UPDATE 2: Characterisation of the water and seabed environment of the blue mussel farm in Jervis Bay.

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Final Report to South Coast Mariculture

February 2023

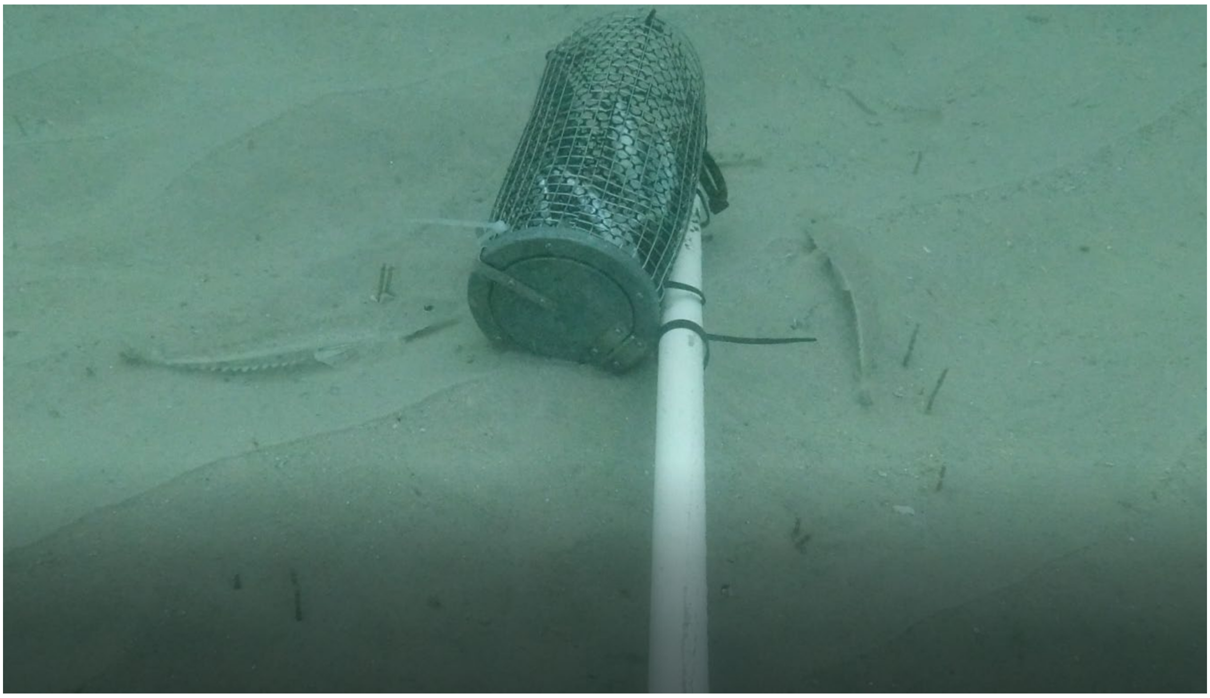


Plate 1 Flathead (*Platycephalus caeruleopunctatus*) at Callala South Lease site, observed using BRUVS.

Executive Summary

On 19 and 20 July 2022, sampling of the water quality and seabed environment was undertaken in Jervis Bay at the northern (Callala North and Callala South) lease sites, the first of which is stocked with blue mussels, and at the southern (Vincentia) lease site, with two associated controls for each lease site. This sampling represents the Update 2 survey and was sampled in the same way as for the Baseline and Update 1 studies in 2019 and 2020, respectively, enabling non-confounded comparisons. It is noted that, due to travel restrictions associated with COVID-19, sampling could not be carried out in 2021.

Water quality typically varied little among the nine sites and only occasionally between bottom and surface waters. On average, salinities were slightly less than that of seawater (32-33), waters were cool (14-15°C), pH ranged between 6.0 and 8.2 and waters were always fully saturated with oxygen. Surface salinities were lower than at depth at three of the nine sites, presumably reflecting recent rainfall and subsequent freshwater influx. Salinities were similar to Update 1, but slightly lower than in Baseline, reflecting ongoing La Niña conditions in 2021 and 2022.

Remote Operated Vehicle (ROV) surveys were not able to be conducted in this survey, owing to poor conditions both above and below the water. Alternatively, examinations of the videos for the BRUVS deployed for the fish assemblages showed that substrates were again characterised by pale rippled sand and shell debris, drift algae and small attached macrophytes. However, owing to the limited field of view in the BRUVS, it was not possible to draw any usable comparisons between the nine sites. It is recommended that, for future Update sampling events, that ROV sampling be carried out during no-rainfall days, or that a robust on-board shelter be constructed.

With regards to %TOC from the currently stocked site (Callala North Lease), no significant change was detected from that site in Baseline, with the mean (and SE) values being 0.082 (0.004) at Update 2 and 0.068 (0.008) at Baseline. %TOC differed significantly among the nine sites overall in Update 2, with mean (and SE) values ranging from 0.065 (0.007) at Callala North Control 1 (CN.C1) to 0.195 (0.092) at Callala South Control 1 (CS.C3).

Mean sediment grain size did not differ significantly between Baseline and Update 2, while % mud was significantly less in Update 2 than Baseline, with mean (SE) values overall being ~2% in Update 2 vs ~5% in Baseline. This is encouraging, despite recent La Niña conditions, as flooding waters have been linked with increases in % mud and declines in water quality in another Australian embayment.

Mean grain size did not differ significantly between the nine sites in Update 2, with means (and SE) ranging from 0.125 (0.004) to 0.284 (0.067) mm for the nine study sites. In contrast, significant differences were detected for % mud, with a greater amount of these finer sediments (5-6%) at two of the Vincentia study sites vs 1-2% elsewhere.

All replicates for the benthic macroinvertebrate taxa were collected, sieved through 1 mm mesh and stored in 70% ethanol. However, the lack of a significant difference for %TOC between Baseline and Update 2, with particular reference to the stocked site, means there is no requirement (as per South Coast Mariculture (2015)) to examine and enumerate the benthic macroinvertebrate taxa for this report, and samples have been securely stored at the University to facilitate any future examinations.

Twenty seven of the four Baited Remote Underwater Video Systems (BRUVS) deployments at each of the nine sites recorded 13 species and 538 organisms, with the fish faunas being dominated by Yellowtail Scad, Blue-Spotted Flathead and Trumpeter Whiting and, for the elasmobranchs, the

Eastern Fiddler Ray was most abundant. Significantly more taxa were observed in Update 2 than Baseline, while the total MaxN showed no such differences between surveys. Multivariate analyses showed that differences between Update 2 and Baseline surveys were statistically significant (as was also the case with Update 1 vs Baseline), but these may not be biologically significant, as there is still a limited understanding of the fish assemblages in the study area. It is noteworthy that fish assemblages at the site at which mussels were stocked (Callala North Lease) did not differ significantly to the fish assemblages at any other site in the study area.

The results from this Update 2 survey, based on water quality, broad seabed characteristics, sedimentary characteristics (particularly %TOC), and fishes, provide evidence that the present stocking of blue mussels at the Callala North Lease site is having no detectable 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 2023.

Contents

1. Introduction

The blue mussel aquaculture lease operated by South Coast Mariculture in Jervis Bay contains one lease site (Callala North) that is presently stocked with mussels, while the two other lease sites (Callala South and Vincentia) are yet to be developed, with locations of all shown in Fig. 1.1. It is noted that Vincentia, which has previously been used for mussel raft aquaculture (Joyce et al., 2010) is smaller in size (10 ha) than the two 20 ha leases (Callala North and Callala South) (Fig. 1.1).

