

Final Report 2019

Port Coogee Marina fish diversity monitoring programme



Dr Glen Whisson
Alex Hoschke

December 2019



AQUA RESEARCH & MONITORING SERVICES

EXECUTIVE SUMMARY

Aqua Research & Monitoring Services (ARMS) conducted a year-long survey of fish diversity and associated biotic (other species—corals, seagrass, etc) and abiotic (sediment, temperature etc) parameters—ending December 2019—in order to begin a baseline monitoring programme for Marina Management to reference in the future. ARMS recorded, photographed and identified 85 finfish species from 47 families in 2018 and 2019. The distribution of brown macroalgae *Sargassum* sp. was mapped from aerial photographs and found to proliferate in the winter months before dying back during summer. The *Sargassum* was photographed at several meters height in some parts of the Marina; however, its holdfast system requires hard structure for attachment (rocks, rock walls, submerged debris, etc), which ultimately will determine its distribution within the Marina. Water temperatures varied from a maximum daily average of 25.2°C in February 2019 to a minimum of 15.3°C in June 2019. Water analysis, sediment heavy metals, and sediment particle size distributions are presented for the baseline record.

ARMS recommends:

- repeated monitoring of fish diversity at 2-3 year intervals;
- *in situ* data loggers are re-deployed to measure water temperature as part of a permanent monitoring programme (continuing the data set begun in December 2018). Two data loggers should be purchased/deployed to allow for redundancy/failures;
- coral growth and abundance/diversity monitoring is recommended, as they are a good indicator of system health;
- repeat water/sediment analysis as requested by Marina Management;
- continue monitoring progress of *Sargassum* throughout Marina;
- the emerging *Posidonia* seagrass stands should be assessed/reported each year as seagrass health/adundance has a positive correlation with ecosystem health.

Alexandra Hoschke
Glen Whisson
Aqua Research & Monitoring Services
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OVERVIEW

A Fish Diversity Monitoring Programme of the Port Coogee Marina, Western Australia was undertaken by Aqua Research and Monitoring Services for the City of Cockburn. The survey spanned December 2018 to December 2019, and included:

1. Fish Diversity assessment
2. Marine Habitat mapping
3. Sea Temperature monitoring
4. Water sampling/analysis
5. Sediment sampling, analysis and particle sizing

1.0 OBJECTIVE

1.1 To design and implement an aquatic monitoring programme for Port Coogee Marina that:

- 1.1.1** focusses on the fish assemblage currently prevailing in the Marina;
- 1.1.2** documents current fish diversity using standard ecological biodiversity indicators;
- 1.1.3** includes baseline sediment minerals analysis;
- 1.1.4** includes baseline, elemental water analysis;
- 1.1.5** identifies macrophyte stands and utilises a geographic information system to create a layered habitat map providing an indication of seasonal changes over time;
- 1.1.6** includes the establishment of a long-term water temperature monitoring programme;
- 1.1.7** utilises a multi-tool approach to data gathering (*in situ* video, diver observation, habitat sampling, etc);
- 1.1.8** is repeatable.

2.0 Personnel

- Dr Glen Whisson, Aqua Research and Monitoring Services
- Alexandra Hoschke, Aqua Research and Monitoring Services

3.0 METHODS

3.1 Fish Diversity Assessment

Six 100 m transects were selected as suitable/accessible sites representing the prevailing Marina habitats following reconnaissance dives in February 2019 (Fig 1). Scuba and snorkel surveys were undertaken along both the seafloor and surface on all transects between February and April 2019, and repeated in November/December 2019. During the surveys fish species were photographed and subsequently recorded in a spreadsheet with location, date, species name and count. Photographs of any species requiring identification/classification were sent to Dr Glenn Moore, Fish Curator at the WA Museum for confirmation. In addition to the transects, all remaining internal walls of the Marina and representative open silty areas within the channels were covered with reconnaissance scuba surveys and all fish species encountered photographed or recorded.

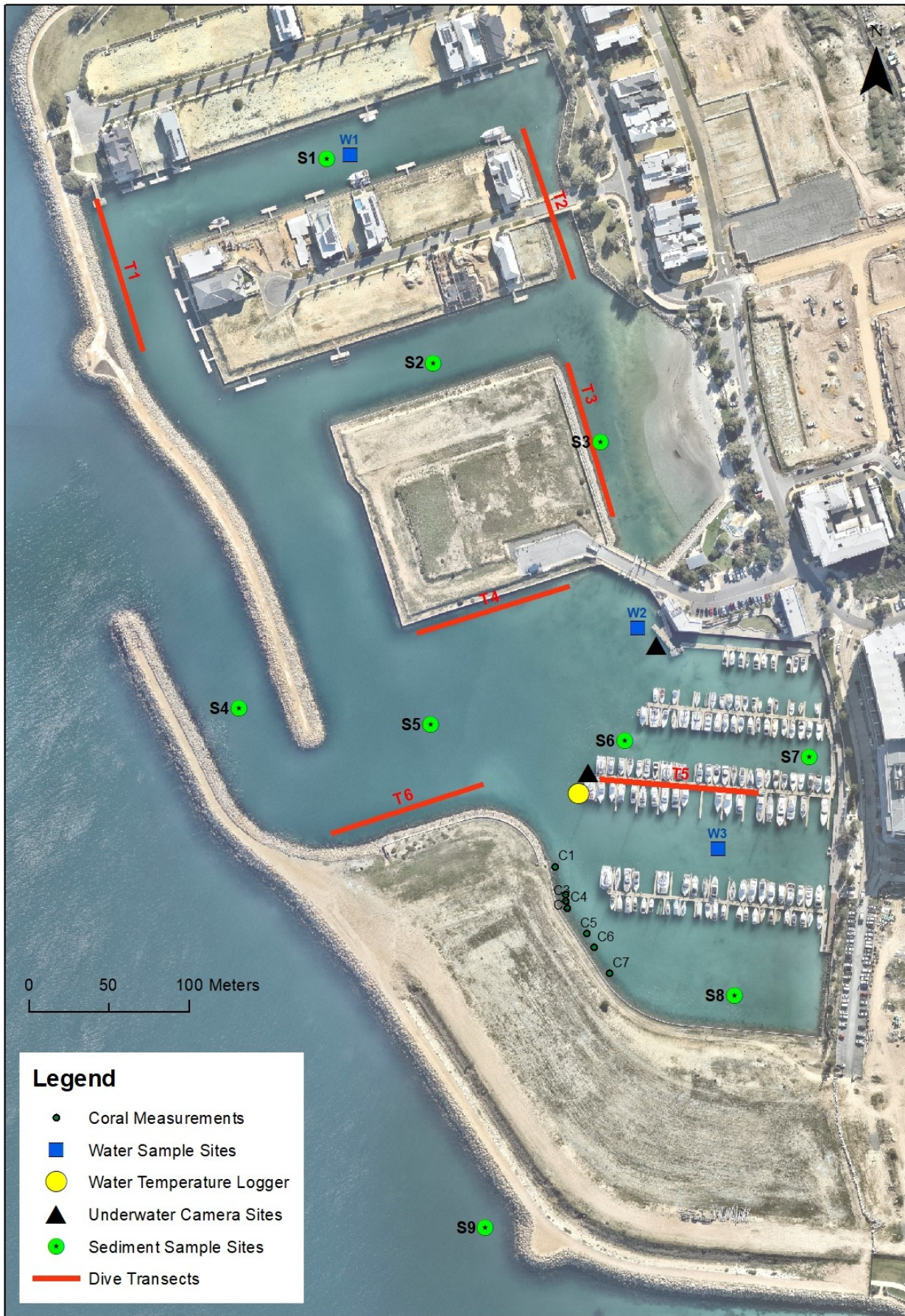


Figure 1: Survey and monitoring locations

Night-time video footage was recorded from the seaward end of T5 and off the fuel jetty in February and April 2019 and used to identify additional nocturnal species. Incidental surface observations, including fish associated with floating weed following storms, were added to the total species list.

