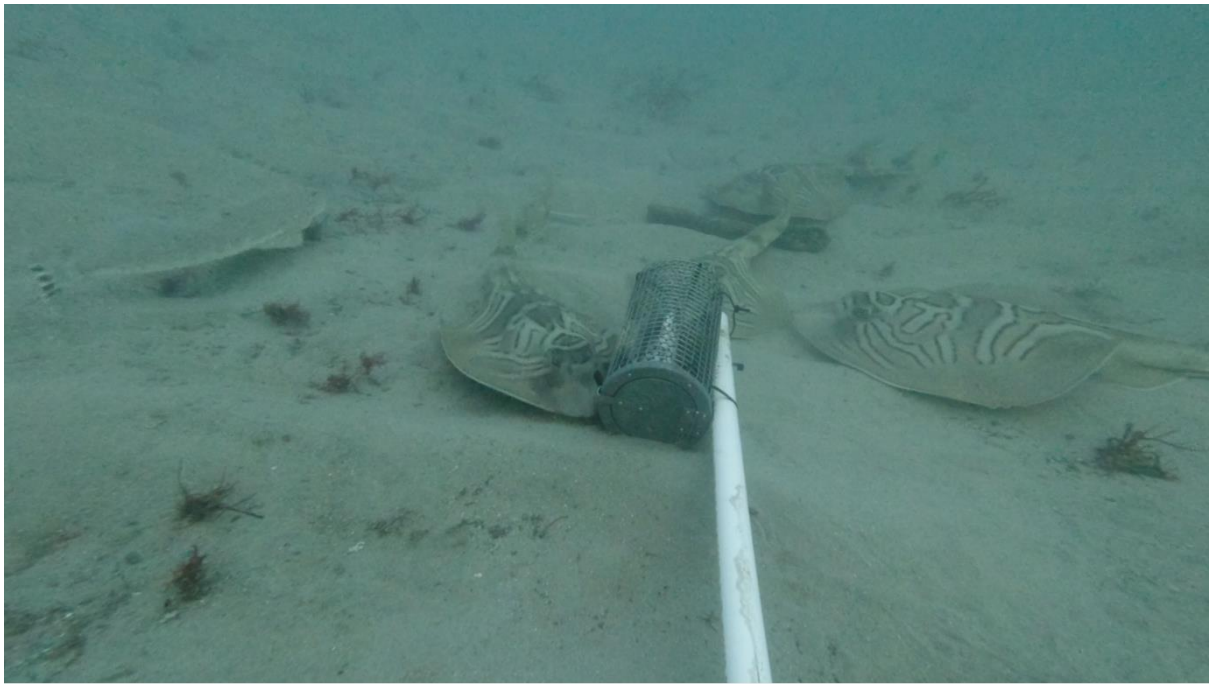


Plate 1 Flathead and Fiddler Rays at Callala North Lease site, observed using BRUVS.

Executive Summary

In August 2020, sampling of the water quality and seabed environment was undertaken at the pre-existing southern (Vincentia) and new northern (Callala North and Callala South) lease sites, with two associated controls for each lease, in Jervis Bay. This sampling represents the Update 1 survey and was sampled in the same way as for the Baseline study in July 2019, enabling non-confounded comparisons.

Water quality varied little among the nine sites and between bottom and surface waters. The waters were cool (16°C), pH was 7.7 and waters were always fully saturated with oxygen. Salinities were slightly less than seawater (32-33) and also of that recorded in Baseline, likely related to heavy rainfalls in late July 2020.

Remote Operated Vehicle (ROV) surveys showed that the seabed at all sites was sandy substrates, with drift algae and small attached macrophytes sometimes present. Small sharks and rays, seastars and some fish of commercial and recreational importance were observed, and also smaller fish species that were associated with drift algae. Masses of drift algae were present at four sites but were not structured in "rows" recorded during Baseline and kelp fragments were still only recorded at Vincentia. Neither flathead (*Platycephalus* spp.) and large schools of Yellowtail Scad were observed during ROV, unlike Baseline, although they were "captured" using BRUVS. Single and small clumps of mussels were sometimes observed on the seabed at CN.L, but with no evidence of darker sediments around those mussels that could imply sediment anoxia. The mooring base now has a substantial amount of encrusting organisms that have developed since Baseline and may eventually impact the durability of the structure. No further inspections of the lease infrastructure or the mussels themselves were undertaken.

The % Total Organic Carbon (%TOC) in the sediments at the Callala North Lease site (where mussels are presently stocked) and all other sites did not change significantly between the two winter sampling periods (Baseline and Update 1), indicating that there is no statistical evidence that the stocking of mussels is acting to increase the %TOC beneath the Lease site. Thus, mean (and SE) values for %TOC at the Callala North Lease site were 0.040 (0.004) at Update 1, which was less than the 0.068 (0.008) at Baseline. The lack of a significant difference means there is no requirement (as per South Coast Mariculture (2015)) to examine and enumerate the benthic macroinvertebrate taxa for this report.

The mean %TOC values from Update 1 were typically lower at Callala North and Callala South (0.040-0.070) than at Vincentia (0.137-0.195), with the %TOC at the three sites in the last location slightly (but not significantly) higher in Update 1 vs Baseline (noting that no mussels are presently stocked at this site). The apparent increase in %TOC at the three sites in Vincentia may warrant future investigation as this indicator of organic enrichment may be arising from sources that are unrelated to the stocking of mussels (see e.g. Pelleteir, 2011).

Sedimentary characteristics of mean grain size and %mud were generally similar to Baseline. Thus, mean grain size was similar between the lease and the two control sites at each of the three locations and significantly smaller at the Vincentia location (167-193 µm) vs Callala North and Callala South (237-263 µm). This pattern in mean grain size was reflected by the %mud being higher at Vincentia (0.11-0.15) vs all other sites (0.01-0.03).

All replicates for the benthic macroinvertebrate taxa were collected, sieved and picked. During picking of the samples, a similar range of taxa was observed to that of Baseline. Samples are safely stored at UoN.

Thirty one of the 36 Baited Remote Underwater Video Systems (BRUVS) deployments recorded a total of 754 organisms. Yellowtail Scad (374) were again very common but were present in smaller schools than in Baseline. Unlike Baseline, substantial numbers of Trumpeter Whiting and Blue-spotted Flathead were observed, which partially explains the significantly higher taxa richness in Update 1. The fish assemblages significantly differed between Update 1 and Baseline, but the biological significance is difficult to assess, given the presently limited understanding of temporal (including annual) changes in fish assemblages in Jervis Bay. The fish assemblages at CN.L (where mussels are presently stocked) were not statistically significant from those of any of the other sites in the study area.

The results from this Update 1 survey, based on water quality, gross seabed characteristics, sedimentary characteristics (particularly %TOC), benthic macroinvertebrate taxa and fishes, provide no evidence that the present stocking of mussels at CN.L is having an adverse effect on the marine environment in this area of Jervis Bay. It is noted that annual sampling is to be continued at the same time of year (winter), with the next occasion expected to be in July/August 2021.

Contents

1. Introduction

A mussel aquaculture lease expansion by South Coast Mariculture in Jervis Bay included a pre-existing lease (Vincentia), which used raft culture and ceased operation in 2008 (Joyce et al., 2010) and two new leases (Callala North and Callala South) to the north (Fig. 1.1). Only one lease site (Callala North) is stocked with mussels, while both Callala South and Vincentia currently have no installed infrastructure.

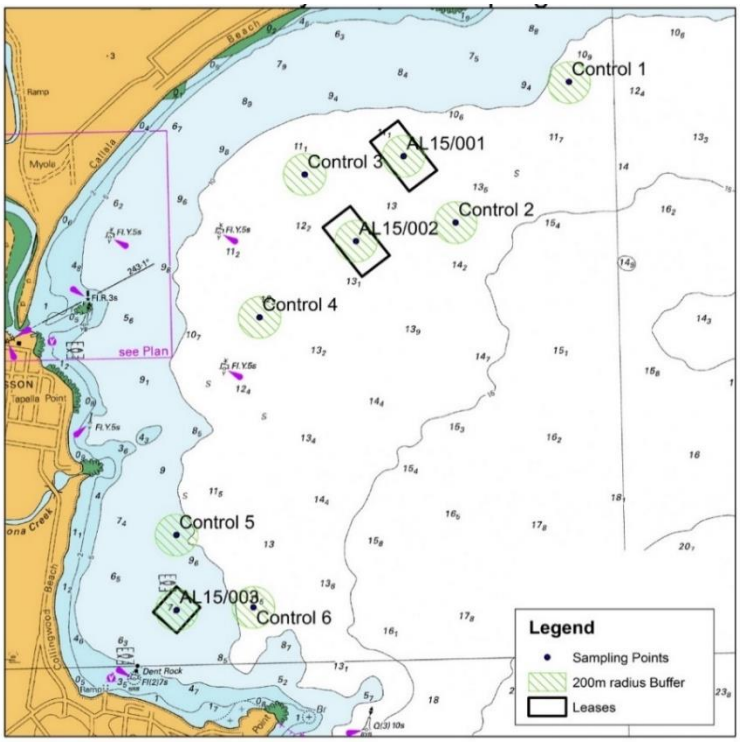
For each of the lease sites there are two control sites that formed the experimental design for the Update 1 survey, which are the same as reported in the Baseline Survey (nine sites in total, Platell et al. 2020). Sampling of the water quality and seabed environment at these nine sites (Fig. 1.1) occurred in August 2020, following the guidelines established in the South Coast Mariculture (2015) Benthic Monitoring Plan for Jervis Bay that was submitted to the NSW DPI.

For the purposes of this report:

AL 15/001 = Callala North Lease (CN.L) with Control 1 and 2 (CN.C1 & CN.C2)

AL 15/002 = Callala South Lease (CS.L) with Control 3 and 4 (CS.C3 & CS.C4)

AL 15/003 = Vincentia Lease (V.L) with Control 5 and 6 (V.C5 & V.C6)



SITE	LATITUDE	LONGTITUDE
AL15/001	35° 1' 22.967"	150° 42' 41.398" E
AL15/002	35° 1' 49.131"	150° 42' 23.020" E
AL15/003	35° 3' 42.802"	150° 41' 13.188" E
Control 1	35° 1' 0.958" S	150° 43' 43.429" E
Control 2	35° 1' 44.008"	150° 43' 0.162" E
Control 3	35° 1' 27.997"	150° 42' 4.545" E
Control 4	35° 2' 12.196"	150° 41' 46.531" E
Control 5	35° 3' 19.414"	150° 41' 13.744" E
Control 6	35° 3' 42.530"	150° 41' 41.706" E

Source: data from NSW DPI and Australian Hydrographic Service
Datum: GDA94 MGA Zone 56

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Prepared by Aquaculture Management October 2015

NSW Department of Primary Industries

Figure 1.1 Map showing location and coordinates of the sampling sites in Jervis Bay (from South Coast Mariculture (2015).

Sampling occurred on the South Coast Mariculture vessel, skippered by Hika Rountree, between 4 and 6 August, 2020. Water quality and sediment (and benthic macroinvertebrate) collection occurred on the first day, with Remotely Operated Vehicle (ROV) and Baited Underwater Remote Video System (BRUVS) sampling over the next two days (Table 1.1).