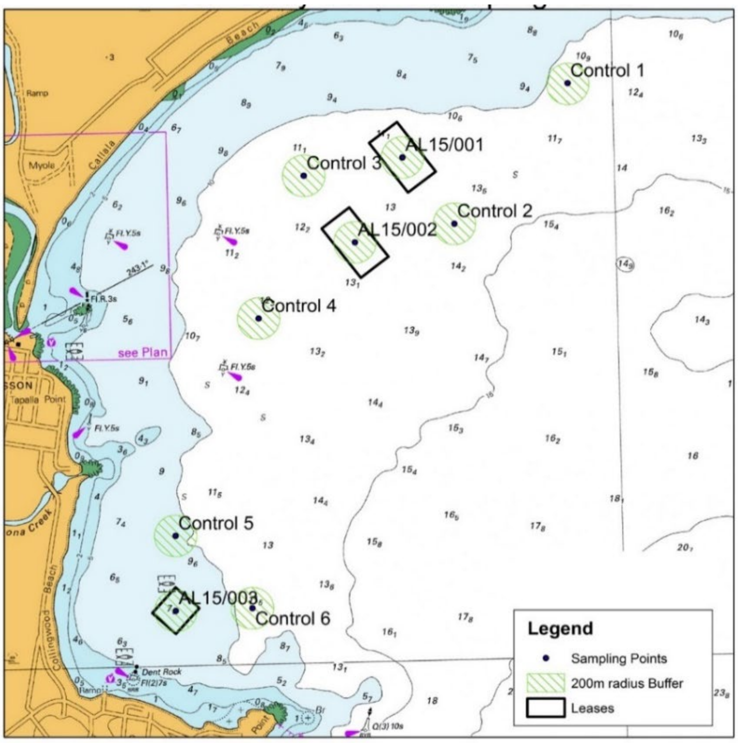
For each of the three lease sites, there are two control sites that formed the experimental design for the Update 2 survey, which are the same sites as reported on in the Baseline and Update 1 Survey (nine sites in total, Platell et al., 2020, 2021). Sampling of the water quality and seabed environment at these nine sites occurred in July 2022, 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 and CN.C2)

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

AL 15/003 = Vincentia Lease (V.L) with Control 5 and 6 (V.C5 and 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 GOVERNMENT Department of Primary Industries

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

Sampling occurred on the SCM Blue Revolution, skippered by Hika Rountree, on the 19 and 20 July, 2022. Water quality, sediment (and benthic macroinvertebrate) collection and Baited Underwater Remote Video System (BRUVS) were deployed over the two days (Table 1.1). Owing to rainfall during sampling (11.4 and 22.4 mm on the 19th and 20th, July, respectively) and heavy rainfall preceding the sampling (including 128.4 mm and 64.8 mm on the 2nd and 4th of July, respectively (BOM, 2022a), the Remotely Operated Vehicle (ROV) could not be be deployed to visually survey the seabed.

Table 1.1 Details of sample collection at each of the nine sites for the South Coast Mariculture operations in Jervis Bay. AS – Alessandra Suzzi (Project Manager); MG – Molly Grew; HS – Hayden Swift; IR– Isabel Roberts.

Date	Sites	Water quality	Sediment collection	BRUVS	ROV Survey
19.7.2022	CN.C1, CN.C2, V.C5, V.C6, V.L	MG, HS, IR	AS, MG	HS, IR	MG attempted
20.7.2022	CN.L, CS.C3, CS.C4, CS.L	MG, HS, IR	AS, MG	HS, IR	MG attempted

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 location of each study site. Parameters included temperature (°C), salinity, pH, turbidity (NTU) and dissolved oxygen (mg/L and % saturation), with values for each site in Appendix z..

The depth was recorded at each site using the vessel depth sounder, with Vincentia Lease site (V.L) again being shallowest (8.2 m) and Calla North Control 2 (CN.C2) the deepest (14.8 m). The seven other sites ranged in depth between 10.1 and 13.6 m in depth (Table 2.1).

Table 2.1 Water depth (m) and time of sampling (24 hr clock) for each of the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded 19-20 July, 2022.

Area name	Site type	Site name	Water depth (m)	Date/time
Callala North	Control	CN.C1	10.8	19th – 9:30
Callala North	Control	CN.C2	14.8	19th – 10:45
Callala North	Lease	CN.L	Not recorded	20th – 12:00
Callala South	Control	CS.C3	12.3	20th – 11:00
Callala South	Control	CS.C4	13.0	20th – 9:00
Callala South	Lease	CS.L	13.6	20th – 10:00
Vincentia	Control	V.C5	10.1	19th – 12:00
Vincentia	Control	V.C6	11.5	19th – 12:45
Vincentia	Lease	V.L	8.2	19th – 13:30

Water quality parameters were measured on a rising or high tide for both the 19th (1.46 m at 13:03) and 20th (1.47 m at 13:57). Water temperatures were similar between surface and bottom waters, indicating potentially good mixing of the water column (Table 2.2) during this cooler time of the year

(Winter). The same was generally true for salinity, with values typically between 33 and 34 at both the surface and at depth, except that surface waters were fresher at three sites, ranging from as low as 22 at V.C5 to approximately 29 at the other two sites (CN.C2 and V.C6), indicating the potential influence of land-based runoff at those sites (see also Fig. 1.1). This site variability is reflected in the values for salinity showing a lower mean but greater variation (SE) for surface waters in comparison to bottom waters in the present survey, unlike that in 2020 and 2019 (Table 2.2).

The slightly lower water temperatures and occasional salinity differences in the Update 2 sampling is considered to reflect the just over 190 mm of rainfall on 2nd-4th and the 34 mm during the sampling period (BOM, 2022a), more than the mean rainfall (116.5 mm) in July between 2001 and 2022 (BOM, 2022b). Joyce et al. (2010) noted that land discharges (with resultant moderate-salinity waters) tend not to mix within the bay, but rather flow out in a generally clockwise direction in relation to the embayment mouth.

It is also noted that the air temperatures during the sampling period were very similar to that of long-term climate records (BOM, 2022b). The water temperature and salinity are consistent with those for within this region of NSW (CSIRO, 1994) and the same is true for other parameters reviewed by Joyce et al. (2010).

Table 2.2 Means (± SE) for water temperature (°C), salinity, pH, turbidity (NTU) and dissolved oxygen (mg/L) 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), 4 August, 2020 (Update 1) and 19-20 July, 2022 (Update 2). Note that dissolved oxygen concentrations always exceeded saturation.

Survey	Water column	Water temperature (°C)	Salinity	pH	Turbidity (NTU)	Dissolved oxygen (mg/L)
Baseline	Surface	15.4 (0.2)	35.7 (0.3)	8.4 (0.0)	6.6 (1.2)	7.4 (0.2)
	Bottom	15.7 (0.2)	36.3 (0.0)	8.4 (0.0)	8.2 (1.3)	7.8 (0.3)
Update 1	Surface	15.6 (0.1)	32.3 (0.1)	7.7 (0.0)	4.4 (1.4)	9.9 (1.1)
	Bottom	16.0 (0.1)	32.7 (0.1)	7.6 (0.1)	4.2 (1.6)	10.4 (0.3)
Update 2	Surface	14.7 (0.1)	31.3 (1.4)	6.8 (0.3)	6.0 (1.8)	14.1 (1.4)
	Bottom	14.9 (0.1)	33.3 (0.2)	7.6 (0.2)	4.2 (1.6)	9.7 (0.4)

3. Seabed survey

The appearance of the seabed was intended to be 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 to be operated through a waterproof Panasonic Toughbook and a wireless Logitech controller.

Unfortunately, the rainfall and exposure on deck meant that the Panasonic Toughbook and thus the ROV could not be deployed during the 19th-20th of July. It is recommended that, for future Update events, that ROV sampling be carried out during no-rainfall days, or that a robust on-board shelter be constructed.

Where possible, features of the seafloor were determined qualitatively from the BRUVS deployed at each site (Section 5). The substrate for each of the fish BRUVS deployed was characterised by pale rippled sand and shell debris, drift algae and small attached macrophytes. However, owing to the limited field of view, it was not possible to draw any comparisons between the nine sites.

Remote Operated Vehicle (ROV) surveys were not able to be conducted in Update 2, owing to poor conditions both above and below the water. Alternatively, examinations of the videos for the BRUVS deployed for the fish assemblages showed that substrates were again characterised by pale rippled sand and shell debris, drift algae and small attached macrophytes. However, owing to the limited field of view in the BRUVS, it was not possible to draw any usable comparisons between the nine sites. It is recommended that, for future Update events, that ROV sampling be carried out during no-rainfall days, or that a robust on-board shelter be constructed.

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 on the 19th and 20th of July (Table 2.1). 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 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 a NATA-accredited laboratory (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

The following account is essentially the same as that reported in September of last year (Platell and Gaston, 2022), with the exception that the dates for collection are as shown in Table 2.1, the Figure number is adjusted and minor grammatical changes made. It is noted that the %TOC for Update 1 is not included in this account, as the main aim is to determine any difference from Baseline (as per lease approval requirements, South Coast Mariculture, 2015), and Update 1 values have been clearly analysed and reported on in Platell et al. (2021).