During the fish surveys other common marine flora and fauna were photographed and recorded.

3.2 Marine habitat Mapping

Aerial images of the Port Coogee Marina taken between 2015 and 2019 were obtained from the City of Cockburn GIS Services Department. The images were used as basemaps in ArcGIS to identify the different substrate types within the Marina which were then ground-truthed with scuba surveys. Surface areas of different habitat types were calculated from the images. Four images from different dates were selected to show incremental growth of macroalgae from year to year. Measurements of various flora and fauna were taken at the outset of the study, including a number of coral heads along the southern Marina wall (Appendix 3). Coral locations were marked on the exposed concrete retaining wall so that individual coral growth rates can be monitored going forward.

3.3 Sea Temperature

Sea temperature was recorded at half-hour intervals from 28 November to 3 December 2019 using a HOBO UA-001-64 data logger installed 50cm above the seabed at the western end of D Jetty (water depth 3m). The logger was retrieved and downloaded at approximately 3 month intervals.

3.4 Water Sampling

Water samples were collected in February 2019 from 30cm below sea surface at three sites inside the Marina (Fig. 1). The sites were chosen to represent areas remote from the Marina entrance (W1); near the fuel jetty (W2) and close to boat pens (W3). All samples were submitted to LabWest for ICP-MS analysis (multi-acid digestion with Inductively-Coupled-Mass Spectrometry).

3.5 Sediment Sampling

Sediment samples were collected using a 50mm PVC pipe to take 10cm cores from the seafloor at 9 sites inside the Marina in February 2019 (Fig. 1). Sites were selected to include channels remote from the Marina entrance bordering new housing developments (S1 & S2); opposite the public beach (S3); a transect from the Marina entrance channel through the boats to the eastern boardwalk (S4—S7); and a shallow site near the southern Marina boundary wall. Samples were submitted to LabWest for ICP-MS analysis.

3.6 Sediment particle sizing

The laboratory offered a complementary laser-sizing service for all nine sediment samples submitted. This will provide a baseline for future comparisons with respect to siltation, sand distribution, etc.

4.0 RESULTS

4.1 Fish Diversity Assessment

A total of 85 finfish species from 47 families were photographed and identified within the Marina during 2018 and 2019 (Table 1), with 82 species from 46 families recorded during the survey period, December 2018—December 2019, and an additional three species (*Hippocampus tuberculatus*, *Lissocampus runa* and *Chelidonichthys kumu*) recorded earlier in 2018. A complete list of all identifications in phylogenetic order is provided in Appendix 1. A selection of photographs of representative species are included in Appendix 2.

Table 1. Fish families and representative species richness recorded at Port Coogee Marina in 2018/19

	Family	Number of species		Family	Number of species
1	APOGONIDAE	3	25	NEMIPTERIDAE	1
2	ARACANIDAE	2	26	ORECTOLOBIDAE	1
3	ARRIPIDAE	2	27	PARALICHTHYIDAE	1
4	ATHERINIDAE	2	28	PEGASIDAE	1
5	BLENNIIDAE	3	29	PEMPHERIDAE	1
6	CALLIONYMIDAE	3	30	PINGUIPEDIDAE	1
7	CARANGIDAE	2	31	PLATYCEPHALIDAE	2
8	CHAETODONTIDAE	1	32	PLOTOSIDAE	1
9	CLUPEIDAE	2	33	POMACENTRIDAE	2
10	ENGRAULIDAE	1	34	SCORPIDIDAE	1
11	ENOPLOSIDAE	1	35	SERRANIDAE	1
12	GERREIDAE	2	36	SILLAGINIDAE	2
13	GIRELLIDAE	1	37	SPARIDAE	3
14	GOBIIDAE	6	38	SPHYRAENIDAE	1
15	KYPHOSIDAE	2	39	SYNGNATHIDAE	6
16	LABRIDAE	5	40	TERAPONTIDAE	1
17	LATIDAE	1	41	TETRAODONTIDAE	1
18	LATRIDAE	2	42	TETRAROGIDAE	1
19	MICROCANTHIDAE	1	43	TRIGLIDAE	1
20	MONACANTHIDAE	4	44	TRIPTERYGIIDAE	1
21	MONODACTYLIDAE	1	45	TRYGONORRHINIDAE	1
22	MUGILIDAE	2	46	UROLOPHIDAE	1
23	MULLIDAE	2	47	XIPHIIDAE	1
24	MURAENIDAE	1	TOTAL SPECIES COUNT		85



Figure 2: Marine habitats and habitat photo locations

The number of species recorded (richness) and total estimated abundance were highest along the southern wall of the Marina entrance channel (T6) and the north-west corner of the western sea wall (T1) (Fig. 3). This abundance/richness data will provide a baseline for comparisons in the future during repeat surveys.

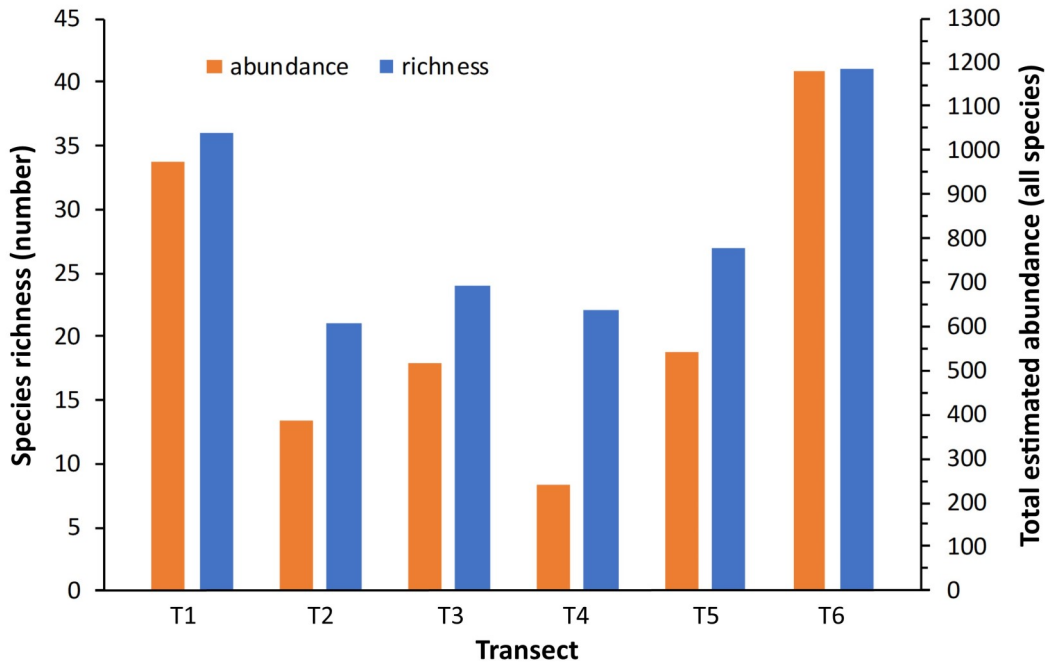


Figure 3. Fish species richness and abundance recorded at Port Coogee Marina

Some of the more common species seen were: Weeping Toadfish (*Torquigener pleurogramma*), Western Gobbeguts (*Ostorhinchus rueppellii*), Western Striped Grunter (*Helotes octolineatus*), Western Buffalo Bream (*Kyphosus cornelii*), Silver Drummer (*Kyphosus sydneyanus*) and Black Bream (*Acanthopagrus butcheri*). More unusual species included a Swordfish (*Xiphias gladius*) which was seen on two occasions in January, a Spikey Bass (*Hypopterus macropterus*) that was recorded both inside and outside the Marina wall, and Dusky Frillgobies (*Bathygobius fuscus*) from near the fuel jetty, all of which are out of their normal geographic range. A number of species that are more commonly seen in the Swan River Estuary were also recorded—such as the Yellowtail Flathead (*Platycephalus westraliae*), the Southern Longfin Goby (*Favonigobius lateralis*), the Striped Sandgoby (*Acentrogobius pflaumii*), which is an introduced species, and the Black Bream (*Acanthopagrus butcheri*). A Wobbegong Shark was recorded from T6, and another shark was recorded on video footage from the seaward end of T5 but poor visibility prevented positive identification.