Table 1.1 Details of sample collection at each of the nine sites for the South Coast Mariculture operations in Jervis Bay. HS - Harrison Smith; FJ - Finlay Johnson; AS - Alessandra Suzzi; BC – Ben Cuerel.

Date	UoN personnel	Water quality	Sediment collection	ROV Survey	BRUVS
4.8.2020	HS, FJ, AS, BC	Completed	Completed		
5.8.2020	HS, FJ, AS, BC			Completed	Partial
6.8.2020	HS, FJ, AS, BC				Partial

2. Water quality

Water quality was measured using a calibrated Horiba u-50 Multiparameter Water Quality Meter, at both the surface and at depth, at the approximate centre of each study site. Parameters included temperature (°C), salinity, pH, turbidity (NTU) and dissolved oxygen (mg/L and % saturation).

The depth was recorded at each site using the depth sounder of the vessel, with Vincentia Lease (V.L) again being shallowest (8.2 m). Most sites ranged between 10.4 and 13.3 m and the deepest site was CN.C2 (15.1 m; Table 2.1).

Table 2.1 Water depth at each of the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded 4 August, 2020.

Area name	Site type	Site name	Water depth (m)
Callala North	Control	CN.C1	12.5
Callala North	Control	CN.C2	15.1
Callala North	Lease	CN.L	13.0
Callala South	Control	CS.C3	12.0
Callala South	Control	CS.C4	13.3
Callala South	Lease	CS.L	12.9
Vincentia	Control	V.C5	10.5
Vincentia	Control	V.C6	10.7
Vincentia	Lease	V.L	8.2

Water quality parameters varied little over the study area (Appendix A) and were similar to Baseline values (Table 2.2). Water quality parameters were similar between surface and bottom waters, except for dissolved oxygen (%) which was slightly greater at depth. The water temperature and salinity are consistent with those for within this region of NSW (CSIRO, 1994) and other parameters consistent with those reviewed by Joyce et al. (2010). The slightly lower salinity in the Update 1 sampling is considered to reflect the nearly 170 mm of rainfall between 26 and 28th July (BOM, 2020a), more than the mean rainfall (104.6 mm) in July between 2001 and 2020 (BOM, 2020b).

Table 2.2 Means (± SE) for water temperature (°C), salinity, pH, turbidity (NTU) and dissolved oxygen (mg/L and % saturation) measured at the surface and at depth for each of the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded 9 July 2019 (Baseline) and 4 August 2020 (Update 1).

Survey	Water column	Water temperature (°C)	Salinity	pH	Turbidity (NTU)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)
Baseline	Surface	15.4 (0.2)	35.7 (0.3)	8.4 (0.0)	6.6 (1.2)	7.4 (0.2)	95.7 (2.5)
	Bottom	15.7 (0.2)	36.3 (0.0)	8.4 (0.0)	8.2 (1.3)	7.8 (0.3)	100.2 (3.0)
Update 1	Surface	15.6 (0.1)	32.3 (0.1)	7.7 (0.0)	4.4 (1.4)	9.9 (1.1)	106.3 (1.1)
	Bottom	16.0 (0.1)	32.7 (0.1)	7.6 (0.1)	4.2 (1.6)	10.4 (0.3)	125.8 (2.6)

3. Seabed survey

The appearance of the seabed was recorded at each site by undertaking 4 x replicate transects for 2 min duration, travelling ~1m above the seabed in a straight line using a BlueRobotics BlueROV2 Remotely Operated Vehicle (ROV) with a Heavy Lift kit modification and 4 LED lights. The ROV was operated through a Panasonic Toughbook and a wireless Logitech controller. Headings were maintained using the stabilize mode function, which holds the heading automatically using the on-board compass and accelerometer. To help ensure that transects were of similar length between sites, speed was controlled by moving at 25% gain and full forward thrust which leads to a movement speed of ~1m/s. The ROV was also used to film the base of the existing underwater infrastructure at Callala North Lease site. The positions of all initial dives were located by GPS. Videos were recorded at 1080p resolution and 30 frames per second.

ROV videos were scored for features of the seabed and any fauna or flora, using timestamps and screenshots. Full details are reported in Appendix C and the main findings, including a "typical" screenshot of the seabed at that site provided in Table 3.1. The digital recordings are stored on a secure University of Newcastle server.

ROV videos showed that the environment at all sites was characterised by pale rippled sand and shell debris, drift algae and small attached macrophytes, with *Luidia* seastars, stingarees (*Trygonoptera testacea*) and Port Jackson Sharks (*Heterodontus portusjacksoni*) sometimes observed. Most notable differences are between the Vincentia sites (more small attached macrophytes and limited drift algae, including kelp) and the more northern sites that contained sometimes extensive areas of combined red/green/brown drift algae, sometimes with the encrusting organisms that are likely pteriid bivalves (Platell et al. 2020).

For the seabed, shell debris was observed whenever the ROV was sufficiently close to the seabed but different molluscs were not able to be distinguished. Some very large feeding pits were observed at CN.C1, presumably from the larger stingrays that occur in Jervis Bay (*Bathytosia* spp).

For the observed fauna, few branching sponges were present at CN.C1 (Table 3.1), which is in contrast to Baseline. The range of elasmobranch and fish species observed included stingarees (*Trygonoptera testacea*), Eastern Fiddler Ray (*Trygonorrhina fasciata*), Port Jackson shark (*Heterodontus portusjacksoni*), apogonid, labrid, sillaginid and carangid fishes, and a suspected Yellowtail Kingfish was sighted at CS.L. Some species were not sighted in Update 1, such as the stingaree *Urolophus cruciatus,* flathead (*Platycephalus* spp.), and Yellowtail Scad was recorded, but not in the large schools

that were recorded in Baseline. For flathead, however, there were also further identifcations to species, rather than genus level. Larger inververtebrates again included the *Luidia* seastar and seapens (Table 3.1)

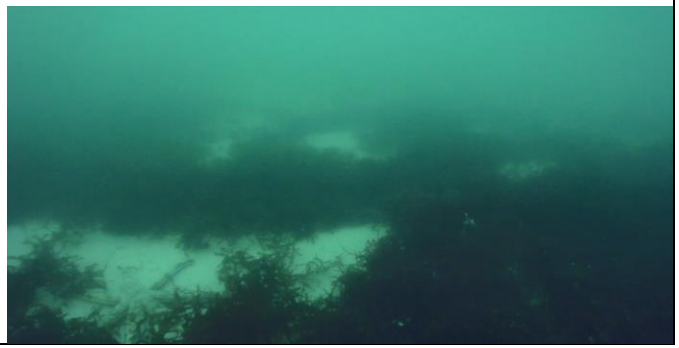
For the observed flora, there was sparse drift algae and small attached macrophytes at the three sites at Callala North, with some larger clumps also at CN.C2 and CN.L. However, the extensive and profuse "rows" of drift algae recorded at Baseline at three sites (CN.C2, CS.C3 and CS.C4), and which were present but less developed at CS.L., were not observed in Update 1, although very large masses of drift algae were observed at both CS.C3 and CS.C4 during the present survey. Kelp fragments were only observed at Vincentia, as also in Baseline.

Single and small clumps of mussels were sometimes observed on the seabed at CN.L, but with no evidence of darker sediments around those mussels. The mooring base now has a substantial amount of encrusting organisms that have developed since Baseline. The ROV was not used to make further further inspections of the lease infrastructure or the mussels themselves.

Table 3.1 Summary of the observations for ROV filming for each of the nine sites, for the South Coast Mariculture operations in Jervis Bay, recorded 5 August 2020. Note that a question mark before the name of an organism indicates that identification is most likely to be accurate, but cannot be confirmed owing to key features not being observed.

Site	Total Duration (min)	Site Type	Comments	Images
CN.C1	8:15	Control	**Seabed**: Rippled pale sand, some shell debris, occasional feeding pits **Fauna**: Sponge, seapens, *Luidia* seastar and a ?sea tulip **Flora**: Sparse drift algae and some small attached macrophytes **In Baseline,** greater amounts of sponges were observed	
CN.C2	8:11	Control	**Seabed**: Rippled pale sand, one small rock outcrop **Fauna**: None observed **Flora**: Sparse to clumps of drift algae and some attached macrophytes **In Baseline**, there were dense, profuse rows of drift algae and there were far more fish (schools of 100 + sandy sprat and Yellowtail Scad, apogonids over drift algae, large flathead, fanbellied leatherjacket *Monacanthus chinensis*, wrasse and *Luidia* seastar)	

Site	Total Duration (min)	Site Type	Comments	Images
CN.L	8:13	Lease	**Seabed**: Rippled pale sand, little shell debris (some suspected dark), one large feeding pit **Fauna**: Schools of apogonids near drift algae, *Luidia* seastars, stingaree *Urolophus testacea,* wrasse and scalyfin also associated with algae, single and clumps of mussels observed, no darker sediments beneath **Flora**: Small attached macrophytes, sparse drift algae, a few larger and sometimes quite substantial accumulations of drift algae **In Baseline,** the large accumulations of drift algae were not present and no fish were seen	
CN.L.1	2:02	Lease Infrastructure	**Mooring base:** Relatively heavily covered with encrusting organisms **Mooring line**: Algal growth and some encrusting organisms near base, not followed up to surface **Mooring top**: Not followed up to surface **In Baseline,** there was very little growth and the large iron hoop was clearly visible, line was followed by the ROV up to the surface	
CS.C3	12:12	Control	**Seabed**: Rippled pale sand patches between drift algae **Fauna**: Schools of small fish (probably agogonids or labrids), ?sea urchin and unknown white objects **Flora**: Dense rows of drift algae, appears a mixture of green/brown/red algae, some white encrusting organisms (suspect some pteriids), small attached macrophytes, a few pieces of drift kelp **In Baseline**, there were also schools of small fish, but large sponges and an Eastern Fiddler Ray were also observed	

Site	Total Duration (min)	Site Type	Comments	Images
CS.C4	16:38	Control	**Seabed**: Rippled pale sand patches between drift algae, little shell debris **Fauna**: Some small fish and an Eastern Fiddler Ray *Trygonnorhina fasciata* **Flora**: Clumps and large masses of drift algaevery few/some white encrusting organisms, some small attached macrophytes, **In Baseline**, drift algae was present in dense rows and other fish species observed (stingaree *Trygonoptera testacea*, apogonids, Port Jackson Shark *Heterodontus portusjacksoni*, striped wrasse and flathead)	
CS.L	8:08	Lease	**Seabed**: Rippled pale sand areas, some medium areas between drift algae, some shell debris **Fauna**: Schools of small fish (perhaps apogonids), some larger fish, inc wrasse and a ?Yellowtail Kingfish, *Luidia* seastar and branching sponge **Flora**: Some small rows and clumps of drift algae with white encrusting organisms, small attached macrophytes **In Baseline**, drift algae was present in less dense rows and other fish species also observed (stingaree *Trygonoptera testacea* and *Urolophus cruciatus* and flathead), but not a Yellowtail Kingfish	

Site	Total Duration (min)	Site Type	Comments	Images
V.C5	8:08	Control	**Seabed**: Gently rippled pale sand areas (generally large), shell debris, few feeding pits **Fauna**: *Luidia* seastar, 2 x Port Jackson Sharks, Brokenline Wrasse and school of small fish over drift algae **Flora**: Sparse clumps of drift algae and loose kelp, sometimes larger clumps with white encrusting organisms, small attached macrophytes **In Baseline,** sand appeared more bioturbated with more frequent feeding pits, less clumps of algae and none had white encrusting organisms and a large school of Yellowtail Scad was present	
V.C6	8:20	Control	**Seabed**: Gently rippled pale sand areas, shell debris, feeding pits, some larger, more rippled areas **Fauna**: Sponge, suspected whiting, Stingaree *Trygonoptera testacea* **Flora**: Sparse drift algae and loose kelp, sometimes clumps of drift algae, small attached macrophytes, some larger attached macrophytes **In Baseline,** sand appeared more bioturbated, there were no clumps of drift algae and a seapen was observed	

Site	Total Duration (min)	Site Type	Comments	Images
V.L	8:11	Lease	**Seabed**: Gently rippled pale sand areas, shell debris, some feeding pits **Fauna**: None observed **Flora**: Very sparse drift algae clumps, some fragments including kelp, small attached macrophytes **In Baseline**, areas appeared more bioturbated, and stingarees were observed	

4. Sedimentary characteristics and benthic macroinvertebrates

Invertebrates and sediment were collected using a 3L Ekman grab within 200 m of the centre point of each sampling site. Six samples were taken from each site, with 30 g sub-samples taken for Total Organic Carbon (TOC) and grain size analyses. All TOC and grain size samples were were placed into separate, labelled plastic bags and on ice until the end of the day. These samples were then frozen until analysis, with TOC samples being transported to ALS Newcastle for analysis. Invertebrate samples were sieved through a 1 mm mesh and preserved in 70% ethanol on the same day of collection.