TOC was expressed as a percentage of the weight of the total sample for each sample (raw data for % TOC is provided in Appendix B). The first three of the six samples, from each of the nine sites, were analysed for % TOC at ALS in Newcastle). Two-way ANOVA, with factors of Time (Baseline, Update 2) and Site (n = 9) detected a significant difference for % TOC values between Baseline and Update 2 ($F_{1,81}$ = 4.319, $P < 0.05$). Therefore, the data for all six samples were compared, which again detected a significant difference with Time ($F_{1,108}$ = 7.236, $P < 0.01$). The overall mean (and SE) for Baseline of 0.076 (0008) was therefore significantly less than the 0.120 (0.012) for Update 2.

After plotting the means (and SE) for each site, it became clear that the mean values for % TOC in Update 2 were greater than in Baseline for seven of the nine sites, with this difference being most marked for Callala South Control 3 (CS.C3) (Fig. 4.1). In this case, there was also a large standard error, which reflects the fact that one of the six samples returned a value of 0.65, while the other five samples ranged between 0.07 and 0.15 (Fig. 4.1). This value of 0.65 exceeds that reported for waters to the south in Jervis Bay, i.e. 0.30, by GeoScience Australia (2009), but not that for sites of 20 to 5000 m in depth around Australia (Radke et al., 2017) .

The same two-way ANOVA for the six % TOC samples at each site in the two surveys also showed a significant difference between sites ($F_{8,108}$ = 3.789, P < 0.001). Tukey's posthoc tests that were restricted to the Update 2 samples, however, failed to detect a significant difference between any of the nine sites. Mean (and SE) values were least at Callala North Control 1, i.e. 0.065 (0.007) and greatest at CS.C3, i.e. 0.195 (0.092) (Fig. 4.1). There was no significant interaction between Time and Site.

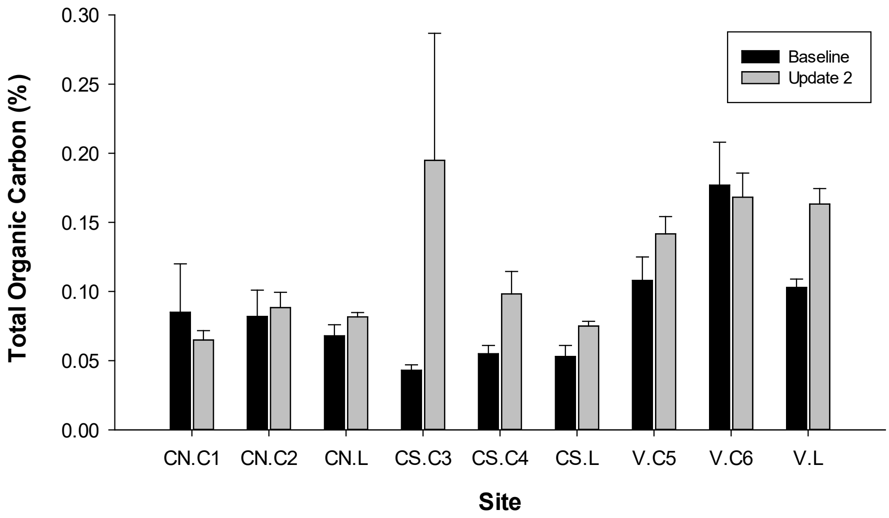

Figure 4.1. Mean (and SE) of Total Organic Carbon (%) from each of the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded at Baseline (9 July 2019, n = 6) and Update 2 (19-20 July 2022, n = 6).

The above significant difference with Time (shown by two-way ANOVA of the six % TOC samples) and no interaction between Time and Site, highlights that the overall increase for % TOC between Baseline (2019) and Update 2 (2022) occurred in the same way at each of the nine sites, and thus irrespective of whether they were stocked with mussels, i.e. the Callala North Lease. It should be noted that the mean (and SE) %TOC at the lease site was 0.068(0.008) at Baseline and 0.082(0.004) at Update 2, and that a one-way ANOVA for Time **did not detect a significant difference at Callala North Lease.**

It is therefore recommended, as per the conditions in the Benthic Monitoring Program for Commercial Shellfish Aquaculture Leases, Jervis Bay, NSW (DPI NSW, 2015) that there **is no requirement to examine the benthic infauna in the six sediment samples,** and that **sampling be conducted again in the same way at the same time next year (2023).**

4.2. Sediment - Grain size and percentage (%) mud

Samples for grain size analyses were dried for 24 hours at 65°C, weighed to the nearest 2 dp then put through a vertical sediment shaker containing a nested series of sieves (4000, 2000, 1000, 500, 250, 125 and 63 µm), with a pan below for those sediment particles of <63 µm. The shaker was operated for 5 min for each sample and the sediment on each sieve (and pan) was brushed into a weighboat and weighed to 2 dp. Comparisons of the total sample before weighing, and the cumulative weights for each fraction following shaking (when adjusted for the weight of the weighboat) showed an acceptable percentage error of 1-2%. The raw data for the weights of the various grain size fractions is given in Appendix C. GRADISTAT (Blott and Pye, 2001) was used to calculate the mean grain size and percentage (%) mud in each sample. Note that mean grain size is reported as µm in this report (1 mm = 1000 µm).

The mean grain size and % mud were analysed using a a two-way ANOVA, with factors being Time (Baseline, Update 1 and Update 2) and Site (nine sites), to ascertain whether there were any significant differences that involved Time, and then using a one-way ANOVA to examine for any differences between sites in Update 2).

For mean grain size, Levene's test showed no significance (Levene's statistic = 1.70 and $P > 0.05$ For the full data set), and two-way ANOVA found mean grain size to be significantly related to both Time ($F_{2,107} = 3.49$, $P < 0.05$) and Site ($F_{8,107} = 16.8$, $P < 0.001$) but not to the interaction between Site and Time ($F_{16,107} = 1.06$). The weaker Time effect was shown by Tukey's post hoc test to be due to significant differences for mean grain size between Update 2 and Update 1, but not between Update 2 and Baseline, with the average grain size being 231.3 µm in Update 2 compared to 225.2 µm in Baseline and 206.2 µm in Update 1.

When a one-way ANOVA of the mean grain size for the Update 2 samples was conducted, testing for any site differences, Levene's test showed a significant difference (Levene's statistic = 6.02 and $P < 0.001$) and log10 transformation did not reduce the size of this effect, meaning that any significance from ANOVA needed to be interpreted at the $P < 0.01$, rather than at the $P < 0.05$ level. No difference was detected between Site ($F_{8,27} = 3.44$, $P > 0.01$), see also Fig. 4.2. The average (and SE) mean grain size in Update 2 ranged between 125.6 (4.2) and 284.3 (67.7) µm across the nine study sites in Jervis Bay (Fig. 4.2a).

For % mud, Levene's test showed significance (Levene's statistic = 7.11 and $P < 0.001$), and log10 transformation did not significantly reduce the size of this effect, again meaning that any significance from ANOVA was interpreted at the $P < 0.01$ level. Two-way ANOVA of % mud found a highly significant difference among Site ($F_{8,107} = 20.27$, $P < 0.001$) and Time ($F_{2,107} = 3.21$, P < 0.001) but not for their interaction. Subsequent Tukey's tests showed that the % mud was significantly less ($P < 0.001$) in Update 2 than both Baseline and Update 1 (Fig. 4.2), with mean (SE) values being ~2% in Update 2 vs ~5% in the previous two surveys. This is encouraging, despite the recent La Nina events in NSW, as flooding waters have been linked with increases in % mud in a large tropical embayment (Moreton Bay – Lockington et al. (2017)).

When a one-way ANOVA of the % mud for the Update 2 samples was conducted, Levene's test again showed a significant difference (Levene's statistic = 4.78 and $P < 0.003$) and there was a highly significant difference between Site ($F_{8,27} = 10.26$, $P < 0.001$). Tukey's test showed that the % mud was statistically similar between the vast majority of the nine sites (the three sites in each of Calalla North and Callala South and one site in Vincentia V.C5), and the % mud at these seven sites were collectively significantly less than at V.C6 and V.L, i.e. 1-2% vs 5-6% (Fig. 4.2b).