Three different species of pipefish and one seahorse were photographed in the Marina during the period of the survey (an additional seahorse *Hippocampus tuberculatus* and pipefish *Lissocampus runa* had been photographed in the Marina in 2018 but not recorded in 2019—Appendix 1).

Blennies and gobies were abundant throughout the Marina but show spatial variation according to their preferred habitat. Germain's Blenny (*Omobranchus germaini*), False Tasmanian Blenny (*Parablennius postoculomaculatus*) and the tiny Twospot Eviota (*Eviota bimaculata*) were common on the rock walls where

they inhabit crevices. The Shorthead Sabretooth Blenny (*Petroscirtes breviceps*) has similar habitat but was also found in pipes and other artificial structures (Appendix 2). The Dusky Frillgoby (*Bathygobius fuscus*) and Southern Longfin Goby (*Favonigobius lateralis*) were common in sandy/silty areas on the eastern side of the Marina where they inhabit burrows, and the Whitebarred Goby (*Amblygobius phalaena*) was common in burrows underneath or very close to the rock walls, particularly opposite the beach and in other areas where the sediment was more sandy. The introduced Striped Sandgoby (*Acentrogobius pflaumi*) was only observed near burrows on Transect 1 on the west side of the Marina.

Other species do not reside in the Marina but at certain times of the year come into the Marina in large schools—e.g. Australian Herring (*Arripis georgianus*), Sea Mullet (*Mugil cephalus*), West Australian Salmon (*Arripis truttaceus*), Western Buffalo Bream (*Kyphosus cornelii*) and Silver Drummer (*Kyphosus sydneyanus*).

4.2 Other fauna

In addition to fish species, other fauna observed within the Marina during the survey included dolphin, turtle, octopus, squid, cuttlefish, crayfish, crabs (including blue manna), mussels, prawns, sea stars, sea squirts, sea cucumbers and nudibranchs.

4.3 Corals

Hard corals have naturally recruited on many of the rocks used to construct the Marina walls, particularly on the inside of the southern wall, with species from at least 8 different families (*Favia*, *Favites*, *Goniopora*, *Montastrea*, *Pocillopora*, *Turbinaria* and *Zoanthids*) photographed during the survey (Appendix 3). In addition, six corals were photographed (see locations in Fig. 1) with a scale bar so that future growth can be monitored (Appendix 4). The corals generally appeared healthy, although there was some evidence for sediment and algae smothering coral (Appendix 3).

4.4 Marina Habitats

The water inside the Marina covers an area of approximately 115,500m² at high tide. There is a constant influx of fresh water (particularly around the area behind the fuel jetty), which sometimes results in obvious stratification of the water column and appears to be influencing the fish assemblages locally. Three main marine habitats can be defined within the Marina with surface areas calculated as follows: silt (91,361m²), submerged rock wall (17,575m²) and sand (6,580m²) (Fig. 2). In addition, at certain times of the year brown macroalgae (*Sargassum* sp.) forms a significant habitat within the Marina. Photos from various habitats are included in Appendix 5.

4.4.1 Silt

The majority of the Marina floor is covered in silty sediment—fine and muddy in parts, and sometimes more sandy with coarser debris including shell fragments and organic debris (Appendix 5, photo 7). It is poorly consolidated and bioturbated in parts (Appendix 5, photo 8), and elsewhere has a covering of turf algae, and in places has macro algae growing on rocks or other more solid debris within the sediment. A few small patches of *Posidonia* sp. seagrass was observed seawards of D jetty (Appendix 5, photo 12). Within the main entrance channel and spilling into the Marina is seagrass wrack which collects during

storms and forms a thick mat overlying the silt (Appendix 5, photo 1). Visibility is often poor near the seafloor, but flathead, fiddler rays, stingarees and gobies are some of the families that were recorded on the silty sediments, and juvenile fish shelter in the seagrass wrack.

4.4.2 Rock wall

The Marina wall has been constructed of large limestone boulders that have spilled onto the adjacent Marina floor. The rock is stacked in such a way that it contains abundant caves and cavities, which provide habitat and shelter for numerous fish (including larger species such as wobbegong sharks), crustaceans, cephalopods etc. The rocks are covered with turf algae (Appendix 5, photo 5), hard corals (Appendix 5, photo 10), molluscs, sponges and tunicates. During the winter, rapid growth of macro algae (*Sargassum* sp.) on the rocks forms dense stands up to 4m tall (Appendix 5, photos 2, 3 & 4). The sargassum dies back in the warmer summer months, allowing enough light to support coral growth. In November 2019 filamentous algae was observed growing on the rock wall in T6 (Appendix 5, photo 11). It may be of interest to monitor this over summer as it has the potential to inhibit growth of other species including corals, and may be an indicator of high dissolved nutrients within the Marina.

4.4.3 Sand

The sand habitat is defined as the area where coarser sand has been introduced to form an artificial beach area within the Marina, and much of it is exposed at low tide. The Southern Longfin Goby (*Favonigobius lateralis*) is common in the areas below the low tide level just off the beach.

4.4.4 Macroalgae

The brown macroalgae *Sargassum* sp. grows on any firm substrate in the Marina, particularly during the winter months. It is mostly confined to the rock walls around the edge of the Marina, where it can reach heights of several metres by October/November before dying back over the summer months. However, it also grows in the sediment where there is any hard structure (e.g. rocks or debris) for it to attach to with its holdfast, and can be clearly seen on the aerial images as dark patches (Fig. 4). The requirement for a solid anchor point therefore determines its distribution in the Marina and explains why it tends to grow in similar spots every year (Fig. 4). Few clear satellite images were available in the summer months to show the dieback, mostly due to ripples/sunlight reflection on the surface of the water or poor visibility in the Marina at that time of the year. However, scuba surveys in October and November indicated maximum height of the sargassum, and surveys earlier in the year (February) showed only few sparsely distributed small plants, with the rock walls largely free of Sargassum.

In addition to the basal habitats, there are numerous artificial structures (pylons, pontoons etc.) within the Marina that are covered with various species of red, brown (including *Sargassum* sp.) and green algae (including *Ulva* sp.), mussels, sponges, tunicates etc (Appendix 5, photos 5 & 9).

4.5 **Sea Temperature**

Half hourly measurements of sea temperature were converted to daily averages and plotted to show the variation throughout the year (Fig. 5). During the logger's final deployment it failed due to water incursion, so data is missing from 24 September 2019 until the end of the survey (end November 2019). Temperatures varied from a maximum daily average of 25.2°C on 28 February 2019, to a minimum of 15.3°C on 11 June 2019.