4.1. Sediment – Total Organic Carbon

TOC was expressed as a percentage of the weight of the total sample for each sample (raw data for %TOC is provided in Appendix C). The %TOC data were initially analysed using a two-way ANOVA, with factors being Time (Baseline, Update 1) and Site (nine sites). The factor Time ($F_{8,90}$ = 0.052, P > 0.05) and the interaction term Time x Site ($F_{8,90}$ = 1.795, P > 0.05), were not significantly different, which implies no change in %TOC between the two sampling occasions and that the overall pattern of differences also remained similar, i.e. no significant tendency for the lease sites to show a greater (or lesser) %TOC between the two periods.

There was little consistent difference in %TOC between sites in the two sampling periods (Figure 4.1). The %TOC values from Update 1 are lower in the three Callala North sites (the location which included the Lease site at which mussels were stocked at that Lease site), and similar or slightly higher in the three more southern sites (Callala South and Vincentia) – where no mussels are yet stocked. For the Lease site at Callala North (where mussels are currently stocked), mean (and SE) values were 0.040 (0.004) at Update 1 and 0.068 (0.008) at Baseline.

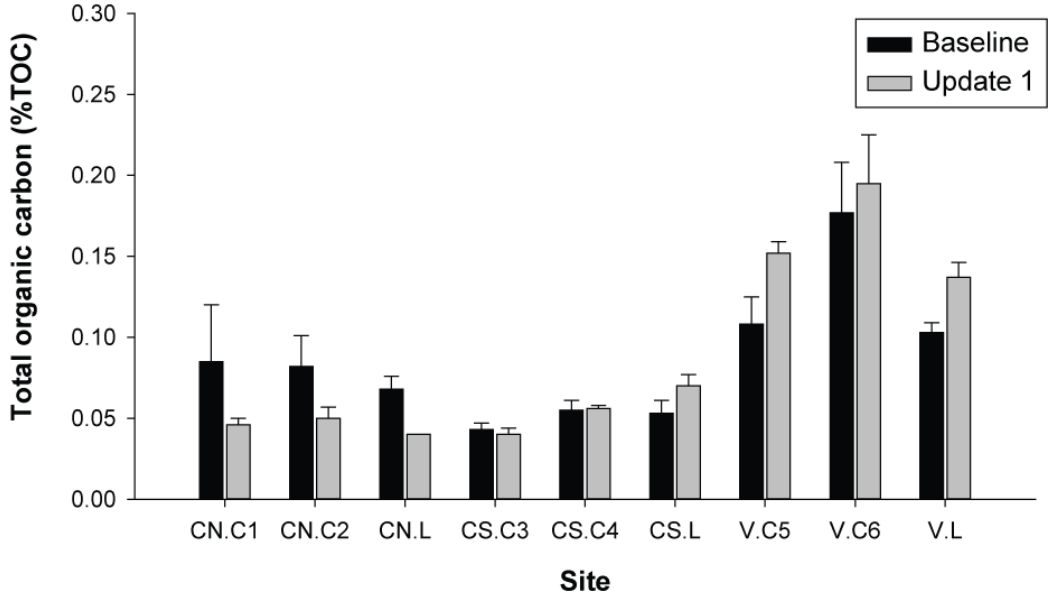


Figure 4.1 Mean (+ SE) of Total Organic Carbon (%TOC) from each of the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded at Baseline (9 July 2019) and Update 1 (4 August, 2020).

Both two-way ANOVA ($F_{8,90}$ = 18.921, P < 0.000) and one-way ANOVA ($F_{8,45}$ = 24.777, P < 0.000) of just the Update 1 samples detected a significant difference among sites, with pairwise comparisons demonstrating that the %TOC was lower at the three sites in each of Callala North and Callala South, i.e. mean %TOC ranging between 0.040 and 0.072, in comparison to at Vincentia, i.e. 0.136 – 0.195.

This apparent increase in %TOC at the sites in Vincentia, a site at which mussels are not directly stocked, may warrant further investigation as this indicator of organic enrichment may be arising from a different source (see e.g. Pelleteir, 2011).

Research relating to %TOC has shown that:

(1) Globally, ranges from 0.01 to ~20, with a median concentration of 0.62 and the 25th-75th percentile range of 0.34 to 1.22 (Seiter, 2004)
(2) Sites of ~20 to 5000 m in depth around Australia ranged from 0.02 to 2 (Radke et al., 2017) and are considered to be relatively impoverished in comparison to global waters (Seiter, 2004)
(3) An investigation by GeoScience Australia (2008 and 2009) in waters to the south in Jervis Bay returned mean values of 0.15 and a maximum of 0.30.
(4) Matthai et al. (2009), in the Hawkesbury-Nepean River, considered a value of 10 to represent organic enrichment (note this is an approximate order of magnitude greater, but this is an urbanised estuary).
(5) Carroll et al. (2003), examining fish farms in Norway, determined that less than 0.02 indicates an “excellent” environmental classification.

4.2. Sediment - Grain size

Samples for grain size were dried for 24 hours at 65°C, weighed to the nearest 2 dp then put through a sediment shaker containing a nested series of sieves (0.063, 0.125, 0.25, 0.5, 1, 2 and 4 mm), with a tray below for those sediment particles of < 0.063 mm in size. The shaker was operated for 5 min for each sample. Sediment on each sieve was weighed to 2 dp and GRADISTAT (Blott & Pye, 2001) was used to calculate the mean grain size and percentage (%) mud in each sample.

The mean grain size and %mud and were analysed using a a two-way ANOVA, with factors being Time (Baseline, Update 1) and Site (nine sites), to ascertain whether there were any significant differences that involved Time, and then to examine for any differences between sites in Update 1.

For mean grain size, there was a significant difference between both Time ($F_{1,80}$ = 4.97, P < 0.05) and Site ($F_{8,80}$ = 13.38, P < 0.001) but no interaction between the two (P > 0.05). For Update 1 only, Tukey’s test demonstrated there were no significant differences for mean grain size among sites in both Callala South and Vincentiana, while the mean grain size at CN.C2 was significantly lower than the other two sites at Callala North, which was similar to Vincentina sites. Two-way ANOVA of %mud also found a difference among Sites ($F_{8,79}$ = 23.067, P < 0.001) but not for either Time or the Time x Site interaction. There were no significant difference in % mud among sites within a location (i.e. CN.C1 = CN.C2 = CN.L; CS.C3 = CS.C4 = CS.L; V.C5 = V.C6 = V.L) for just Update 1.

Site CS.C3 has the largest mean grain size (284.3 µm) and site V.L the smallest grain size (124.8 µm; Fig. 4.2a). Conversely, the %mud values were greatest in V.C6 (0.15), only slightly higher than the two other sites in Vincentiana and far exceeding those of the sites in Callala North and Callala South (Fig. 4.2b).

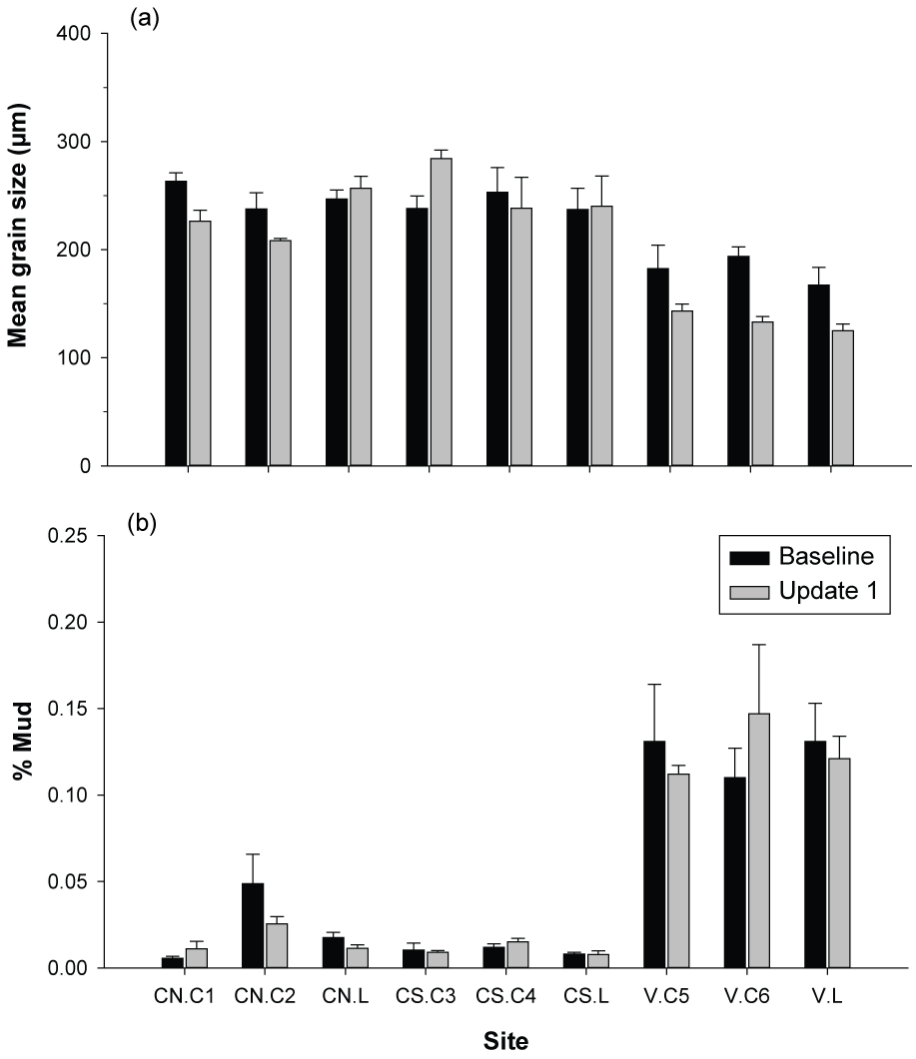


Figure 4.2 Mean (+ SE) of (a) mean grain size (µm) and b) percentage mud, extracted via Gradistat (Blott & Pye, 2001), for each of the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded at Baseline (9 July 2019) and Update 1 (4 August, 2020).