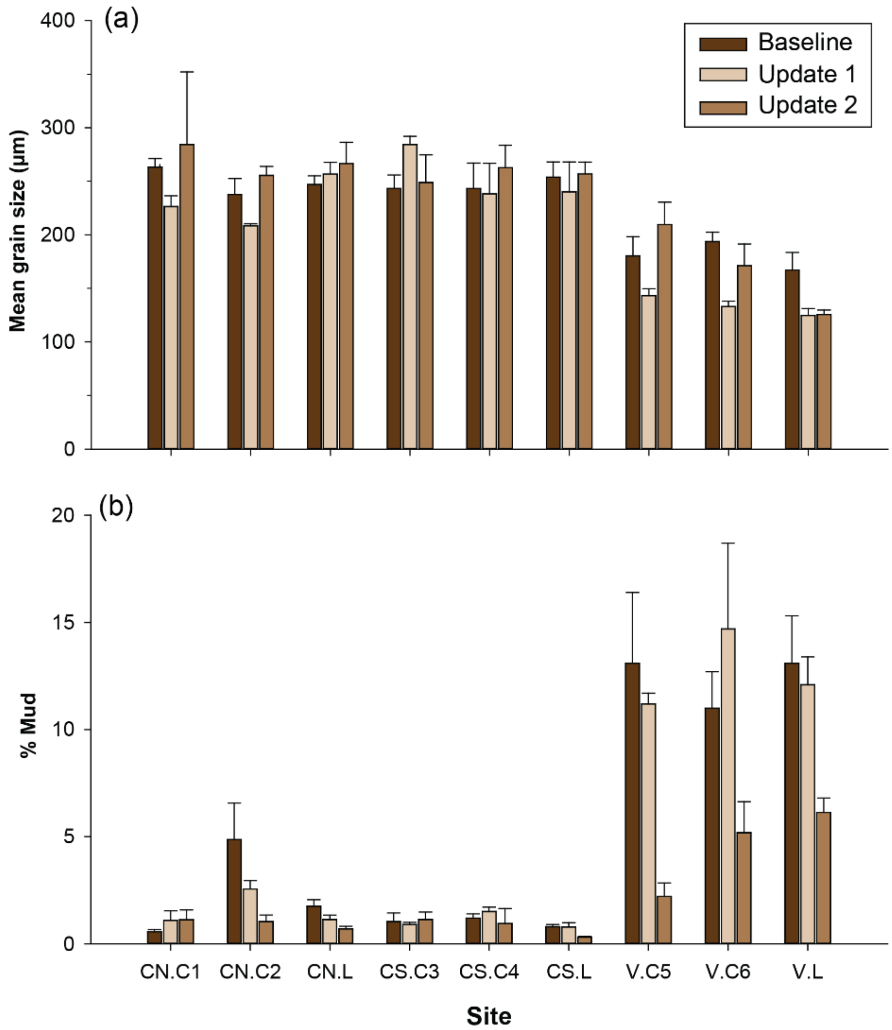

Figure 4.2 Mean (+ SE) of (a) mean grain size (µm) and b) percentage mud, extracted via Gradistat (Blott and Pye, 2001), for each of the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded at Baseline (9 July, 2019), Update 1 (4 August, 2020) and Update 2 (19-20 July, 2022).

The cumulative grain size curves for the different sampling locations each approach the asymptote (> 90%) at 250 µm (Figs 4.3a, b and c). Both 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 steeper curve, being closer to asymptoting at 125 µm.

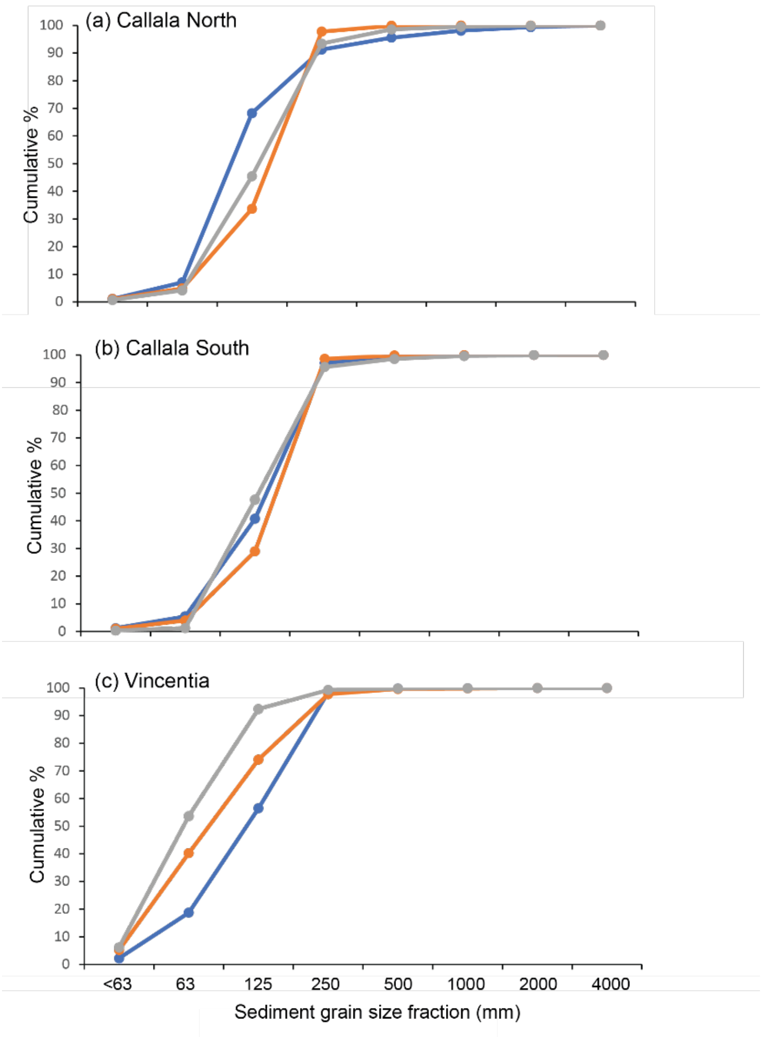

Figure 4.3 Cumulative percentage (%) grain size fractions for (a) Callala North, (b) Callala South and (c) Vincentia locations for each of the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded at Update 2 (19-20 July, 2020). Blue, First control site; Orange, Second control site; Grey, Lease site.

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).

The samples were prepared for possible later examinations, by checking labels and ethanol levels, and then storing in a clearly-labelled flammable storage cupboard in a secure University facility.

5. Fish

5.1. Methods of observation and video analysis

Fish and invertebrate faunas 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, at least 50 m apart from each other, for a period of 30 min within each of the nine sites. An additional camera was also deployed at each site as a contingency in case of poor deployment or malfunction, and as a safeguard against the poor visibility noted prior to sampling.

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). Assessments were also made of the visibility, as either Poor (bait bag could not be clearly visualised) or Good (bait bag could be easily visualised). To assist with species identifications and correct nomenclature for fishes, Kuiter (1990), Gomon et al. (2008) and FishBase (2022) were used, while for the invertebrates, Edgar (1997) was used.

5.2. General description

Of the 36 BRUVS drops, nine of those were scored as poor visibility, and either 0, 1 or 2 organisms were observed within those drops – in comparison to the 8-108 observed at those 27 drops with good visibility. The sites with poor visibility were all in Vincentia, with 2 usable replicates for V.C6, one for V.L. and none for V.C5 (Appendix C). The very few organisms observed in total (7) at these sites contained no new species (Appendix C) and were not included in further analyses.

At least 13 species and a total of 538 organisms were observed, including 21 sharks, 57 rays, 459 bony fishes and one echinoderm (Table 5.1). As with Baseline, the most numerous fish was Yellowtail Scad (292), in which moderate numbers were recorded at most replicates and at all sites, although total abundance was less than in Baseline (687, Platell et al. (2020)). The Blue-spotted Flathead (78) and Trumpeter Whiting (73) were similarly abundant, and more so than in Baseline (32 Flathead that could not be further identified and no Trumpeter Whiting, Platell et al. (2020)). Of the echinoderms, one Common Seastar was observed (Table 5.1).

It is noted that a similar number of species was recorded in Baseline (14), although more individuals were recorded in Baseline (805) than Update 2 (538), and that the number of "missing" replicates were similar in both, i.e. eight in Baseline and nine in Update 2 (cf. Platell et al. (2020)). The lower number of inviduals in Update 2 is perhaps related to these "missing" replicates being entirely located within Vincentia in 2022, rather than as being more dispersed across the nine sites as they were in 2019. It is also noted that very large schools of the Yellowtail Scad were not observed, with upper estimates of schools of fish being ~30, similar to that of Update 2 but not in Baseline, where schools of >100 individuals were sometimes observed.