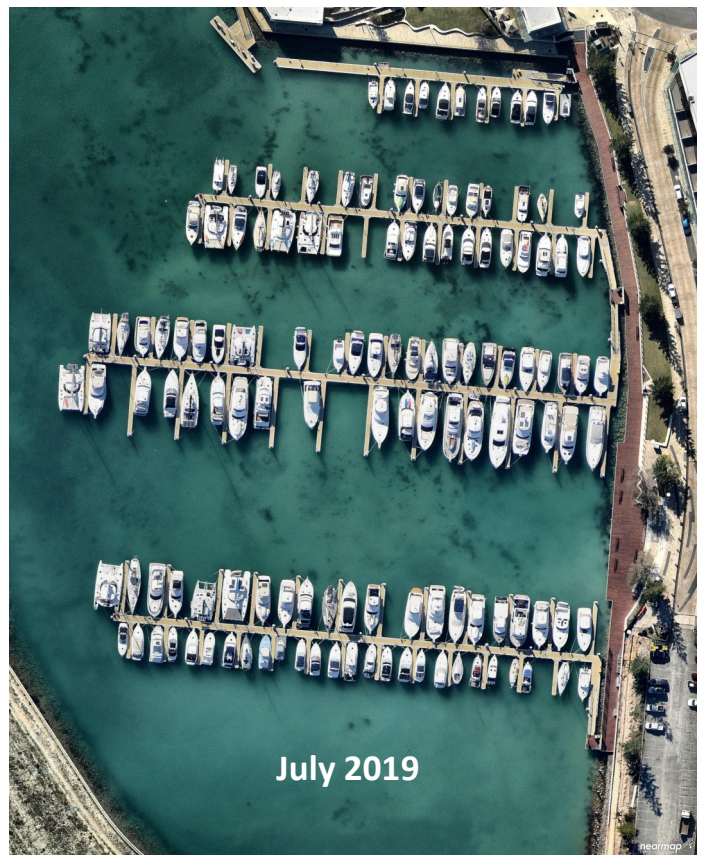
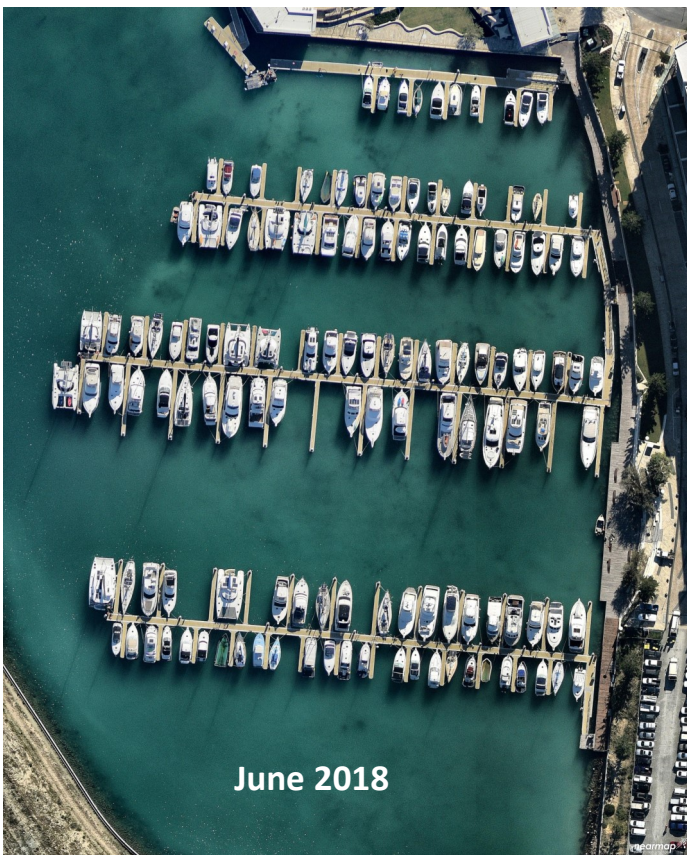
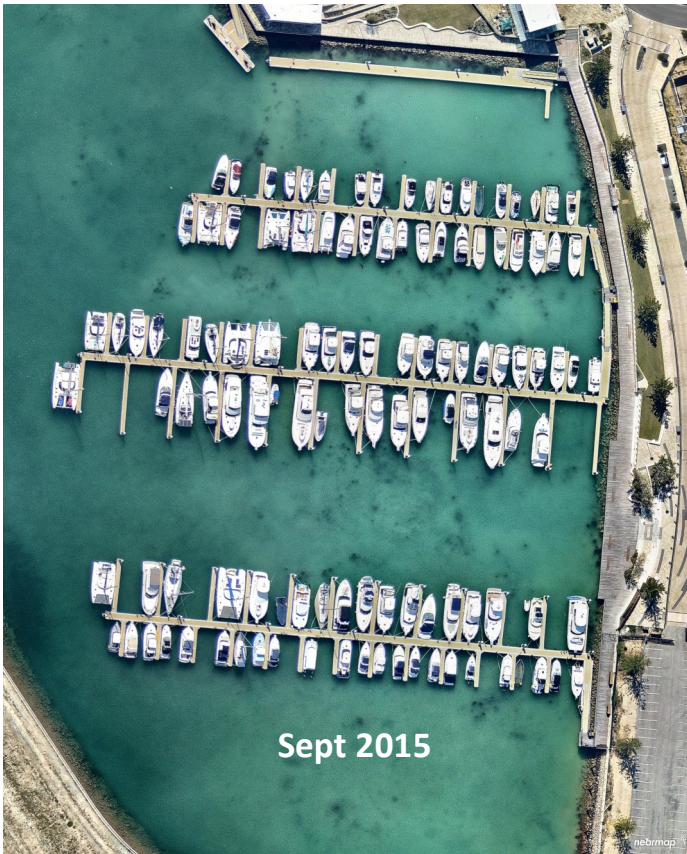


Figure 4: Port Coogee Marina images showing growth of Sargassum weed (dark patches). Images sourced from Nearmap, Dec 2019.



Figure 5: Daily average water temperature from 3m depth in Port Coogee Marina (location Fig. 1)

4.6 Sediment Sampling

Elemental analysis focussing on select heavy metals returned baseline data for future comparisons. Results were unremarkable on the whole; however the open water sample point S5 and the southern-most sample point S8 (Fig. 1) were consistently lower for most heavy metals analysed (Figs 6 & 7).