The cumulative grain size curves for the different sampling locations each approach the asymptote (>90%) at 0.250 mm (Figures 4.3a, b and c). Locations Callala North and Callala South have similar cumulative grain size curves, however, an increase in the importance of smaller grain sizes at Vincentia, particularly site V.L, shows a different curve.

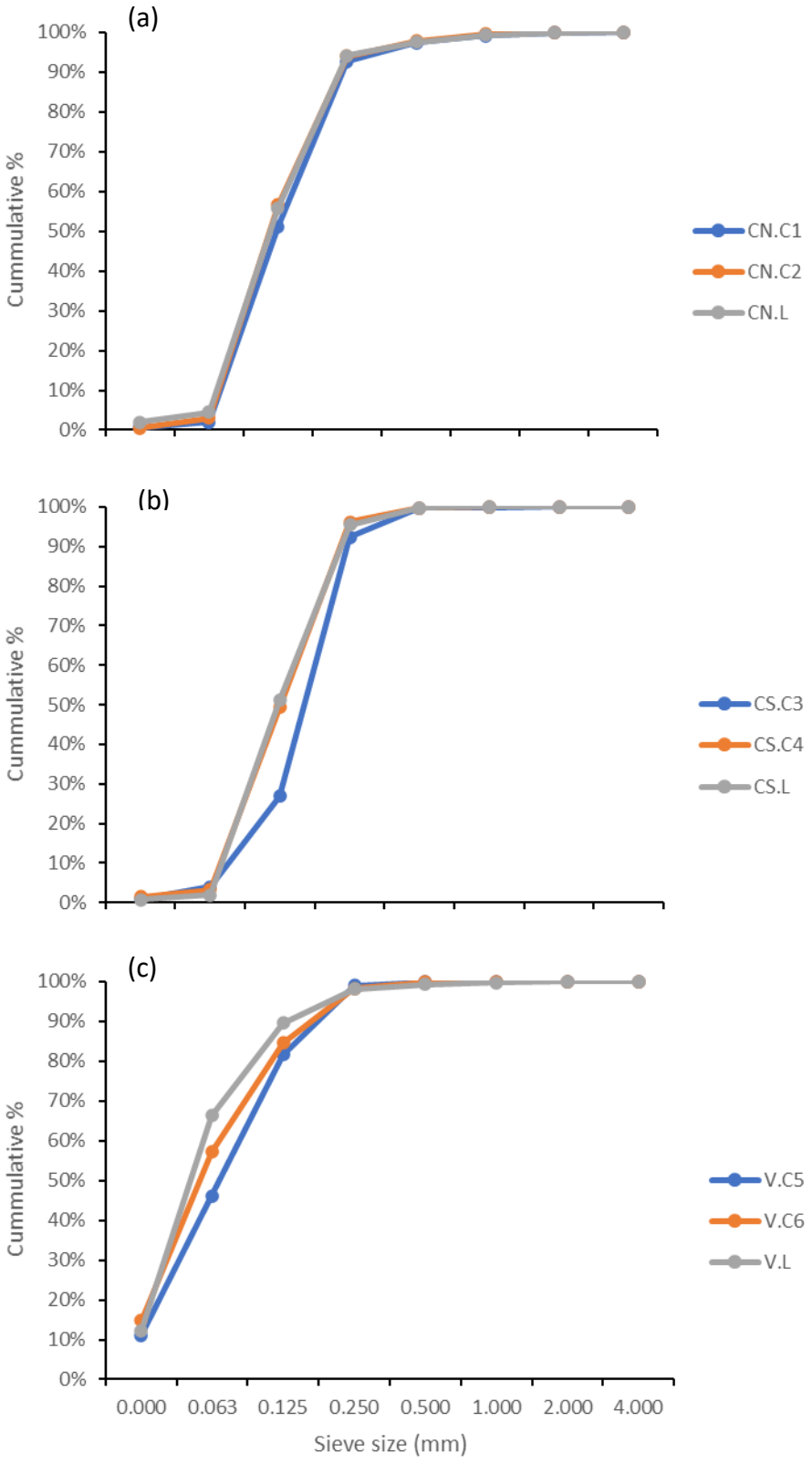


Figure 4.3 Cumulative percentage (%) grain size fractions for (a) Callala North, (b) Callala South and (c) Vincentia locations for each of the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded at Update 1 (4 August, 2020).

4.3. Benthic macroinvertebrates

All samples containing benthic macroinvertebrates were sieved through a 1 mm mesh brass sieve directly after collection onboard the sampling vessel from South Coast Mariculture Operations. The residue on the sieve – which contained macroinvertebrates, small amounts of sediment, some algae and shell grit was generally less than 200 mL in volume. Samples were stored separately in 70% ethanol (500 ml containers) and transported to UoN Ourimbah campus for subsequent laboratory examination.

The %TOC results, which showed no significant difference from Baseline, indicated that there was no requirement for subsequent examination of the samples for enumeration of the different taxa that would lend itself to the types of analyses that were presented in the Baseline report (Platell et al., 2020). However, the samples were subjected to preliminary procedures in the laboratory to ensure appropriate long-term preservation of the samples. Thus, each sample was rinsed with water through a fine-mesh sieve (250 µm), such that all material was retained and then examined under a dissecting microscope. Animals were removed using fine forceps (picking) and identified to a relatively coarse taxonomic level and their presence recorded for each of the 54 samples (see Appendix C), and then stored in 70% ethanol within a flammable cupboard.

A wide range of taxa was again observed (Appendix D), and which was consistent with that recorded for Baseline (Platell et al., 2020)

5. Fish

5.1. Methods of observation and video analysis

Fish communities were investigated using baited remote underwater video systems (BRUVS), consisting of a GoPro camera mounted on a 5 kg free weight, attached to a 50 cm PVC pipe at the end of which a mesh bait bag was attached. A 15-20 m rope, with a marked float, was attached to the 5 kg weight for easy retrieval. Four separate BRUVS were baited with 3-4 crushed pilchards and deployed within 200 m of the centre point of each sampling site for a period of 30 min.

Video footage was downloaded from each GoPro, placed on the UON Marine Research cloud storage into clearly marked folders and later viewed using Event Measure™ to determine the species present at each sampling site and their MaxN (maximum number of fish viewed at any one time). To assist with species identifications and correct nomenclature for fishes, Kuiter (1990), Gomon et al. (2008) and FishBase (2020) were used, while for the invertebrates, Edgar (1997) was used.

5.2. General description

Of the 36 BRUVS drops, five did not return usable footage, with the water either being too turbid, or by having fell in awkwardly (sometimes vision obscured by algae), with three (rather than four) replicates available for CN.CL, CS.C4, and each of the three sites at Vincentia (Appendix E).

At least 18 species and a total of 754 organisms were observed, including 30 sharks, 133 rays, 563 bony fishes and 28 echinoderms (Table 5.1). As with Baseline, the most numerous fish was Yellowtail Scad (374), in which moderate numbers were recorded at most replicates and at all sites, although total abundance was less than in Baseline (687). Next most abundant were the Trumpeter Whiting (121), which was not recorded in Baseline, followed by the Eastern Fiddler Ray (85) and the Flathead (unidentified and the Blue-spotted - 50), both of which were observed at all sites and were more abundant than in Baseline (30 and 32, respectively). Brittle Stars were the most conspicuous echinoderm at the three study sites in Vincentia (Table 5.1).

Table 5.1 MaxN of the sharks, rays, fish and invertebrate taxa, overall, for the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded in Update 1 (5-6 August 2020).

Main groups	Common Name	Species Name	Number
Sharks	Port Jackson Shark	*Heterodontus portusjacksoni*	24
	Gummy Shark	*Mustelus antarcticus*	6
Rays	Eastern Shovelnose Ray	*Aptychotrema rostrata*	22
	Eastern Fiddler Ray	*Trygonorrhina fasciata*	85
	Smooth Stingray	*Bathytosia brevicaudata*	2
	Common Stingaree	*Trygonoptera testacea*	13
	Southern Eagle Ray	*Myliobatis tenuicaudatus*	11
Fish	Eastern Fortescue	*Centropogon australis*	2
	Flathead	*Platycephalus* spp.	5
	Blue-spotted Flathead	*Platycephalus caeruleopunctatus*	45
	Sand Whiting	*Sillago ciliata*	7
	Trumpeter Whiting	*Sillago maculata*	121
	Longfin Pike	*Dinolestes lewini*	1
	Orange-spotted Puffer	*Torquigener vicinus*	2
	Banded Toadfish	*Torquigener pleurogramma*	6
	Yellowtail Scad	*Trachurus novaezelandiae*	374
Echinoderms	Common Seastar	*Luidia australiae*	5
	Brittle Star	*Ophionereis schayeri*	23
		Total	**754**

5.3. Univariate analyses

The number of fish taxa (taxa richness) and the total MaxN of fish were each analysed using two-way ANOVA with Time and Site as the factors, to explore whether there were differences between Baseline and Update 1 times. To explore site differences within the Update 1 sampling, a one-way ANOVA for Site was conducted. Levene's test showed that taxa richness and total MaxN had similar variances across each group ($P > 0.05$), and thus no transformation was applied. However, total MaxN did not have a similar variance (Levene's = 4.79, $P < 0.001$), with $\log_{10}$ transformation showing little effect, and significance was interpreted at the 1%, rather than 5% level.

There was a highly significant difference in taxa richness between Time ($P < 0.001$) but not Site ($P > 0.05$) and there was no interaction between these two factors (Table 5.2). For total MaxN, no significant differences were detected for either Time or Site or their interaction, and there was a relatively large variation unaccounted for by either of these terms (Table 5.2). Mean taxa richness over the nine sites was significantly greater in Update 1 (5.74, SE = 0.32) than in Baseline (3.11, 0.28) while the mean total MaxN was not significantly different between the two surveys, being 29.2 (8.2) and 23.4 (2.5), respectively.

Table 5.2 Results of two-way ANOVA of Time (for Baseline and Update 1) and Site of the taxa richness and the total MaxN of fish (including sharks, rays and bony fishes) obtained from up to four replicate BRUVS for the South Coast Mariculture operations in Jervis Bay, recorded at Baseline (10-11 July 2019) and Update 1 (5-6 August 2020). Df, degrees of freedom; MS mean squares. Significant values in bold.

Source	Df	MS	F	*P*
Taxa richness (two-way)				
Time	1	69.4	**31.879**	**<0.001**
Site	8	3.4	1.559	0.168
Time x Site	8	3.7	1.697	0.129
Residual	40	2.2		
Total MaxN (two-way)				
Time	1	525.1	0.463	0.005
Site	8	173.6	0.153	0.996
Time x Site	8	799.3	0.704	0.686
Residual	40	1135.3		

One-way ANOVA for taxa richness showed that there was a significant difference between Site for the Update 1 survey (Table 5.3), with means ranging from 4 at both CS.C4 and V.L. to nearly double (7.25) at CN.C1 and CS.L (Figure 5.1a). The total Max N also differed significantly with Site, and Tukey's test showed that mean values were significantly lowest at CS.C4, V.C6 and V.L (i.e. 9.3-10.3) in comparison to CN.C1 (40.5), with the mean values for the other five sites ranging between 19.5 and 33.8 (Figure 5.1b). The standard errors (and thus variation) for the mean total MaxN were greater in Baseline than in Update 1 (Figure 5.1b), indicating that there is less variability in numbers in the present survey (Table 5.3). This trend is perhaps related to the schooling behaviour of fish changing between the two periods, but the same trend was not evident for taxa richness (Figure 5.1a). Variation in taxa richness and fish abundances between the two different sampling times are likely to be driven by local natural variation.