Table 5.1 Cumulative MaxN of the sharks, rays, fish and invertebrate taxa, overall, in alphabetical order by common name, for the nine sites for the South Coast Mariculture operations in Jervis Bay, recorded in Update 2 (19-20 July, 2022).

Main groups	Common Name	Species Name	Update 2
Sharks	Gummy Shark	*Mustelus antarcticus*	5
	Port Jackson Shark	*Heterodontus portusjacksoni*	16
Rays	Common Stingaree	*Trygonoptera testacea*	3
	Eastern Fiddler Ray	*Trygonorrhina fasciata*	44
	Eastern Shovelnose Ray	*Aptychotrema rostrata*	7
	Southern Eagle Ray	*Myliobatis tenuicaudatus*	3
Fish	Banded Toadfish	*Torquigener pleurogramma*	12
	Blue-spotted Flathead	*Platycephalus caeruleopunctatus*	78
	Orange-spotted Puffer	*Torquigener vicinus*	2
	Rock Cale	*Aplodactylus lophodon*	2
	Trumpeter Whiting	*Sillago maculata*	73
	Yellowtail Scad	*Trachurus novaezelandiae*	292
Echinoderm	Common Seastar	*Luidia australiae*	1
		Total	**538**

It is also noted that the collective number of species recorded in the three years of sampling is now 20 and therefore close to the 21 species recorded by Rees et al. (2018) during unvegetated substrate surveys in Jervis Bay between December 2013 and March 2014, which included demersal BRUVS (as in our studies) but also mid-water BRUVS (unlike our studies). The data provided in reports to South Coast Mariculture (Platell et al., 2020, 2021) are now building our knowledge of the demersal fish faunas over unvegetated substrates within Jervis Bay, noting that algal wracks are often present.

5.3. Univariate analyses

The number of fish taxa (taxa richness) and the total MaxN of fish, and thus including sharks, rays and bony fishes, were each analysed using two-way ANOVA with Time and Site as the factors, to initially explore whether there were differences between Baseline, Update 1 and Update 2 surveys, focussing on differences between Baseline and Update 2. To explore site differences within the Update 2 survey only, a one-way ANOVA for Site was conducted.

Levene's test showed that taxa richness (Levene's = 1.171, $P > 0.05$) required no transformation. However, both total MaxN and log10 total Max N were significantly different, and the effect of transformation was minor (Levene's = 5.34 and 3.61, $P < 0.001$), with analyses therefore using the untransformed data and any significance interpreted at the $P < 0.01$level.

For taxa richness in the full data set, a highly significant difference was detected between Time ($P < 0.001$) but not with Site ($P > 0.05$) or the interaction between these two factors (Table 5.2). Tukey's post hoc tests indicated that there was a significant difference between Baseline and Update 2 surveys, but not between Update 2 and Update 1. This difference reflects the greater overall richness in both the Update 1 and 2 surveys in comparison to Baseline (Fig. 5.1a).

Table 5.2 Results of two-way ANOVA of Time (for Baseline, Update 1 and Update 2 surveys) and Site, for both the taxa richness and the total MaxN of fish (including sharks, rays and bony fishes) recorded from up to four replicate BRUVS for the South Coast Mariculture operations in Jervis Bay, recorded at Baseline (10-11 July, 2019), Update 1 (5-6 August, 2020) and Update 2 (19-20 July, 2022). Df, degrees of freedom; MS mean squares. Significant values in bold.

Source	Df	MS	F	*P*
Taxa richness (two-way)				
Time	2	34.7	**17.866**	**<0.001**
Site	8	3.9	2.033	0.058
Time x Site	15	2.6	1.383	0.186
Residual	85	1.9		
Total MaxN (two-way)				
Time	2	481.6	0.592	0.556
Site	8	259.4	0.319	0.956
Time x Site	15	482.6	0.594	0.868
Residual	85	813.2		

For taxa richness in just the Update 2 survey, a one-way ANOVA of site did not detect a significant difference (Table 5.3) and the mean taxa richness (at those sites where four replicates were obtained) had a narrow range, i.e. 4.25 - 5.75 (Fig. 5.1a).

For total MaxN using the full dataset, no significant differences were detected among Time or Site or their interaction, and there was a relatively large variation unaccounted for by either of these terms (Table 5.2). The mean (and SE) taxa richness in the three surveys was 3.11 (0.28) in Baseline, 5.74 (0.32) in Update 1 and 4.93 (0.24) in Update 2 (see also Fig. 5.1b).

One-way ANOVA for total MaxN, testing for Site, showed that there was no significant difference among the eight sites, and for this survey only, the value for residual variation was still considerable (Table 5.3). The mean total MaxN ranged from 9.25 to 31 at the six sites where four replicates were obtained) and the associated standard errors typically ranged from 3.5 to 8 (but see those for CS.L) (Fig. 5.1b).

It is worth noting that the lack of site differences in the taxa richness and total MaxN in the Update 2 survey, as shown by one-way ANOVA, is consistent with that reported in Baseline (Platell et al., 2020).

Comparisons of the results for taxa richness from Update 2 with that for 30-min BRUVS deployments at unvegetated substrates at Callala North, as reported in Rees et al. (2018), found that the taxa richness was consistent with that reported in the present study. The Total MaxN in Update 2, however, was slightly lower than in Rees et al. (2018), possibly reflecting differences in the time of year for that study, i.e. summer/early autumn vs winter in Update 2.

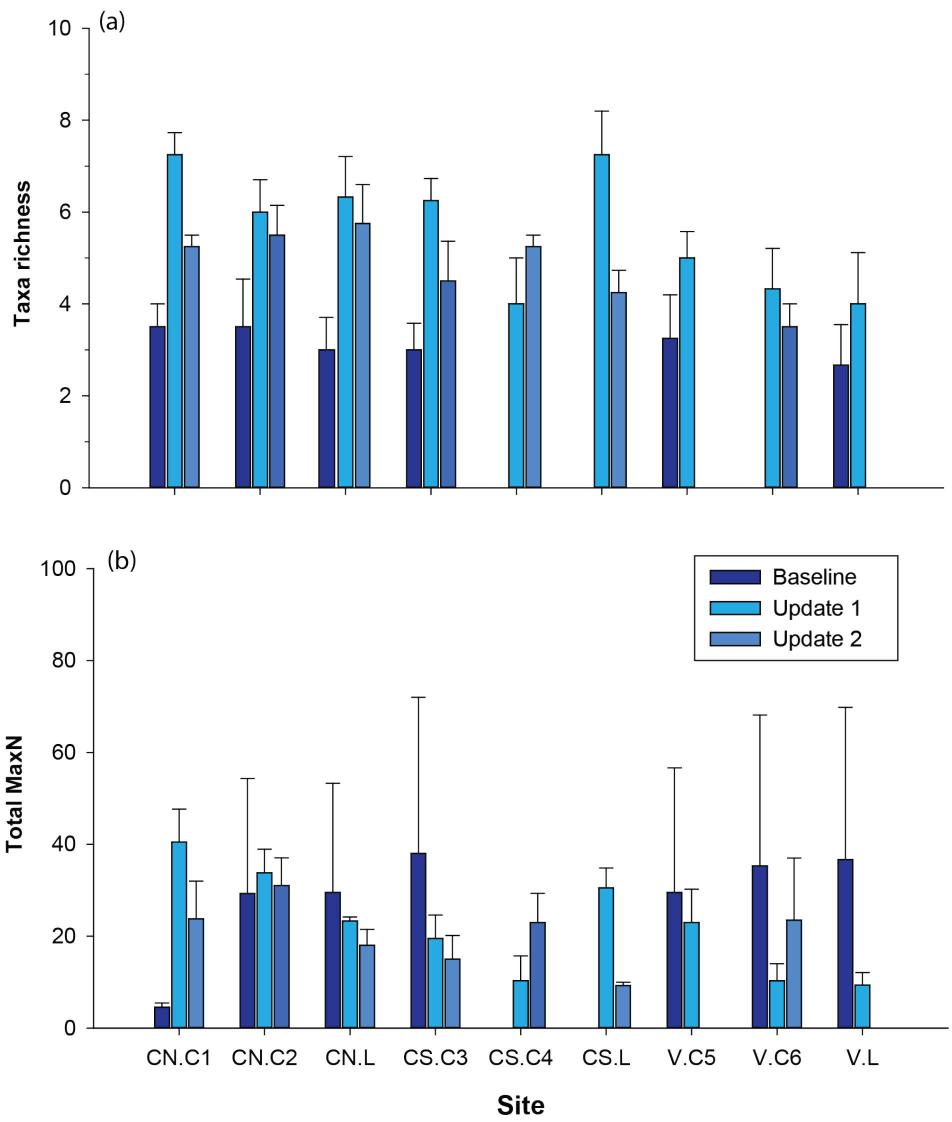

Figure 5.1 Mean (+ SE) taxa richness (a) and the total MaxN of of the sharks, rays and bony fishes (b) obtained from up to four replicate BRUVS (minimum n=2) for the South Coast Mariculture operations in Jervis Bay, recorded in Baseline (10-11 July, 2019), Update 1 (5-6 August, 2020) and Update 2 (19-20 July, 2022).