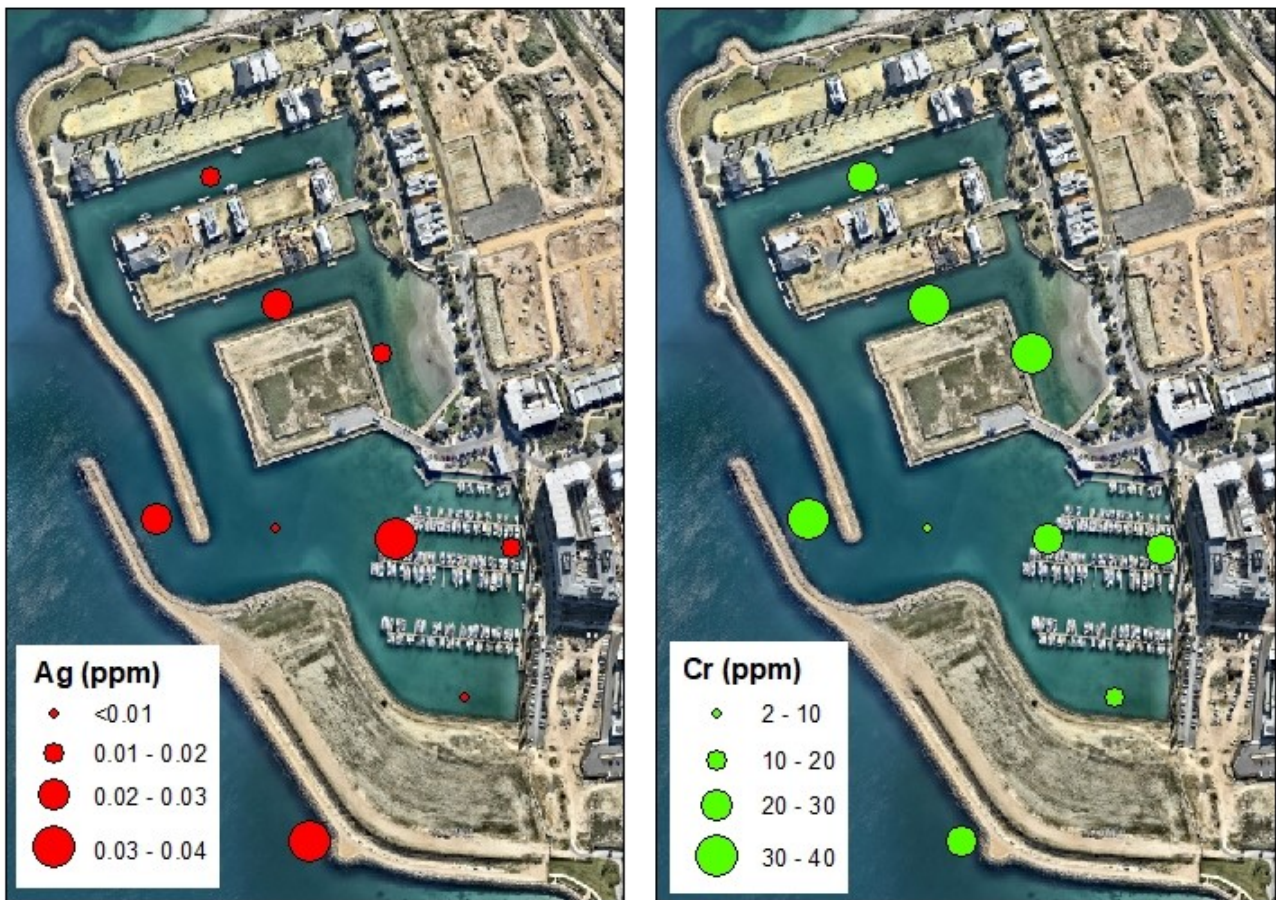


Figure 6: Cartogram for Silver (Ag) Chromium (Cr) at 9 locations at the Port Coogee Marina (March 2019)



Figure 7: Cartogram for Iron (Fe), Copper (Cu), Lead (Pb) and Zinc (Zn) at 9 locations at the Port Coogee Marina (March 2019)

Arsenic (As) and Cadmium (Cd) sediment geochemistry assays were all less than twice the detection limits of 5 ppm and 0.05 ppm respectively, and tin (Sn) results were also low with a maximum of 0.5ppm (detection limit 0.2 ppm). Mercury (Hg) only returned one result (0.08 ppm at S1) above the detection limit of 0.05 ppm, and all results for Nickel (Ni) were below detection (2 ppm). The complete analysis as received is provided in Appendix 6.

4.6 Sediment particle size distributions

Laser particle size analysis of sediment samples was conducted as part of this baseline study as it may assist in comparative assessments of siltation and sand movement/spread in the future. The full analysis and particle distributions are provided as received in Appendix 7.

4.7 Water Sampling

Elemental analysis via mass spectrometry for 64 elements is presented as received in Appendix 8. The authors are not environmental chemists and provide this data for Marina Management as part of the baseline collection of information. It is noted that there appears to be minimal variation across the water samples taken from the three locations (see Fig. 1).

5.0 DISCUSSION AND RECOMMENDATIONS

This study indicated a relatively diverse fish assemblage with over 80 species documented. Interestingly this included a number of species that are usually more common in estuaries than in the ocean, possibly reflecting the high input of fresh water, particularly under the fuel jetty and area along the Marina edge behind “F” jetty. Black Bream (*Acanthopagrus butcheri*) were abundant in this area of the Marina but are rarely seen elsewhere along the Perth Coast apart from in the Swan River. The species normally breeds in rivers/estuaries so any evidence of this species breeding in the Marina should be recorded. Black bream are also a prized target of recreational fishers so ongoing monitoring of this population may indicate whether fishing is having an impact into the future. Fish biodiversity measurements are an important indicator of the Marina health in general—and long-term monitoring to compare future assemblages with the species diversity outlined in this report is recommended at least every 2-3 years.

It is recommended that sea temperature measurements, sediment and water sampling, as well as monitoring of filamentous and macro algae growth, are repeated on an annual or biennial basis to provide baseline data for assessing Marina health. Sea temperature data was lost for the last two months of the survey period due to a water incursion in the data logger, hence it is recommended that two loggers be deployed at the same location to provide backup in the event of another failure.

Limited seawater circulation at certain times of the year, potential spillages from boats or the fuel jetty, high sediment influx during storms, and high sea water temperatures during summer months may all impact the health of the flora and fauna and affect the quality and oxygen content of both the water and sediments in the Marina. By continuing the baseline monitoring approach suggested on an annual basis, recommendations can be made for maintaining or improving the health of the Marina.

In addition, coral growth and abundance/diversity monitoring is recommended, as corals require low nutrient conditions and adequate water quality to thrive, and are therefore a good indicator of the health of the system. As the corals are spread throughout the Marina, they are also useful indicators of any spatial variation of water quality with distance from the main flushing channel.

The emerging patch of *Posidonia* seagrass in the open water section of the Marina (Fig. 8) was an unexpected find during the survey. Seagrass beds are often associated with healthy and biodiverse marine systems. Of particular interest in a marina, seagrass root systems have an important role in stabilizing sediments and are efficient nutrient recyclers. The authors therefore encourage continued monitoring of this stand.



Figure 8: *Posidonia* seagrass discovered in Port Coogee Marina (Box 12, Fig. 2)

APPENDIX 1: Fish species recorded in Port Coogee Marina; 2018-2019 (in phylogenetic order)

*refers to species recorded/identified in 2018 before the official survey commenced