Table 5.3 Results of one-way of Site (for Update 1) of the taxa richness and the total MaxN of fish (including sharks, rays and bony fishes) obtained from up to four replicate BRUVS for the South Coast Mariculture operations in Jervis Bay, recorded at Baseline (10-11 July 2019) and Update 1 (5-6 August 2020). Df, degrees of freedom; MS mean squares. Significant values are in bold.

Taxa richness (one-way)				
Site	8	5.79	**2.679**	**0.032**
Residual	22	2.16		
Total MaxN (one-way)				
Site	8	434.9	**4.568**	**0.002**
Residual	40	95.2		

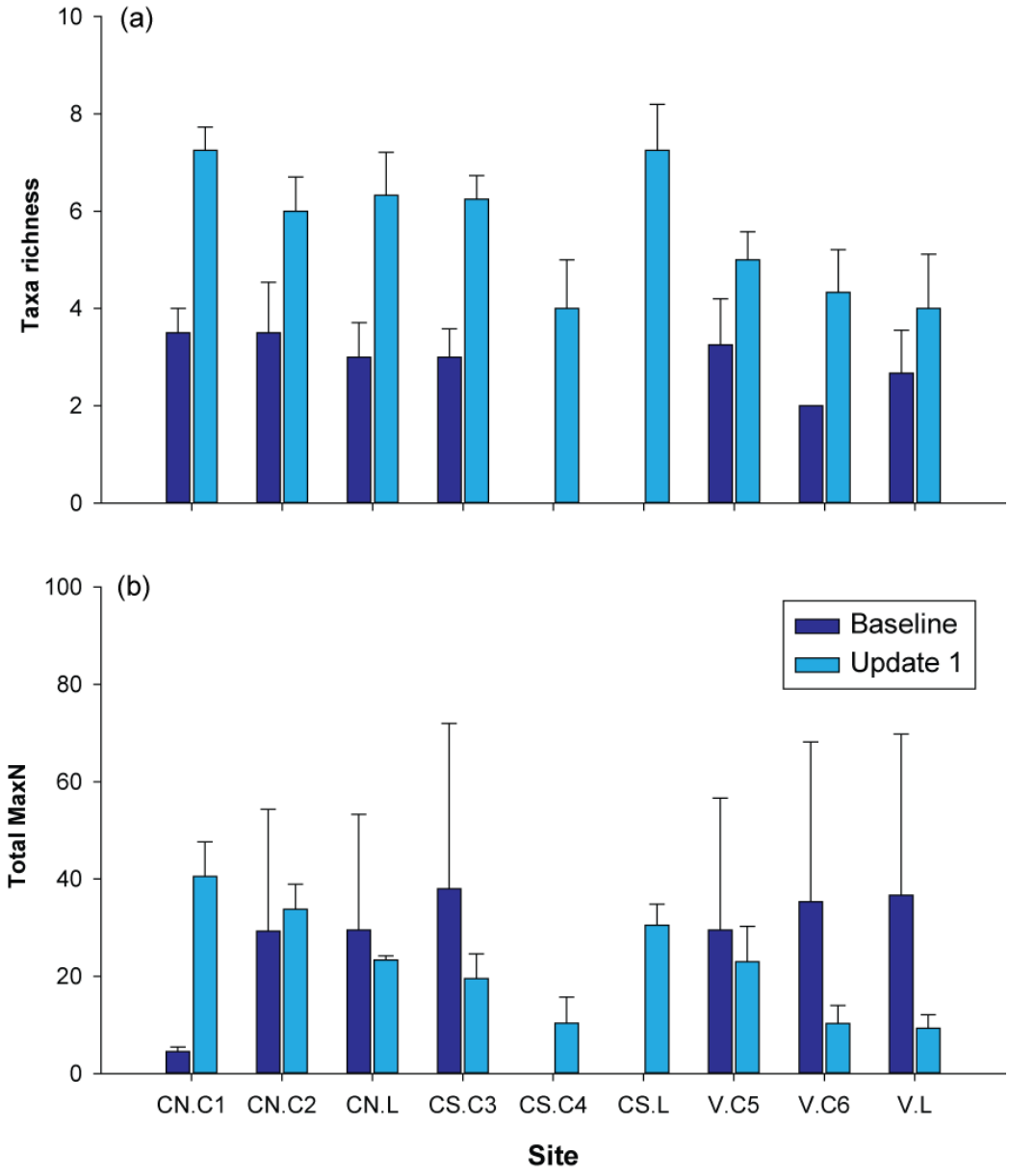


Figure 5.1 Mean (+ SE) taxa richness (a) and the total MaxN of of the sharks, rays and fishes (b) obtained from up to four replicate BRUVS (single values only for CS.C4 and CS.L) for the South Coast Mariculture operations in Jervis Bay, recorded in Baseline (10-11 July 2019) and Update 1 (5-6 August 2020).

5.4. Multivariate analyses

Multivariate analyses were used to examine for trends in the fish assemblages (including fish, sharks and rays), using samples from all sites as such analyses cope better with unbalanced replication. Invertebrates were excluded from the analyses, as they were not the focus of this report.

The MaxN of the different sharks, rays and fishes recorded for the all samples from Baseline and Update 1 were analysed in PRIMER 7 (Clarke and Gorley, 2016), each $\log_{10}$ transformed and the Bray-Curtis measure used to calculate a similarity matrix. This matrix was analysed using two-way (testing for Time and Site) and one-way (testing for site differences for Update 1 only) PERMANOVA (Anderson et al., 2008). Thus, both main and pairwise tests, using unrestricted permutations of the raw data and Type III sums of squares, were conducted.

PERMANOVA showed that there was a significant overall difference for fish assemblages between Baseline and Update 1 (P = 0.001) with the greatest Pseudo-F recorded, indicating this was the strongest effect in the model (Table 5.4). The nine sampling sites (P = 0.013) and the interaction term (P = 0.001) were both also significant, but had lower Pseudo-F and thus weaker effects (Table 5.4).

Table 5.4 Results of one-way PERMANOVA, based on Site, of the Bray-Curtis similarity matrix derived from the $\log_{10}$ transformed MaxN of the various sharks, rays and fish obtained from up to four replicate BRUVS at each of the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded 10-11 July 2019. Df, degrees of freedom; MS, mean squares. Significant values are in bold.

Source	Df	MS	Pseudo-F	*P*
Two-way ANOVA				
Time	1	23123	**18.795**	**<0.001**
Site	8	2173.7	**1.767**	**0.013**
Time x Site	8	3578.4	**2.908**	**0.001**
Residual	40	1230.3		
One-way ANOVA				
Site	8	2460.8	**2.834**	**0.001**
Residual	22	868.4		

On the nMDS ordination plot generated from the same similarity matrix used for two-way PERMANOVA, there is a clear grouping by sampling time (Figure 5.3a). SIMPER analyses (Clarke and Gorley, 2006) showed that fish assemblages were dominated by The Eastern Fiddler Ray and Yellowtail Scad during both surveys, but that there were consistently greater MaxN of both species in Update 1 than Baseline, and both Trumpeter Whiting and Blue-spotted Flathead were recorded only (and as reasonable MaxNs) in the Update 1 Survey. It is noted that Flathead spp., may have included the Blue-Spotted Flathead in each survey, but insufficient visual details were available for further identification to species, i.e. distinguishing features were not always visible.

For the nMDS plot showing the samples from only Update 1 the four replicate samples from CN.C1 now lie close together in the centre of the plot (unlike in Baseline – Platell et al. (2019) , and close to the other two sites in Callala North (Figure 5.3a). As for Baseline, the replicate samples for the other sites are scattered over the plot, and there is no tendency for the samples from CN.L (where mussels are presently stocked) to form a separate group. Pairwise PERMANOVA showed that there were no

significant differences in the fish assemblages between CN.L vs any other sites, or between the three sites in each location, apart from those of CS.C4 and CS.L (P = 0.037). The other significant site differences involved CN.C1 and CN.C2 vs CS.C4, V.C6 and V.L (P=0.02-0.036), respectively, and V.C6 vs CS.C3 and CS.L (P = 0.031).

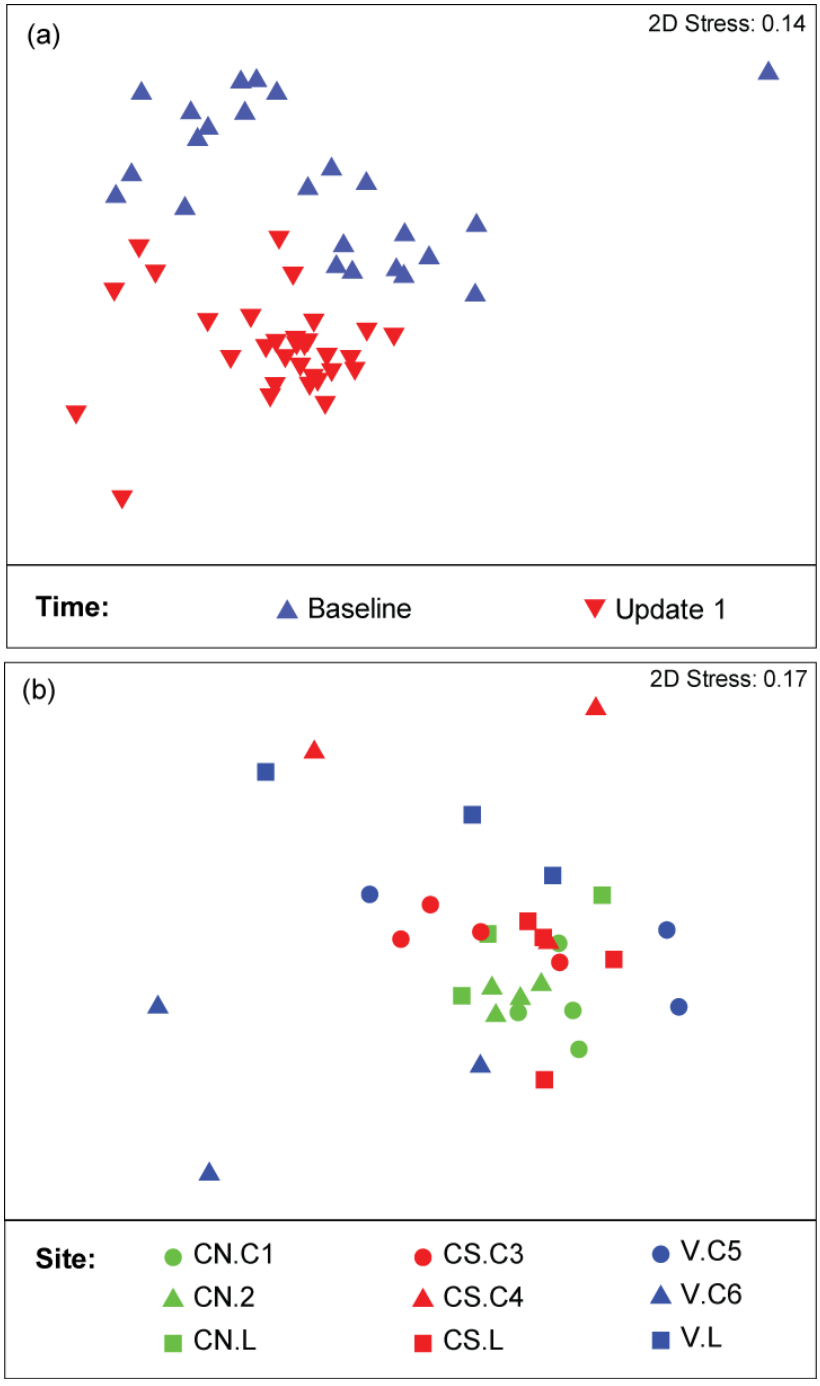


Figure 5.2 nMDS ordination of the Bray-Curtis similarity matrix derived from the $\log_{10}$ transformed abundances of the sharks, rays and fishes observed in up to four replicate BRUVS at each of the nine sites for the South Coast Mariculture operations in Jervis Bay, shown for both (a) Baseline (10-11 July 2019) and Update 1 (5-6 August 2020) and (b) Update 1 only.