Table 5.3 Results of one-way ANOVA of Site (for Update 2) of the taxa richness and the total MaxN of fish (including sharks, rays and bony fishes) recorded from up to four replicate BRUVS for the South Coast Mariculture operations in Jervis Bay, recorded at Update 2 (19-20 July, 2022). Df, degrees of freedom; MS mean squares.

Source	Df	MS	F	*P*
Taxa richness (one-way)				
Site	7	1.77	1.219	0.340
Residual	27	1.45		
Total MaxN (one-way)				
Site	7	182.67	1.354	0.280
Residual	27	134.95		

5.4. Multivariate analyses

Multivariate analyses were used to examine for trends in the fish assemblages (including sharks, rays and bony fishes), excluding the sole echinoderm.

The total MaxN of the different sharks, rays and bony fishes recorded for all samples from Baseline, Update 1 and Update 2 were analysed in PRIMER 7 (Clarke and Gorley, 2016), with each $\log_{10}$ transformed (to downweight the influence of the most abundant species) and the Bray-Curtis measure used to calculate a similarity matrix. This matrix was analysed using PERMANOVA, both as two-way (testing for Time and Site) and one-way (testing for site differences for Update 2 only) (Anderson et al., 2008). Thus, both main and pairwise tests, using permutations of residuals for the two-way test and unrestricted permutations of raw data for the one-way test, with Type III sums of squares for both, were conducted.

Two-way PERMANOVA, testing for Time and Site, showed that there was a significant overall difference for fish assemblages between the three surveys ($P = 0.001$) with the greatest Pseudo-F recorded, indicating this was the strongest effect in the model (Table 5.4). The nine sampling sites ($P = 0.016$) and the interaction term ($P = 0.001$) were both also significant, but had lower Pseudo-F and thus weaker effects (Table 5.4). Pairwise PERMANOVA showed that the samples for the different surveys each differed significantly from each other, with the differences being most marked for Baseline vs both Update 1 and Update 2.

On the nMDS ordination plot generated from the same similarity matrix used for two-way PERMANOVA, the group of samples from Baseline lie to the left of both those for Update 1 and Update 2, which overlap more on the plot (Fig. 5.2a). SIMPER showed that Yellowtail Scad and the Eastern Fiddler Ray typified the species composition of fish of all three surveys, with the fish faunas in Baseline being distinguished by consistently greater contributions of Flathead while both Blue-spotted Flathead and Trumpeter Whiting made consistently greater contributions to fish faunas in both the Update 1 and Update 2 surveys (in comparison to Baseline (Appendix E).

One-way PERMANOVA, testing for differences in species composition between the eight sites in Update 2, detected no significant difference with Site (Table 5.4). This contrasts with the significant differences for Site detected within both Baseline and Update 1 surveys (Platell et al., 2020, 2021). This may reflect the lower than expected number of replicates in the Vincentia location for Update 2 survey in comparison to previous surveys, or may also reflect natural variation within Jervis Bay.

Table 5.4 Results of PERMANOVA, with the two-way test based on Time and Site for the Baseline, Update 1 and Update 2 surveys and the one-way test, based on Site, of the Bray-Curtis similarity matrix derived from the $\log_{10}$ transformed MaxN of sharks, rays and bony fishes 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, 4-5 August, 2020 and 19-20 July, 2022. Df, degrees of freedom; MS, mean squares. Significant values are in bold.

Source	Df	MS	Pseudo-F	*P*
Two-way PERMANOVA				
Time	2	18739	**16.806**	**<0.001**
Site	8	1999	**1.7932**	**0.016**
Time x Site	15	2606	**2.3372**	**0.001**
Residual	84	1115		
One-way PERMANOVA				
Site	7	1169	1.3404	0.204
Residual	19	872		

For the nMDS plot showing the samples from only Update 2, the replicate samples for each site tend to lie in different parts of the large group in the centre of the plot, being interspersed with one another (Fig. 5.2b). This is consistent with the lack of a significant difference as shown by PERMANOVA (Table 5.4). Those four replicates for the presently-stocked lease at Callala North (CN.L) lie in the middle and the bottom of that large group (Fig. 5.2b).

SIMPER was used to determine only those species that made consistently greatest contributions to the overall fish faunas at the various sites during Update 2. SIMPER showed that the fish faunas at all sites were always typified by Blue-spotted Flathead and at all but V.C6 by Eastern Fiddler Ray. Trumpeter whiting also typified the fish faunas at four other sites (CN.C1, CN.L, CS.C3 and CS.L) and Yellowtail Scad at three other sites (CN.C1, CN.C2 and CS.C4). These findings are consistent with that of Rees et al. (2018) who also found that flathead (most likely Blue-spotted flathead (Wraith et al., 2013), were most abundant on unvegetated substrates, and that the Eastern Fiddler Ray was relatively relatively more abundant over those substrates than rocky reef or seagrass.

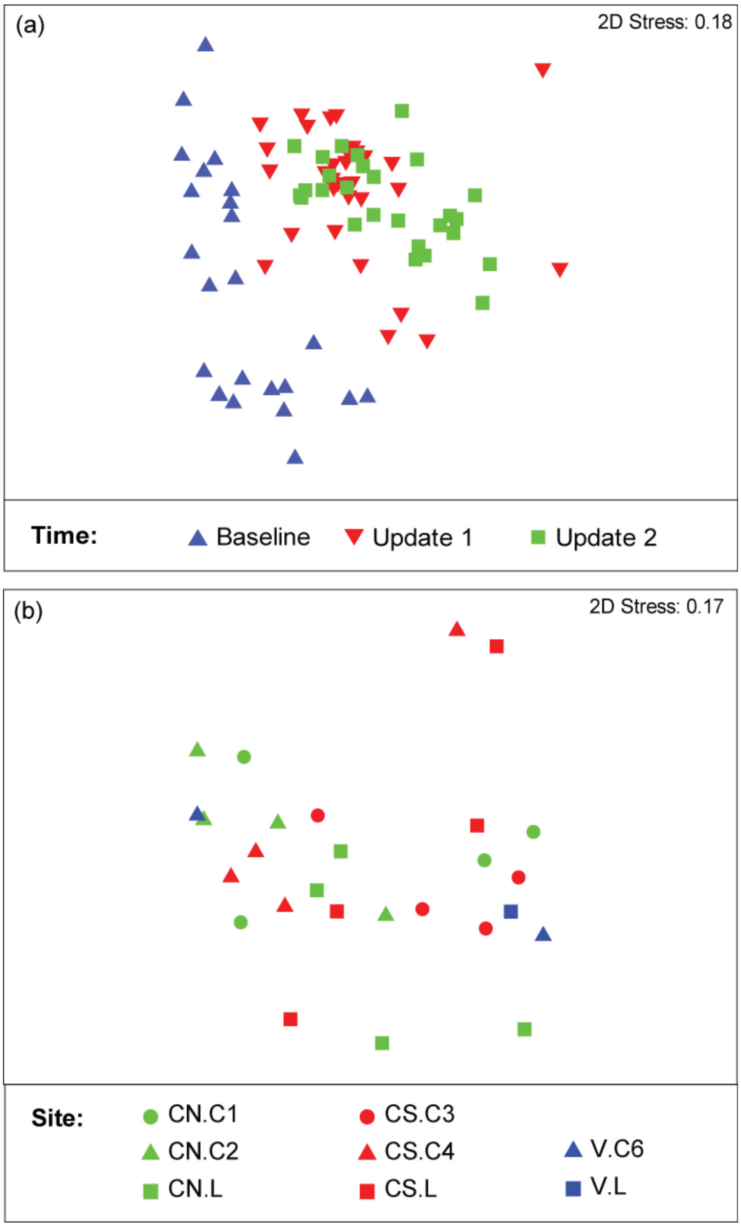

Figure 5.2 nMDS ordination of the Bray-Curtis similarity matrix derived from the $\log_{10}$ transformed abundances of the sharks, rays and fishes observed in up to four replicate BRUVS for the different sites for the South Coast Mariculture operations in Jervis Bay, shown for both (a) Baseline (10-11 July, 2019) Update 1 (5-6 August, 2020) and Update 2 (19-20 July, 2022) and (b) Update 2 only.