	FAMILY	Common Name	Species Name (‡ endemic)	2018*
1	ORECTOLOBIDAE	Spotted Wobbegong	<i>Orectolobus maculatus</i>	
2	TRYGONORRHINIDAE	Southern Fiddler Ray	<i>Trygonorrhina dumerilii</i>	
3	UROLOPHIDAE	Western Shovelnose Stingaree	<i>Trygonoptera mucosa</i>	
4	MURAENIDAE	Highfin Moray	<i>Gymnothorax pseudothyrsoides</i>	
5	CLUPEIDAE	Scaly Mackerel	<i>Sardinella lemuru</i>	
6	CLUPEIDAE	Blue Sprat	<i>Spratelloides robustus</i>	
7	ENGRAULIDAE	Australian Anchovy	<i>Engraulis australis</i>	
8	PLOTOSIDAE	Striped Catfish	<i>Plotosus lineatus</i>	
9	MUGILIDAE	Yelloweye Mullet	<i>Aldrichetta forsteri</i>	
10	MUGILIDAE	Sea Mullet	<i>Mugil cephalus</i>	
11	ATHERINIDAE	Common Hardyhead	<i>Atherinomorus vaigiensis</i>	
12	ATHERINIDAE	Silver Fish	<i>Leptatherina presbyteroides</i>	
13	SYNGNATHIDAE	Tiger Pipefish	<i>Filicampus tigris</i>	
14	SYNGNATHIDAE	West Australian Seahorse	<i>Hippocampus subelongatus</i>	
15	SYNGNATHIDAE	Knobby Seahorse	<i>Hippocampus tuberculatus</i>	2018*
16	SYNGNATHIDAE	Rhino Pipefish	<i>Histiogamphelus cristatus</i>	
17	SYNGNATHIDAE	Javelin Pipefish	<i>Lissocampus runa</i>	2018*
18	SYNGNATHIDAE	Spotted Pipefish	<i>Stigmatopora argus</i>	
19	PEGASIDAE	Slender Seamoth	<i>Pegasus volitans</i>	
20	TETRAROGIDAE	Soldier	<i>Gymnapistes marmoratus</i>	
21	TRIGLIDAE	Red Gurnard	<i>Chelidonichthys kumu</i>	2018*
22	PLATYCEPHALIDAE	Longhead Flathead	<i>Leviprora inops</i>	
23	PLATYCEPHALIDAE	Yellowtail Flathead	<i>Platycephalus westraliae</i>	
24	SERRANIDAE	Blowhole Perch	<i>Caesioscorpis theagenes†</i>	
25	APOGONIDAE	Western Gobbleguts	<i>Ostorhinchus rueppellii</i>	
26	APOGONIDAE	Western Striped Cardinalfish	<i>Ostorhinchus victoriae</i>	
27	APOGONIDAE	Wedgehead Siphonfish	<i>Siphamia cuneiceps</i>	
28	LATIDAE	Spikey Bass	<i>Hypopterus macropterus†</i>	
29	SILLAGINIDAE	Southern School Whiting	<i>Sillago bassensis</i>	
30	SILLAGINIDAE	Trumpeter Whiting	<i>Sillago maculata</i>	
31	CARANGIDAE	Silver Trevally	<i>Pseudocaranx georgianus</i>	
32	CARANGIDAE	Yellowtail Scad	<i>Trachurus novaezelandiae</i>	
33	NEMIPTERIDAE	Western Butterfish	<i>Pentapodus vitta†</i>	
34	GERREIDAE	Common Silverbidy	<i>Gerres subfasciatus</i>	
35	GERREIDAE	Silverbelly	<i>Parequula melbournensis</i>	
36	SPARIDAE	Black Bream	<i>Acanthopagrus butcheri</i>	
37	SPARIDAE	Snapper	<i>Chrysophrys auratus</i>	
38	SPARIDAE	Tarwhine	<i>Rhabdosargus sarba</i>	
39	MULLIDAE	Blacksaddle Goatfish	<i>Parupeneus spilurus</i>	
40	MULLIDAE	Bluespotted goatfish	<i>Upeneichthys vlamingii</i>	
41	PEMPHERIDAE	Rough Bullseye	<i>Pempheris klunzingeri</i>	
42	MONODACTYLIDAE	Western Pomfred	<i>Schuettea woodwardi</i>	
43	ARRIPIDAE	Australian Herring	<i>Arripis georgianus</i>	
44	ARRIPIDAE	West Australian Salmon	<i>Arripis truttaceus</i>	

APPENDIX 1 (cont'd): Fish species recorded in Port Coogee Marina; 2018-2019 (in phylogenetic order)
 *refers to species recorded/identified in 2018 before the official survey commenced

	FAMILY	Common Name	Species Name († endemic)	2018*
45	GIRELLIDAE	Zebrafish	<i>Girella zebra</i>	
46	KYPHOSIDAE	Western Buffalo Bream	<i>Kyphosus cornelii</i> †	
47	KYPHOSIDAE	Silver Drummer	<i>Kyphosus sydneyanus</i>	
48	MICROCANTHIDAE	Stripey	<i>Microcanthus strigatus</i>	
49	SCORPIDIDAE	Banded Sweep	<i>Scorpius georgiana</i>	
50	CHAETODONTIDAE	Western Talma	<i>Chelmonops curiosus</i>	
51	ENOPLOSIDAE	Old Wife	<i>Enoplosus armatus</i>	
52	TERAPONTIDAE	Western Striped Grunter	<i>Helotes octolineatus</i>	
53	LATRIDAE	Magpie Morwong	<i>Goniistius gibbosus</i> †	
54	LATRIDAE	Redlip Morwong	<i>Goniistius rubrolabiatu</i> †	
55	POMACENTRIDAE	McCulloch's Scalyfin	<i>Parma mccullochi</i> †	
56	POMACENTRIDAE	Miller's Damsel	<i>Pomacentrus milleri</i>	
57	LABRIDAE	Baldchin Groper	<i>Choerodon rubescens</i> †	
58	LABRIDAE	Western King Wrasse	<i>Coris auricularis</i> †	
59	LABRIDAE	Blue Weed whiting	<i>Haletta semifasciata</i>	
60	LABRIDAE	Little Weed Whiting	<i>Neodax balteatus</i>	
61	LABRIDAE	Brownspotted Wrasse	<i>Notolabrus parilus</i>	
62	PINGUIPEDIDAE	Wavy Grubfish	<i>Parapercis haackei</i>	
63	TRIPTERYGIIDAE	Blackhead Threefin	<i>Enneapterygius larsonae</i> †	
64	BLENNIIDAE	Germain's Blenny	<i>Omobranchus germaini</i>	
65	BLENNIIDAE	False Tasmanian Blenny	<i>Parablennius postoculomaculatus</i> †	
66	BLENNIIDAE	Shorthead Sabretooth Blenny	<i>Petroscirtes breviceps</i>	
67	CALLIONYMIDAE	Finger Dragonet	<i>Dactylopus dactylopus</i>	
68	CALLIONYMIDAE	Painted Stinkfish	<i>Eocallionymus papilio</i>	
69	CALLIONYMIDAE	Longspine Dragonet	<i>Pseudocalliurichthys goodladi</i> †	
70	GOBIIDAE	Striped Sandgoby	<i>Acentrogobius pflaumii</i>	
71	GOBIIDAE	Whitebarred Goby	<i>Amblygobius phalaena</i>	
72	GOBIIDAE	Bridled Goby	<i>Arenigobius bifrenatus</i>	
73	GOBIIDAE	Dusky Frillgoby	<i>Bathygobius fuscus</i>	
74	GOBIIDAE	Twospot Eviota	<i>Eviota bimaculata</i>	
75	GOBIIDAE	Southern Longfin Goby	<i>Favonigobius lateralis</i>	
76	SPHYRAENIDAE	Striped Barracuda	<i>Sphyraena obtusata/pinquis</i>	
77	XIPHIIDAE	Swordfish	<i>Xiphias gladius</i>	
78	PARALICHTHYIDAE	Smalltooth Flounder	<i>Pseudorhombus jenynsii</i>	
79	MONACANTHIDAE	Spinytail Leatherjacket	<i>Acanthaluteres brownii</i>	
80	MONACANTHIDAE	Toothbrush Leatherjacket	<i>Acanthaluteres vittiger</i>	
81	MONACANTHIDAE	Horseshoe Leatherjacket	<i>Meuschenia hippocrepsis</i>	
82	MONACANTHIDAE	Fanbelly Leatherjacket	<i>Monacanthus chinensis</i>	
83	ARACANIDAE	Western Smooth Boxfish	<i>Anoplocapros amygdaloides</i>	
84	ARACANIDAE	Whitebarred Boxfish	<i>Anoplocapros lenticularis</i>	
85	TETRAODONTIDAE	Weeping Toadfish	<i>Torquigener pleurogramma</i>	