In terms of the most widespread fish species, SIMPER showed that Yellowtail Scad were most consistently caught (typified) the fish assemblages at seven of the nine sites and Eastern Fiddler Ray typified six sites across the study area, followed by Trumpeter Whiting which was a typifying species at five of the six sites in Callala North and Vincentia, but not Callala South. The remaining, less common species that typified the fish assemblages included the Blue-spotted Flathead (CN.C1, CN.C2 and V.6), Eagle Ray (CS.C3) and Port Jackson Shark (CS.C4).

The significant differences between CS.C4 and CS.L were related to consistently greater MaxN of the Eastern Fiddler Ray at the first site and of Yellowtail Scad and Trumpeter Whiting at the second site. The significant differences for CN.C1 and CN.C2 vs CS.C4, V.C6 and V.L were mainly related to the consistently greater MaxN of Blue-spotted Flathead, Trumpeter Whiting and Yellowtail Scad at the two northern sites, while elasmobranchs such as the Eagle Ray were present in consistently greater MaxN at CS.C3 than CN.C2, Port Jackson Shark at CS.C4 and V.L vs CN.C2 and Eastern Shovelnose Ray at V.C6 vs both CN.C1 and CS.C3. Full results are in Appendix F (a, b and c).

6. Summary and conclusions

Update 1 sampling of the water quality and seabed environment at the pre-existing southern (Vincentia, V) and new northern (Callala North and Callala South, CN & CS) lease sites, with two associated controls for each lease, and in comparison to Baseline, demonstrated the following:

Water depth: Ranged between 8.2 m (Vincentia Lease, V.L) and 15.1 m (Callala North Control 2, CN.C2).

Water quality: Varied little among the nine sites and between bottom and surface waters. Salinities were slightly less than that of seawater (32-33), waters were cool (16°C), pH was 7.7 and waters were always fully saturated with oxygen. Salinities were slightly lower than in Baseline, reflecting recent rainfall events.

Seabed ROV: Characterised by pale rippled sand and shell debris, drift algae and small attached macrophytes and small sharks and rays and seastars, as well as some fish of commercial and recreational importance, with smaller fish species associated with drift algae For the seabed and flora, differences between sites were mainly due to the extent of drift algae masses (generally greater in northern sites) and the presence of bioturbation and presence of kelp fragments (Vincentia location). The drift algae masses appear to be related to the presence of small fish. In comparison to Baseline, the extent of branching sponges was less at CN.C1, drift algae appeared as masses, rather than as the drift algae rows at four sites (CN.C2 and all in Callala South) in 2019. Some species were not sighted in Update 1, including the stingaree *Urolophus cruciatus,* flathead (*Platycephalus* spp.) and Yellowtail Scad in the large shools that were observed in 2019. Single and small clumps of mussels were sometimes observed on the seabed at CN.L, but with no evidence of darker sediments around those mussels and the mooring base now has a substantial amount of encrusting organisms that have developed since Baseline. It is noted that the there were no further inspections of the lease infrastructure or the mussels themselves.

Sediments: The % Total Organic Carbon (%TOC) at all nine study sites did not significantly increase (or decrease) between the two winter sampling periods (Baseline and Update 1), indicating that there is no statistical evidence that the stocking of mussels is acting to increase the %TOC. However, the %TOC at the three sites in Vincentia were slightly (but not significantly) higher in Update 1 vs Baseline (noting that no mussels are presently stocked in this location), implying that this indicator of organic

enrichment may be arising from a different source. As for Baseline, mean grain sizes were similar within each of the three study locations, but finer sediments, containing greater % mud were recorded at Vincentia study location.

Benthic macroinvertebrates: The lack of a significant difference at all sites for %TOC means there is no requirement (as per South Coast Mariculture (2015)) to examine and enumerate the benthic macroinvertebrate taxa for this report, although samples were sieved, picked and stored at UoN. During picking of the the benthic macroinvertebrate samples, a similar range of taxa was observed to that of Baseline.

Fish: 18 species and 754 organisms were observed using BRUVS, mainly fish such as Yellowtail Scad (similar to Baseline) but also relatively large numbers of Trumpeter Whiting and Blue-Spotted Flathead (both unlike Baseline) and smaller contributions by elasmobranchs such as the Eastern Fiddler Ray, Eastern Shovelnose Ray and the Southern Eagle Ray. Significantly more taxa were observed in Update 1 than Baseline, while the total MaxN was more consistent at the various sites, implying that smaller schools of fish were more consistently recorded than the larger schools of Yellowtail Scad during Baseline. Multivariate analyses showed that differences between surveys were statistically significant but these may not be biologically significant, as there is a limited understanding of temporal changes in the fish assemblages in this area. The fish assemblages at the site at which mussels were stocked (CN.L) were not significantly different to the fish assemblages at any other site.

The results from this Update 1 survey, based on water quality, gross seabed characteristics, sedimentary characteristics (particularly %TOC), benthic macroinvertebrates and fish, do not provide evidence that the present stocking of mussels at CN.L is having an adverse (and significant) effect on the marine environment in this area of Jervis Bay. It is noted that sampling is to be continued at the same time of year (winter), with the next occasion expected to be in July/August 2021.

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Appendices

Appendix A: Water quality raw data

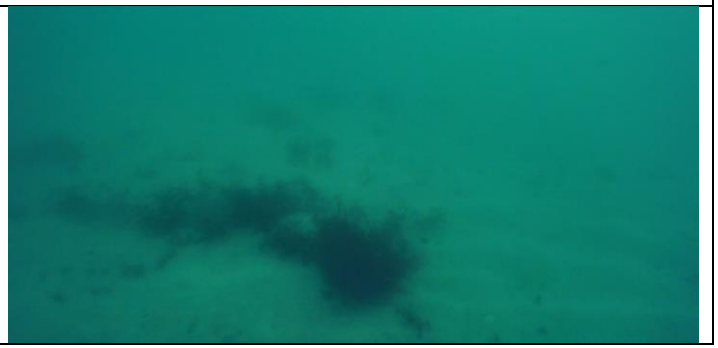
Water quality parameters measured at the surface and bottom of the water column for the nine sites at the South Coast Mariculture operations in Jervis Bay, recorded 4 August 2020.

Site Code	Water column	Temperature (°C)	Salinity	pH	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)
CN.C1	Surface	15.10	31.7	7.59	15.3	8.98	108.7
CN.C2	Surface	15.07	32.1	7.74	2.4	19.08	109.3
CN.L	Surface	15.30	32.0	7.75	1.9	8.55	102.9
CS.C3	Surface	15.60	32.5	7.76	4.7	8.55	105.0
CS.C4	Surface	15.67	32.4	7.74	4.6	8.82	107.3
CS.L	Surface	15.36	32.1	7.79	2.4	8.79	105.6
V.C5	Surface	16.04	32.5	7.79	0.4	8.83	100.1
V.C6	Surface	16.05	32.5	7.78	4.3	8.89	109.7
V.L	Surface	16.11	32.6	7.78	3.6	8.83	108.1
CN.C1	Bottom	16.03	32.8	7.61	16.7	9.70	118.6
CN.C2	Bottom	15.08	32.5	7.78	0.6	9.75	120.0
CN.L	Bottom	16.22	32.7	7.80	2.3	10.65	131.8
CS.C3	Bottom	16.15	33.0	7.00	6.2	9.71	120.4
CS.C4	Bottom	16.14	32.5	7.81	3.5	10.05	122.8
CS.L	Bottom	16.16	32.8	7.03	2.1	10.50	125.1
V.C5	Bottom	16.04	32.6	7.84	2.9	10.70	128.1
V.C6	Bottom	16.03	32.6	7.83	2.1	10.00	122.2
V.L	Bottom	16.03	32.6	7.81	1.5	12.15	143.0

Appendix B: ROV raw data

Details of the ROV footage at each replicate site, for the South Coast Mariculture operations in Jervis Bay, recorded 5 August, 2020. Note that a question mark before the name of an organism indicates that this name is most likely to be accurate, but its identificiation cannot be confirmed owing to key features not being observed.

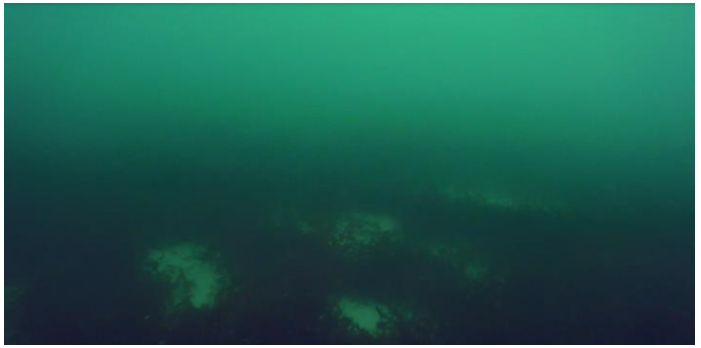
Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
CN.C1.1	Prior to 08:45	2:02	Control	**Seabed**: Rippled pale sand, some shell debris **Fauna**: Large branching sponge (1:07) **Flora**: Small attached macrophytes and sparse drift algae	
CN.C1.2	Prior to 08:45	2:09	Control	**Seabed**: Rippled pale sand, limited shell debris, feeding pit (0.40) **Fauna**: Large *Luidia* seastar (0.25) **Flora**: Sparse drift algae and small attached macrophytes	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
CN.C1.3	Prior to 08:45	2.03	Control	**Seabed**: Rippled pale sand, some shell debris, **Fauna**: Tall sponge (0:28), huge feeding pit (0:54, see right), **Flora**: Limited small attached macrophytes, sparse drift algae, ?*Posidonia* plant (1:10)	
CN.C1.4	Prior to 08:45	2:02	Control	**Seabed**: Rippled pale sand, some shell debris **Fauna**: Seapen (0:16, 0:58), moderate feeding pit (1:00), occasional smaller feeding pits, *Luidia* seastar (1:02, 2:02), ?Sea tulip (1:32) **Flora**: Sparse drift algae, limited small attached macrophytes	
CN.C2.1	08:47:51	2:01	Control	**Seabed**: Rippled pale sand, some shell debris, small rock outcrop (0.34) **Fauna**: None observed **Flora**: ?Large macrophyte (0:41), one clump drift algae (1:47, see right)	