6. Summary and conclusions

Update 2 sampling of the water quality and seabed environment was conducted at the northern (Callala North and Callala South, CN and CS) lease sites, the latter of which is stocked with mussels, and the southern lease (Vincentia, V), which is not presently stocked, and at two associated controls for each lease. Comparisons with Baseline and Update 1 (where appropriate), demonstrated the following:

Water depth: Ranged between 8.2 m (Vincentia Lease, V.L) and 14.8 m (Callala North Control 2, CN.C2).

Water quality: Typically varied little among the nine sites and occasionally between bottom and surface waters. On average, salinities were slightly less than that of seawater (32-33), waters were cool (14-15°C), pH ranged between 6.0 and 8.2 and waters were always fully saturated with oxygen. Surface salinities were lower than at depth at three of the nine sites, presumably reflecting recent rainfall and freshwater influx. Salinities were similar to Update 1, but slightly lower than in Baseline, reflecting ongoing La Niña conditions in 2021 and 2022.

Seabed ROV: Surveys were not able to be conducted in Update 2, owing to poor conditions both above and below the water. The substrate for each of the fish BRUVS deployed was characterised by pale rippled sand and shell debris, drift algae and small attached macrophytes (as in previous surveys). However, owing to the limited field of view in the BRUVS, it was not possible to draw any usable comparisons between the nine sites. It is recommended that, for future Update events, that ROV sampling be carried out during no-rainfall days, or that a robust on-board shelter be constructed.

Sediments: The %TOC from the currently stocked site (Callala North Lease) in Update 2 (2022) showed no significant change from that site in Baseline (2019), with the mean (and SE) values for the Lease site in Callala North being 0.082 (0.004) at Update 2 and 0.068 (0.008) at Baseline. %TOC differed significantly among the nine sites overall in Update 2, with mean (and SE) values ranging from 0.065 (0.007) at Callala North Control 1 (CN.C1) to 0.195 (0.092) at Callala South Control 1 (CS.C3).

Mean sediment grain size did not differ significantly at Baseline and Update 2. In contrast, the % mud was significantly less in Update 2 than Baseline with mean (SE) values being ~2% in Update 2 vs ~5% in the Baseline. This is encouraging, despite the recent La Niña conditions, as flooding waters have been linked with increases in % mud and declines in water quality in another Australian embayment

Mean grain size did not differ significantly between the nine sites in Update 2, with means (and SE) ranging from 0.125 (0.004) to 0.284 (0.067) mm for the nine study sites. In contrast, significant differences were detected for % mud, with a greater amount of these finer sediments (5-6%) at two of the Vincentia study sites vs 1-2% elsewhere.

Benthic macroinvertebrates: All replicates were collected, sieved and stored. However, the lack of a significant difference between Update 2 and Baseline values for %TOC at the Callala North Lease site, means there is no requirement (as per South Coast Mariculture (2015)) to examine and enumerate the benthic macroinvertebrate taxa for this report, and samples have been securely stored at the University to facilitate later examination.

Fish: 13 species and 538 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). Significantly more taxa were observed in Update 2 than Baseline, while the total MaxN showed no such differences between surveys. Multivariate analyses showed that differences between Update 2 and Baseline surveys were statistically significant (as was also the case with Update 1), but these may not be biologically significant, as there is a still a limited understanding of the fish assemblages in the study area area. It is noteworthy that fish assemblages at the site at which mussels were stocked (Callala North Lease) did not differ significantly to the fish assemblages at any other site in the study area.

In final: The results from this Update 2 survey, based on water quality, broad seabed characteristics, sedimentary characteristics (particularly % TOC), and fish faunas, provide evidence that the present stocking of blue mussels at the Callala North Lease site is having no detectable 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 2023.

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8. Appendices

Appendix A: Water quality raw data

Water quality parameters measured at the surface and bottom of the water column for each of the nine sites at the South Coast Mariculture operations in Jervis Bay, recorded 19-20 July ,2022.

Site	Position in water column	Temperature (C°)	Salinity	pH	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)
CN.C1	Surface	14.18	33.17	6.80	1.6	8.83	NOT RECORDED
	Bottom	14.69	33.14	8.09	6.6	10.07	NOT RECORDED
CN.C2	Surface	14.83	28.77	8.13	8.9	10.09	NOT RECORDED
	Bottom	14.91	33.1	8.18	4.5	8.13	98.4
CN.L	Surface	14.55	33.66	5.73	1.5	18.03	218.0
	Bottom	14.60	33.68	6.80	0.6	11.60	138.6
CS.C3	Surface	14.52	34.03	5.96	0.5	12.71	153.9
	Bottom	14.58	34.07	6.72	0.2	9.80	119.2
CS.C4	Surface	14.28	33.70	6.08	0.8	16.53	198.8
	Bottom	14.62	33.77	7.78	25.7	9.61	115.8
CS.L	Surface	14.67	33.99	6.04	6.9	13.70	159.8
	Bottom	14.72	34.09	7.56	0.7	8.54	103.9
V.C5	Surface	15.05	21.95	7.17	14.6	20.56	242.3
	Bottom	15.08	32.13	7.71	2.6	11.26	137.0
V.C6	Surface	14.99	32.90	7.58	8.0	10.60	108.5
	Bottom	15.50	32.99	8.00	2.0	9.60	115.4
V.L	Surface	14.96	29.13	7.26	11.2	15.73	186.9
	Bottom	15.06	33.07	8.00	3.2	8.45	104.9

Appendix B: Total Organic Carbon raw data

Raw % TOC data for each of the six replicate grab samples at each of the nine study sites, for the South Coast Mariculture operations in Jervis Bay, recorded on 19-20 July, 2022.

20220719	CN.C1.1	0.08		20220720	CS.L.1	0.08
20220719	CN.C1.2	0.07		20220720	CS.L.2	0.07
20220719	CN.C1.3	0.07		20220720	CS.L.3	0.07
20220719	CN.C1.4	0.08		20220720	CS.L.4	0.07
20220719	CN.C1.5	0.04		20220720	CS.L.5	0.07
20220719	CN.C1.6	0.05		20220720	CS.L.6	0.09
20220719	CN.C2.1	0.08		20220719	V.C5.1	0.13
20220719	CN.C2.2	0.06		20220719	V.C5.2	0.17
20220719	CN.C2.3	0.08		20220719	V.C5.3	0.10
20220719	CN.C2.4	0.08		20220719	V.C5.4	0.15
20220719	CN.C2.5	0.14		20220719	V.C5.5	0.18
20220719	CN.C2.6	0.09		20220719	V.C5.6	0.12
20220720	CN.L.1	0.07		20220719	V.C6.1	0.13
20220720	CN.L.2	0.09		20220719	V.C6.2	0.11
20220720	CN.L.3	0.08		20220719	V.C6.3	0.20
20220720	CN.L.4	0.08		20220719	V.C6.4	0.22
20220720	CN.L.5	0.08		20220719	V.C6.5	0.19
20220720	CN.L.6	0.09		20220719	V.C6.6	0.16
20220720	CS.C3.1	0.10		20220719	V.L.1	0.18
20220720	CS.C3.2	0.07		20220719	V.L.2	0.21
20220720	CS.C3.3	0.12		20220719	V.L.3	0.15
20220720	CS.C3.4	0.65		20220719	V.L.4	0.14
20220720	CS.C3.5	0.15		20220719	V.L.5	0.16
20220720	CS.C3.6	0.08		20220719	V.L.6	0.14
20220720	CS.C4.1	0.17				
20220720	CS.C4.2	0.07				
20220720	CS.C4.3	0.07				
20220720	CS.C4.4	0.08				
20220720	CS.C4.5	0.08				
20220720	CS.C4.6	0.12				

Appendix C: Sediment grain size raw data

Raw sediment weight (in grams) data for each of the three replicate grab samples at each of the the nine study sites, broken down by the various grain size fractions, for the South Coast Mariculture operations in Jervis Bay, recorded on 19-20 July, 2022.