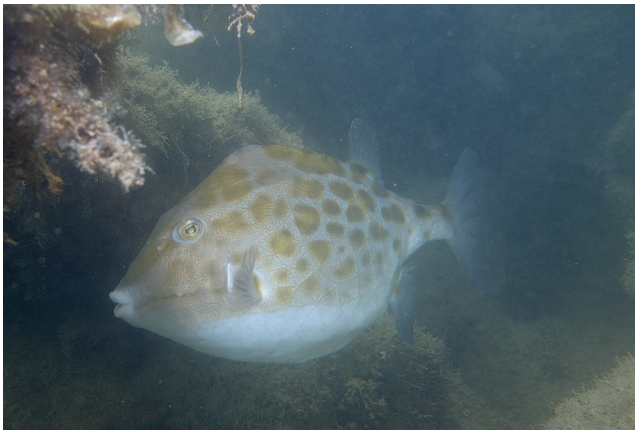
APPENDIX 2: Fish photographs taken during the 2018-19 survey in Port Coogee Marina



Acanthopagrus butcheri



Acentrogobius pflaumii



Anoplocapros amygdaloides



Arenigobius bifrenatus



Bathygobius fuscus



Engraulis australis



Enoplosus armatus



Filicampus tigris

APPENDIX 2 (cont'd): Fish photographs taken during the 2018-19 survey in Port Coogee Marina



Girella zebra



Goniistius gibbosus (juvenile)



Monacanthus chinensis



Mugil cephalus



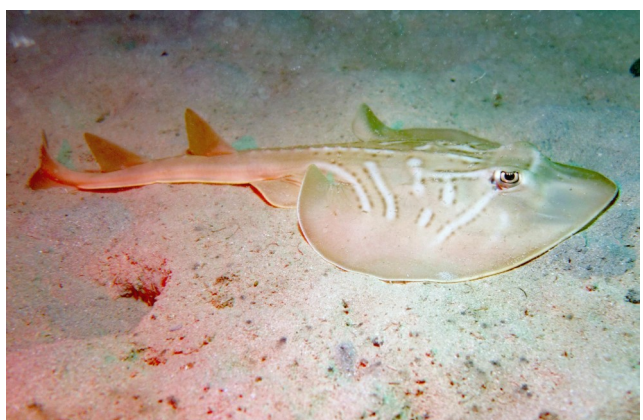
Neodax balteatus



Petrosirtes breviceps



Scorpis georgiana

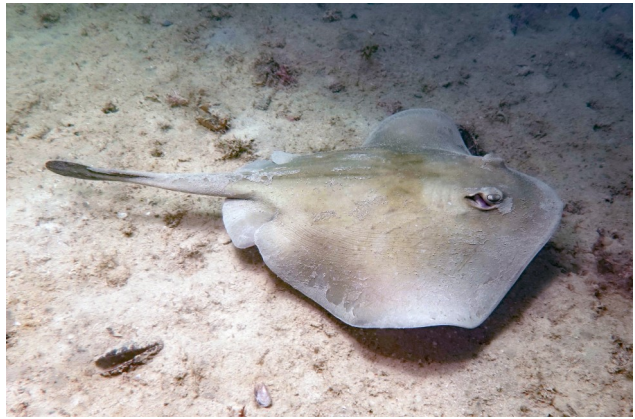


Trygonorrhina dumerlii

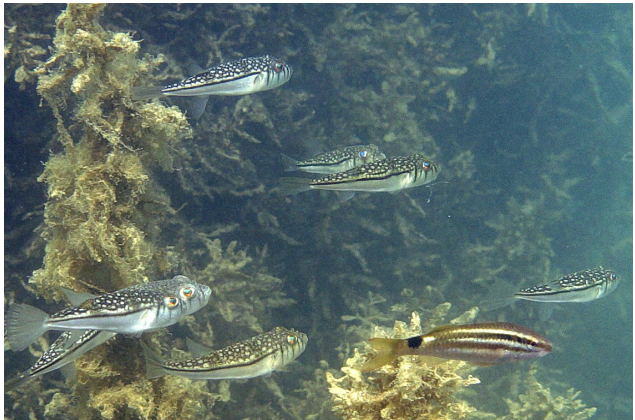
APPENDIX 2 (cont'd): Fish photographs taken during the 2018-19 survey in Port Coogee Marina



Hippocampus subelongatus



Trygonoptera mucosa



Parupeneus spilurus and *Torquigener pleurogramma*



Gymnothorax pseudothyroideus



Siphamia cuneiceps



Hypopterus macropterus



Hippocampus tuberculatus

APPENDIX 2 (cont'd): Fish photographs taken during the 2018-19 survey in Port Coogee Marina



Night time video deployment: Yellowtail Scad



Night time video deployment: school of juvenile Striped Catfish approaching the camera (bottom left)



Night time video deployment: Blue Manna crab at first light

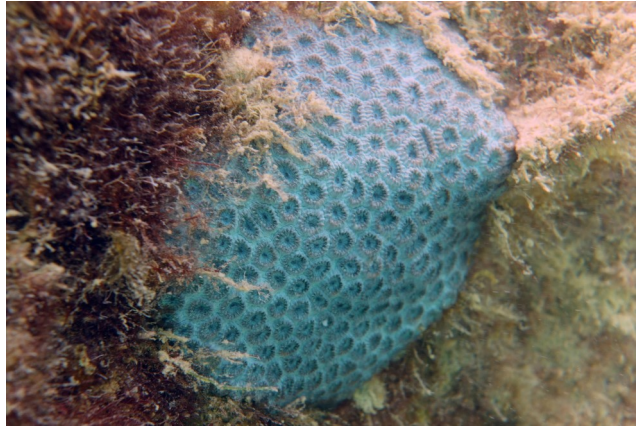


Night time video deployment: juvenile Pink Snapper

APPENDIX 3: Corals photographs taken during the 2018-19 survey in Port Coogee Marina



Corals beneath Sargassum weed



Favia sp.



Favites sp.



Favites sp.



Goniopora sp.



Montastrea sp.

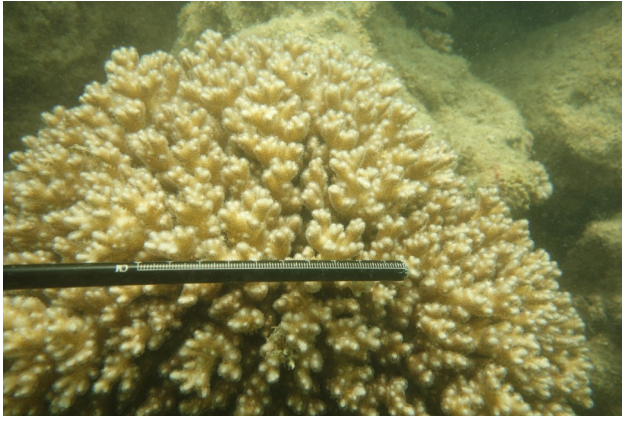


Montastrea sp.