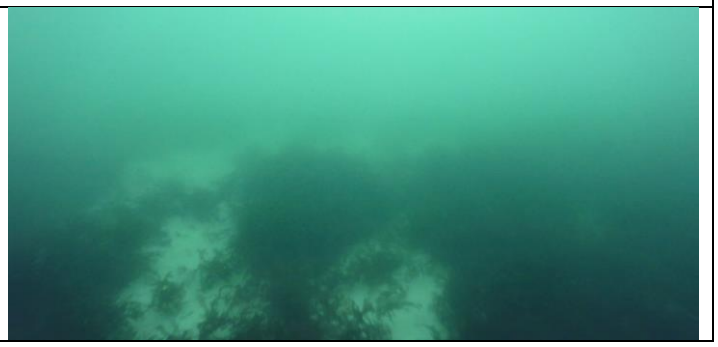
Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
CN.C2.2	08:50:04	2:04	Control	**Seabed**: Rippled pale sand **Fauna**: None observed **Flora**: Some attached macrophytes, small clumps of drift algae	
CN.C2.3	08:52:18	2:03	Control	**Seabed**: Rippled pale sand **Fauna**: None observed **Flora**: Some attached macrophytes, small to moderate clumps of drift algae	
CN.C2.4	08:54:29	2:03	Control	**Seabed**: Rippled pale sand, fine shell debris **Fauna**: None observed **Flora**: Few attached macrophytes, sparse and small clumps of drift algae	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
CN.L.1	08:18:27	2:02	Lease	**Seabed**: Rippled pale sand, limited shell debris **Fauna**: Approx. 50 + small schooling fish (0:30 and O:45, suspect apogonids), encrusting organisms on block (see right), 2 x *Luidia* seastars (1:14, see right, 1:30), a ?scalyfin in drift algae (1:34) **Flora**: Small attached macrophytes, some drift kelp and sparse drift algae, some large, very dense accumulations of drift algae.	
CN.L.2	08:20:32	2:02	Lease	**Seabed**: Rippled pale sand, limited shell debris, feeding pit (1:44) **Fauna**: Dislodged mussel (0:07, see right on far lower left, 1:50) and mussel clump (0:12, see right, 0:13) **Flora**: Small attached macrophytes, some drift algae including clumps, one row of drift green algae (1:30)	
CN.L.3	08:23:04	2:07	Lease	**Seabed**: Rippled pale sand, little shell debris, ?dark shell debris (0:17), large feeding pit (1:38) **Fauna**: Single fish (suspect apogonid, 0.43), dislodged mussel (1:15) and larger clump (1:19, see right), stingaree *Urolophus testacea* (1:50, see right), *Luidia* seastar (1:57) **Flora**: Small attached macrophytes, sparse drift algae, a few larger accumulations of drift algae	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
CN.L.4	08:25:15	2:02	Lease	**Seabed**: Rippled pale sand, no shell debris **Fauna**: Wrasse (0.33, see right in lower left, across clump of algae) **Flora**: Small attached macrophytes, larger accumulations of drift algae but not over whole video	
CN.CL.1	08:18:27	2:02	Lease Infra-structure	**Mooring base:** Relatively heavily covered with encrusting organisms (1:08) **Mooring line**: Algal growth and some encrusting organisms near base, not followed up to surface . **Mooring top**: Not followed up to surface	
CS.C3.1	09:56:16	2:02	Control	**Seabed**: Rippled pale sand patches between drift algae **Fauna**: Small fish, suspect apogonids/labrids (0:07-0:30), wrasse (1.37, 1:50; 2:55), school of ?apogonids (1:38) **Flora**: Dense (and sometimes high) rows of drift algae, including kelp (0:16, see right), some white encrusting organisms (0:20-0:37, 2:00), small attached macrophytes	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
CS.C3.2	09:58:24	2:02	Control	**Seabed**: Rippled pale sand patches between drift algae, shell debris **Fauna**: Single carangid (0.03), ?sea urchin (0.44), ?apogonids (1:28) **Flora**: Dense rows of drift algae (including greens and browns), some white encrusting organisms (0:11-29), see right, 0:48-0.103), small attached macrophytes	
CS.C3.3	10::00:36	2:02	Control	**Seabed**: Rippled pale sand patches between drift algae, some shell debris **Fauna**: 10 + school of small fish (1:33) **Flora**: Dense rows of drift algae with white encrusting organisms (1:10; 1:27-1:30), some loose clumps of drift algae	
CS.C3.4	10:02:45	2:06	Control	**Seabed**: Rippled pale sand patches between drift algae, little shell debris **Fauna**: Two white objects (0:57-0:59), 2 small fish (1:55) **Flora**: Dense rows of drift algae, appears a mixture of green and brown/red algae, some areas profuse, some white encrusting organisms (0:40, 0:50-0.54, 1:33, 1:39)	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
CS.C4.1	10:21:47	2:03	Control	**Seabed**: Rippled pale sand, some shell debris **Fauna**: None observed **Flora**: Clumps of drift algae, one very large mass (1:15-1:33), small attached macrophytes	
CS.C4.2	10:23:58	1:57		**Seabed**: Rippled pale sand **Fauna**: Single small fish (0:20, 0:35) **Flora**: Clumps and some more substantial masses of drift algae, small attached macrophytes	
CS.C4.3	10:25:54	2:03	Control	**Seabed**: Rippled pale sand, some shell debris **Fauna**: 2 x fish (1:06) **Flora**: Clumps of drift algae, one very large mass (1:06-1:25), white encrusting organisms (1:14)	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
CS.C4.4	10:28:07	2:26	Control	**Seabed**: Rippled pale sand **Fauna**: Eastern Fiddler Ray *Trygonnorhina fasciata* (1.43) **Flora**: Clumps and more substantial masses of drift algae, white encrusting organisms (0:20)	
CS.L.1	09:08:24	2:02	Lease	**Seabed**: Rippled pale sand areas and patches between masses of drift algae, odd object (0.05, perhaps a palm frond) **Fauna**: *Luidia* seastar (1:20), 20 + school of small fish (1:24), moderate wrasse in algae (1:47), moderate Yellowtail Kingfish (1:50) **Flora**: Loose clumps of drift algae, more substantial mass (0:50-1:11 and 1:25 to end) containing a very large macrophyte (0:55) and white encrusting organisms throughout	
CS.L.2	09:11:04	2:02	Lease	**Seabed**: Rippled pale sand areas between drift algae **Fauna**: 15 + school of small fish (0:40; 1:25), a larger fish (0:55), 2 x small fish (1;20) **Flora**: Clumps of drift algae with white encrusting organisms, some larger masses (0:33-120), some mall attached macrophytes	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
CS.L.3	09:13:17	2:02	Lease	**Seabed**: Rippled pale sand areas, some medium areas (see right), between drift algae, some shell debris (e.g. 1:13) **Fauna**: School of 20+fish (0:20) **Flora**: Some clumps of drift algae with white encrusting organisms, small attached macrophytes	
CS.L.4	09:15:28	2:04	Lease	**Seabed**: Rippled pale sand patches, some medium areas between drift algae, some shell debris **Fauna**: ?Branching sponge and *Luidia* seastar (0:12, see right), wrasse (1:52) **Flora**: Clumps and larger masses of drift algae (see right), white encrusting organisms, small attached macrophytes	
V.C5.1	11:19:33	2:01	Control	**Seabed**: Gently rippled pale sand areas, shell debris, some feeding pits **Fauna**: *Luidia* seastar (0:01, small Port Jackson Shark *Heterodontus portusjacksoni* (1:32, see right) **Flora**: Occasional clumps of drift algae (0:17, see right), some small attached macrophytes	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
V.C5.2	11:21:20	2:02	Control	**Seabed**: Gently rippled pale sand areas, shell debris, few feeding pits **Fauna**: Buried fish (0:16) **Flora**: Occasional clumps of drift algae and loose kelp (0:48, see right), larger clumps with white encrusting organisms (1:40), sparse small attached macrophytes	
V.C5.3	11:23:56	2:02	Control	**Seabed**: Gently rippled pale sand areas, shell debris, few feeding pits **Fauna**: Brokenline Wrasse (0:24, see right), school of 20+ fish over drift algae clump (0:59) **Flora**: Occasional clumps of drift algae and loose kelp, few larger clumps with white encrusting organisms (0:50, 1:55), sparse small attached macrophytes	
V.C5.4	11:26:05	2:03	Control	**Seabed**: Gently rippled pale sand areas, shell debris, few feeding pits **Fauna**: Port Jackson Shark (0:55) **Flora**: Sparse clumps of drift algae and loose kelp (0:17, see right) , one larger clump with white encrusting organisms (0:20), small attached macrophytes (but large bare areas)	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
V.C6.1	11:35:29	2:01	Control	**Seabed**: Gently rippled pale sand areas, shell debris, feeding pits **Fauna**: Suspected whiting (1:18 and 1:38) **Flora**: Some small clumps drift algae and loose kelp, sparse small attached macrophytes (large bare areas)	
V.C6.2	11:37:39	2:05	Control	**Seabed**: Gently rippled pale sand areas, shell debris, feeding pits **Fauna**: Sponge (0:21, see right) **Flora**: Very sparse drift algae and loose kelp, sparse small attached macrophytes (large bare areas)	
V.C6.3	11:39:50	2:04	Control	**Seabed**: Gently rippled pale sand areas, shell debris, feeding pits **Fauna**: None observed **Flora**: Sparse drift algae and loose kelp, small attached macrophytes	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
V.C6.4	11:42:01	2:10	Control	**Seabed**: Gently rippled pale sand areas, shell debris, feeding pits, some larger more rippled areas **Fauna**: Stingaree *Trygonoptera testacea* (1:19, see right) **Flora**: Sparse drift algae and loose kelp, small attached macrophytes, one larger attached macrophyte (1:26)	
V.L.1	11:59:39	1:59	Lease	**Seabed**: Rippled pale sand areas (see right), shell debris, feeding pits, one large, old (0:23) **Fauna**: None observed **Flora**: Very sparse drift algae, some kelp blades, small attached macrophytes	
V.L.2	12:01.46	2:04	Lease	**Seabed**: Gently rippled pale sand areas, shell debris, feeding pits **Fauna**: None observed **Flora**: Very sparse drift algae, some kelp blades, small attached macrophytes	

Replicate	Time Film Started (24hr)	Duration (min)	Site Type	Comments	Images
V.L.3	12:03:55	2:04	Lease	**Seabed**: Gently rippled pale sand areas, shell debris, feeding pits **Fauna**: None observed **Flora**: Very sparse drift algae clumps (see right), some kelp blades, small attached macrophytes	
V.L.4	12:06:08	2:04	Lease	**Seabed**: Gently rippled pale sand areas, shell debris, feeding pits **Fauna**: None observed **Flora**: Very sparse drift algae clumps (e.g. see right), small attached macrophytes	

Appendix C: TOC raw data

Raw %TOC data for each of the replicate grab samples for the South Coast Mariculture operations in Jervis Bay, recorded 4 August 2020.