Sample	Sample weight (g)	4mm	2mm	1mm	0.5mm	0.250mm	0.125mm	0.63mm	<0.63mm
CN.C1.1	45.91	0.26	0.24	0.52	0.81	6.72	31.61	4.36	0.92
CN.C1.2	68.56	0.85	1.87	3.65	6.03	23.83	29.75	1.54	0.33
CN.C1.3	60.83	-0.01	0.33	0.66	1.3	11.29	41.46	3.53	0.51
CN.C2.1	156.71	0	0.03	0.13	4.33	93.33	43.93	8.29	1.21
CN.C2.2	159.45	0	0.01	0.08	3.36	115.62	32.32	4.02	1.08
CN.C2.3	51.3	0	0.03	0.07	0.648	28.47	18.47	1.73	0.83
CN.L.1	168.17	0.39	0.9	1.53	8.84	90.76	58.73	4.31	1.05
CN.L.2	44.84	0.01	0.08	0.48	1.43	14.15	25.26	2.21	0.41
CN.L.3	50.3	0	0.18	0.46	3.38	28.19	15.33	1.38	0.27
CS.C3.1	47.6	0	0.02	0.05	0.35	18.24	25.44	2.22	0.5
CS.C3.2	162.53	0	0.03	0.15	9.72	126.3	19.07	3.06	0.91
CS.C3.3	95.21	0.08	0.16	0.19	1.09	47.55	37.23	5.83	1.67
CS.C4.1	80.11	0.02	0.07	0.09	0.51	36.15	34.63	5.32	1.85
CS.C4.2	127.71	0.02	0.04	0.13	2.26	103.33	19.25	1.32	0.31
CS.C4.3	141.53	0.05	0.09	0.13	1.67	113.43	22.16	1.58	0.37
CS.L.1	65.4	0.03	0.06	0.61	2.56	33.65	26.44	0.47	0.16
CS.L.2	52.78	0.02	0.12	0.35	1.32	20.45	29.14	0.58	0.2
CS.L.3	164.15	0.02	1.14	2.5	3.671	84.95	68.45	1.39	0.52
V.C6.1	88.7	0.03	0.19	0.28	2.3	24.84	34.07	22.61	3.01
V.C6.2	66.93	0.05	0.04	0.08	1.15	20.84	24.78	16.58	2.7
V.C6.3	54.08	0.03	0.05	0.12	0.69	5.86	13.42	28.96	4.32
V.C5.1	150.84	0.02	0.05	0.15	2.83	94.5	32.5	16.67	1.65
V.C5.2	143.91	0.12	0.06	0.1	1.32	48.46	69.87	18.49	3.18
V.C5.3	42.31	0	0.01	0.03	0.48	11.84	17.57	10.57	1.38
V.L.1	45.43	0.03	0.04	0.07	0.19	3.14	18.78	19.68	2.52
V.L.2	131.4	0.03	0.04	0.06	0.48	8.1	60.52	53.45	6.88
V.L.3	26.33	0	0.01	0.04	0.2	1.9	6.99	14.59	1.92

Appendix D: BRUVS raw data

Raw data for shark, ray, fish and invertebrate taxa, with dates recorded, visibility and 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 19-20 July, 2022.

(a) Callala North

Date	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	20/07/2022	20/07/2022	20/07/2022	20/07/2022
Site	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.3	CN.L.4
Visibility	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Mustelus antarcticus	0	1	0	1	0	0	0	1	0	0	1	0
Heterodontus portusjacksoni	1	0	0	1	1	1	1	0	0	1	0	0
Trygonoptera testacea	0	0	1	0	1	0	0	0	1	0	0	0
Trygonorrhina fasciata	2	1	2	1	1	2	1	2	2	2	6	2
Aptychotrema rostrata	0	0	0	0	0	0	0	1	0	0	0	0
Myliobatis tenuicaudatus	0	0	0	0	0	0	0	0	2	0	0	0
Torquigener pleurogramma	1	1	0	1	1	0	0	1	0	0	0	1
Platycephalus caeruleopunctatus	2	2	1	4	3	3	4	1	3	3	1	2
Torquigener vicinus	0	0	0	0	0	0	0	0	1	0	0	1
Aplodactylus lophodon	0	0	0	0	0	0	0	0	1	0	0	0
Sillago maculata	4	4	4	0	2	4	0	0	5	7	4	2
Trachurus novaezelandiae	0	0	30	30	30	3	30	30	2	15	0	7
Luidia australiae	0	0	0	0	0	0	0	0	0	0	0	0

(b) Callala South

Date	20/07/2022	20/07/2022	20/07/2022	20/07/2022	20/07/2022	20/07/2022	20/07/2022	20/07/2022	20/07/2022	20/07/2022	20/07/2022	20/07/2022
Site	CS.C3.1	CS.C3.2	CS.C3.3	CS.C3.4	CS.C4.1	CS.C4.2	CS.C4.3	CS.C4.4	CS.L.1	CS.L.2	CS.L.3	CS.L.4
Visibility	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Mustelus antarcticus	0	0	0	0	0	0	0	0	0	0	0	1
Heterodontus portusjacksoni	0	0	0	1	0	0	0	2	1	1	0	0
Trygonoptera testacea	0	0	0	0	0	0	0	0	0	0	0	0
Trygonorrhina fasciata	2	1	1	2	1	2	2	2	2	2	1	0
Aptychotrema rostrata	0	0	1	1	1	1	2	0	0	0	0	0
Myliobatis tenuicaudatus	0	0	0	0	1	0	0	0	0	0	0	0
Torquigener pleurogramma	0	0	1	0	1	0	0	0	1	0	3	0
Platycephalus caeruleopunctatus	3	4	3	3	4	4	3	3	2	2	4	4
Torquigener vicinus	0	0	0	0	0	0	0	0	0	0	0	0
Aplodactylus lophodon	0	0	0	0	0	1	0	0	0	0	0	0
Sillago maculata	4	3	6	5	0	1	2	1	2	1	0	2
Trachurus novaezelandiae	0	0	18	1	0	18	10	30	0	4	0	4
Luidia australiae	0	0	0	0	0	0	0	0	0	0	1	0

(c) Vincentia

Date	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022	19/07/2022
Site	V.C5.1	V.C5.2	V.C5.3	V.C5.4	V.C6.1	V.C6.2	V.C6.3	V.C6.4	V.L.1	V.L.2	V.L.3	V.L.4
Visibility	Poor	Poor	Poor	Poor	Good	Good	Poor	Poor	Poor	Poor	Good	Poor
Mustelus antarcticus	0	0	0	0	0	0	0	0	0	0	0	0
Heterodontus portusjacksoni	0	0	0	1	2	1	0	0	1	0	2	0
Trygonoptera testacea	0	0	0	0	0	0	0	0	0	0	0	0
Trygonorrhina fasciata	0	0	1	0	1	0	1	0	0	1	1	1
Aptychotrema rostrata	0	0	0	0	0	0	0	0	0	0	0	0
Myliobatis tenuicaudatus	0	0	0	0	0	0	0	0	0	0	0	0
Torquigener pleurogramma	0	0	0	0	0	0	0	0	1	0	0	0
Platycephalus caeruleopunctatus	0	0	0	0	4	4	0	0	0	0	2	0
Torquigener vicinus	0	0	0	0	0	0	0	0	0	0	0	0
Aplodactylus lophodon	0	0	0	0	0	0	0	0	0	0	0	0
Sillago maculata	0	0	0	0	0	5	0	0	0	0	5	0
Trachurus novaezelandiae	0	0	0	0	30	0	0	0	0	0	0	0
Luidia australiae	0	0	0	0	0	0	0	0	0	0	0	0

Appendix E: SIMPER outputs for fish using 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 for the survey at the top of the column, for those groups identified by PERMANOVA as being significantly different at the South Coast Mariculture operations in Jervis Bay for the Baseline, Update 1 and Update 2 surveys

Survey	Baseline	Update 1	Update 2
Baseline	Eastern Fiddler Ray Flathead Yellowtail Scad		
Update 1	Yellowtail Scad Trumpeter Whiting Eastern Fiddler Ray Blue-spotted Flathead Flathead *	Yellowtail Scad Eastern Fiddler Ray Trumpeter Whiting Blue-spotted Flathead	
Update 2	Blue-spotted Flathead Trumpeter Whiting Flathead *	Yellowtail Scad * Blue-spotted Flathead Eastern Fiddler Ray *	Blue-spotted Flathead Trumpeter Whiting Eastern Fiddler Ray Yellowtail Scad