Sample Date	Sample Code	TOC (%)
4/08/2020	CN.C1.1	0.06
4/08/2020	CN.C1.2	0.05
4/08/2020	CN.C1.3	0.05
4/08/2020	CN.C1.4	0.03
4/08/2020	CN.C1.5	0.04
4/08/2020	CN.C1.6	0.05
4/08/2020	CN.C2.1	0.04
4/08/2020	CN.C2.2	0.04
4/08/2020	CN.C2.3	0.05
4/08/2020	CN.C2.4	0.03
4/08/2020	CN.C2.5	0.08
4/08/2020	CN.C2.6	0.06
4/08/2020	CN.L.1	0.04
4/08/2020	CN.L.2	0.04
4/08/2020	CN.L.3	0.04
4/08/2020	CN.L.4	0.04
4/08/2020	CN.L.5	0.04
4/08/2020	CN.L.6	0.04
4/08/2020	CS.C3.1	0.03
4/08/2020	CS.C3.2	0.05
4/08/2020	CS.C3.3	0.03
4/08/2020	CS.C3.4	0.05
4/08/2020	CS.C3.5	0.05
4/08/2020	CS.C3.6	0.04
4/08/2020	CS.C4.1	0.05
4/08/2020	CS.C4.2	0.06
4/08/2020	CS.C4.3	0.06
4/08/2020	CS.C4.4	0.06
4/08/2020	CS.C4.5	0.06
4/08/2020	CS.C4.6	0.05

Sample Date	Sample Code	TOC (%)
4/08/2020	CS.L.1	0.05
4/08/2020	CS.L.2	0.06
4/08/2020	CS.L.3	0.06
4/08/2020	CS.L.4	0.1
4/08/2020	CS.L.5	0.08
4/08/2020	CS.L.6	0.08
4/08/2020	V.C5.1	0.16
4/08/2020	V.C5.2	0.13
4/08/2020	V.C5.3	0.14
4/08/2020	V.C5.4	0.18
4/08/2020	V.C5.5	0.14
4/08/2020	V.C5.6	0.16
4/08/2020	V.C6.1	0.23
4/08/2020	V.C6.2	0.29
4/08/2020	V.C6.3	0.08
4/08/2020	V.C6.4	0.24
4/08/2020	V.C6.5	0.18
4/08/2020	V.C6.6	0.15
4/08/2020	V.L.1	0.11
4/08/2020	V.L.2	0.16
4/08/2020	V.L.3	0.16
4/08/2020	V.L.4	0.12
4/08/2020	V.L.5	0.15
4/08/2020	V.L.6	0.12

Appendix D: Benthic macroinvertebrate raw data

Raw benthic macroinvertebrate data, with the presence (X) of the different main taxa for each of the replicate grab samples at (a) Callala North, (b) Callala South and (c) Vincentia, for the South Coast Mariculture operations in Jervis Bay, recorded 5-6 August 2020.

(a) Callala North

Sample	CN.C1.1	CN.C1.2	CN.C1.3	CN.C1.4	CN.C1.5	CN.C1.6	CN.C2.1	CN.C2.2	CN.C2.3	CN.C2.4	CN.C2.5	CN.C2.6	CN.L.1	CN.L.2	CN.L.3	CN.L.4	CN.L.5	CN.L.6
Polychaetes	X	X	X	X	X	X	X				X		X	X	X	X		X
Other worms		X	X	X	X	X	X	X		X	X	X	X		X	X	X	
Bivalves	X		X	X		X	X	X	X					X	X	X		
Gastropods	X		X			X					X	X	X	X	X			X
Ostracods			X				X	X	X	X	X	X	X		X	X	X	
Amphipods	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Isopods		X		X								X				X	X	
Prawns											X			X		X		X
Crabs			X															
Heart Urchins										X			X		X	X		
Brittle Stars	X					X											X	
Anemones	X																	

(b) Callala South

Sample	CS.C1.1	CS.C1.2	CS.C1.3	CS.C1.4	CS.C1.5	CS.C1.6	CS.C2.1	CS.C2.2	CS.C2.3	CS.C2.4	CS.C2.5	CS.C2.6	CS.L.1	CS.L.2	CS.L.3	CS.L.4	CS.L.5	CS.L.6
Polychaetes	X		X	X	X		X		X			X	X	X	X	X	X	X
Other worms						X	X		X	X			X		X	X		
Bivalves	X	X	X	X		X		X	X	X	X	X	X	X	X			X
Gastropods		X	X	X		X		X			X	X	X				X	X
Ostracods		X	X	X	X	X	X	X	X		X	X	X	X		X	X	
Amphipods	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Isopods	X															X		
Prawns																	X	X
Crabs		X								X			X				X	
Heart Urchins																		X
Brittle Stars																X		
Anemones																X		

(c) Vincentia

Sample	V.C1.1	V.C1.2	V.C1.3	V.C1.4	V.C1.5	V.C1.6	V.C2.1	V.C2.2	V.C2.3	V.C2.4	V.C2.5	V.C2.6	V.L.1	V.L.2	V.L.3	V.L.4	V.L.5	V.L.6
Polychaetes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Other worms	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Bivalves	X	X	X	X		X	X	X	X			X	X		X	X	X	X
Gastropods									X				X					
Ostracods	X		X		X				X		X		X					
Amphipods	X		X	X	X	X	X		X	X	X	X		X	X	X	X	X
Isopods			X									X	X		X	X		X
Prawns	X													X				X
Crabs	X							X	X		X	X	X	X	X	X	X	
Heart Urchins	X	X	X	X	X		X		X	X	X	X						
Brittle Stars				X		X					X							X
Anemones		X								X								

Appendix E: BRUVS raw data

Raw data for shark, ray, fish and invertebrate taxa, with MaxN of the different taxa for each of the replicate BRUV samples at (a) Callala North, (b) Callala South and (c) Vincentia, for the South Coast Mariculture operations in Jervis Bay, recorded 5-6 August, 2020.

(a) Callala North

Species name	CN.C1.1	CN.C1.2	CN.C1.3	CN.C1.4	CN.C2.1	CN.C2.2	CN.C2.3	CN.C2.4	CN.L.1	CN.L.2	CN.L.4
Heterodontus portusjacksoni		1	2	2						1	
Mustelus antarcticus	1	1			1		1				
Aptychotrema rostrata	1			1	1	1					1
Trygonorrhina fasciata	4	1	1		4	3	4	7	6	6	6
Bathytosia brevicaudata				1							
Trygonoptera testacea		1		1		1	1				1
Myliobatis tenuicaudatus			1							1	1
Centropogon australis											
Platycephalus spp.											
Platycephalus caeruleopunctatus	4	5	2	1	3	2	3	5		2	3
Sillago ciliata									1		
Sillago maculata	5	4	5	3	2	2	4	9	4	2	5
Dinolestes lewini									1		
Torquigener vicinus					1		1				
Torquigener pleurogramma	1	1		1							1
Trachurus novaezelandiae	19	47	27	18	23	13	17	26	11	13	4
Luidia australiae	2			1							
Ophionereis schayeri		1									

(b) Callala South

Species name	CS.C3.1	CS.C3.2	CS.C3.3	CS.C3.4	CS.C4.2	CS.C4.3	CS.C4.4	CS.L.1	CS.L.2	CS.L.3	CS.L.4
Heterodontus portusjacksoni		1	1	1	1	2	1		3	1	1
Mustelus antarcticus	1										
Aptychotrema rostrata				1				1	1		
Trygonorrhina fasciata	4	4	1	4	1	1	2	2	5	2	4
Bathytosia brevicaudata									1		
Trygonoptera testacea			1			1		1	1	1	
Myliobatis tenuicaudatus	1	1	2	1					1		
Centropogon australis										1	1
Platycephalus spp.									1		
Platycephalus caeruleopunctatus	1	2	1	1		1	1			1	2
Sillago ciliata								4	2		
Sillago maculata	1		5	4	4	5		2	11	7	17
Dinolestes lewini											
Torquigener vicinus											
Torquigener pleurogramma											
Trachurus novaezelandiae	3	6	23	7		11		9	9	16	14
Luidia australiae						1		1			
Ophionereis schayeri											

(c) Vincentia

Species name	V.C5.2	V.C5.3	V.C5.4	V.C6.2	V.C6.3	V.C6.4	V.L.2	V.L.3	V.L.4
Heterodontus portusjacksoni	1		1		1	1	1	1	
Mustelus antarcticus		1							
Aptychotrema rostrata			1		1	12			
Trygonorrhina fasciata			4				4	2	3
Bathytosia brevicaudata									
Trygonoptera testacea				1	1			1	
Myliobatis tenuicaudatus				1		1			
Centropogon australis									
Platycephalus spp.	1	1					1	1	
Platycephalus caeruleopunctatus			1	1	1	1			1
Sillago ciliata									
Sillago maculata	11	6			1			2	
Dinolestes lewini									
Torquigener vicinus									
Torquigener pleurogramma	1		1						
Trachurus novaezelandiae	10	27	2		8		5	6	
Luidia australiae									
Ophionereis schayeri	2	3	2	3	2	5	2	1	2

Appendix F: SIMPER outputs for fish via BRUVS

SIMPER analyses, showing typifying (shaded cells) and distinguishing fish taxa, with an (*) denoting that the taxon makes a consistently greater contribution to the fauna at the top of the column, for those sites identified by PERMANOVA as being significantly different at the South Coast Mariculture operations in Jervis Bay, recorded 5-6 August 2020. NS = no significant difference shown by pairwise PERMANOVA.

Callala North	Callala North Control 1	Callala North Control 2	Callala South Control 3	Callala South Control 4	Callala South Lease	Vincentia Control 6	Vincentia Lease
Callala North Control 1	Yellowtail Scad Trumpeter Whiting Blue-spotted Flathead						
Callala North Control 2	NS	Yellowtail Scad Eastern Fiddler Ray Blue-spotted Flathead					
Callala South Control 3	NS	Yellowtail Scad* Eagle Ray Blue-spotted Flathead*	Yellowtail Scad Eastern Fiddler Ray Eagle Ray				
Callala South Control 4	Yellowtail Scad* Blue-spotted Flathead*	Yellowtail Scad* Blue-spotted Flathead* Port Jackson Shark	NS	Port Jackson Shark Eastern Fiddler Ray			
Callala South Lease	NS	NS	Trumpeter Whiting Sand whiting* Eagle Ray*	Yellowtail Scad Trumpeter Whiting Eastern Fiddler Ray*	Yellowtail Scad Trumpeter Whiting Eastern Fiddler Ray		
Vincentia Control 6	Yellowtail Scad* Trumpeter Whiting* Eastern Shovelnose Ray	Yellowtail Scad* Eastern Fiddler Ray* Trumpeter Whiting*	Yellowtail Scad* Eastern Fiddler Ray* Eastern Shovelnose Ray	NS	NS	Blue-spotted Flathead Trumpeter Whiting	
Vincentia Lease	Yellowtail Scad* Trumpeter Whiting* Blue-spotted Flathead* Eastern Fiddler Ray	Yellowtail Scad* Trumpeter Whiting* Blue-spotted Flathead* Port Jackson Shark	NS	NS	Trumpeter Whiting* Yellowtail Scad* Sand Whiting*	NS	Yellowtail Scad Eastern Fiddler Ray