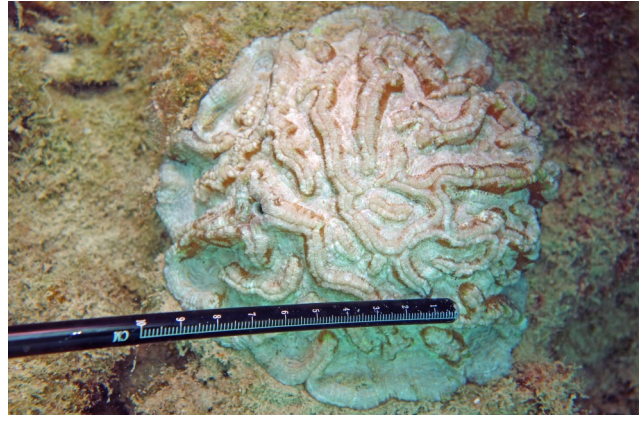


Pocillopora sp.

APPENDIX 3 (cont'd): Corals photographs taken during the 2018-19 survey in Port Coogee Marina



Pocillopora sp.



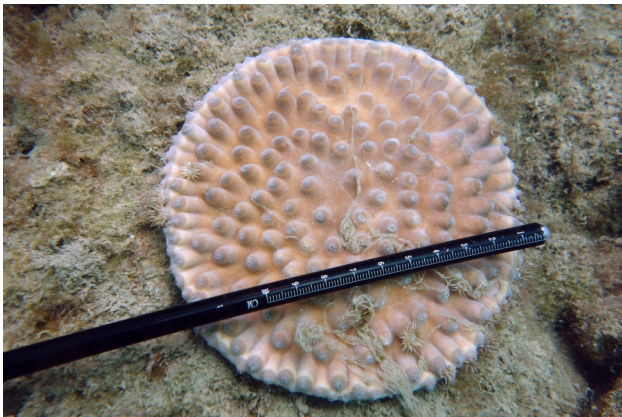
Symphyllia sp.



Turbinaria sp.



Turbinaria sp.



Turbinaria sp.



Turbinaria sp.



Turbinaria sp. partly smothered



Zoanthid sp.

APPENDIX 4: Coral Measurements, Port Coogee Marina, 27 February 2019. See Fig. 1 for locations.



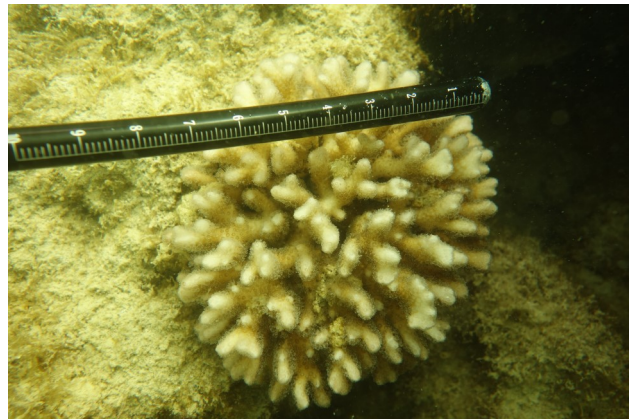
C1 *Montastrea* sp.



C2 *Turbinaria* sp.



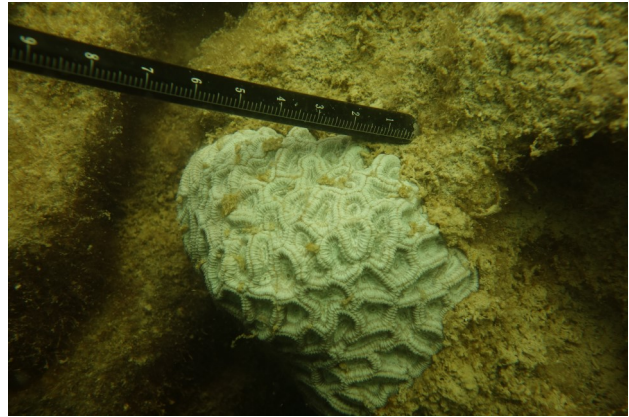
C3 *Montastrea* sp.



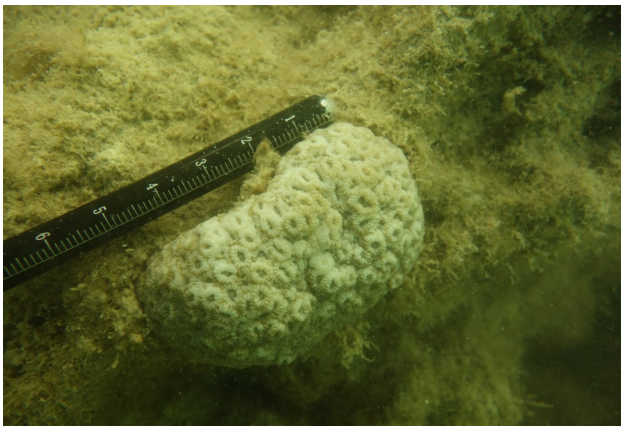
C4 *Pocillopora* sp.



C5 *Pocillopora* sp.



C6 *Favia* sp.



C7 *Montastrea* sp.

APPENDIX 5: Marine habitat examples from Port Coogee Marina survey 2018-19



1. Seagrass wrack in channel



3. *Sargassum* stands



2. Rock wall with *Sargassum* sp.



4. Cuttlefish in *Sargassum* sp.



6. Mussels

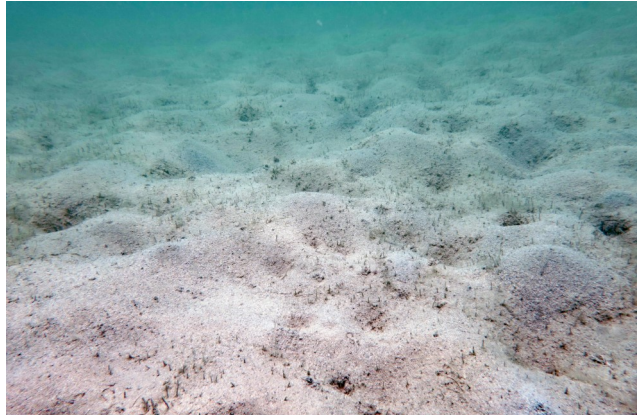


5. Submerged rock wall

APPENDIX 5 (cont'd): Marine habitat examples from Port Coogee Marina survey 2018-19



7. Seahorse on silty habitat



8. Bioturbated sediment



9. Pylon growth



10. Corals growing on rock wall



11. Filamentous algae



12. *Posidonia* seagrass

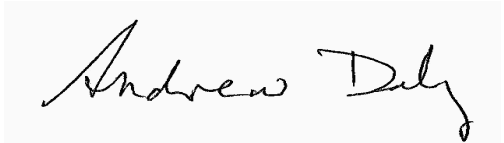
APPENDIX 6: Sediment sample results (see Fig. 1 for sample locations)

Analytical Report

Job No: ALW004542 Date Received: 1/03/2019 Date Reported: 2/04/2019 No Of Samples: 9
Client Ref: GJW001

Client: **Aqua Research and Monitoring Services**
Dr Glen Whisson
29 Pine Terrace

DARLINGTON WA 6070

Signature: 
Andrew Daly, Laboratory Manager
28/03/2019

All results refer to samples as received.

Analytical Report

Element	Ag	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Sn	Zn
Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
DL	0.01	5	0.05	2	2	50	0.05	2	0.2	0.2	2
ClientID\Scheme	MAR04-S	MAR04-S	MAR04-S	MAR04-S	MAR04-S	MAR04-S	MAR04-S	MAR04-S	MAR04-S	MAR04-S	MAR04-S
Method	T-AP-002	T-AP-002	T-AP-002	T-AP-002	T-AP-002	T-AP-002	T-AP-002	T-AP-002	T-AP-002	T-AP-002	T-AP-002
CMSS-01	0.02	7	0.06	28	6	3020	0.08	< 2	4.1	0.2	8
CMSS-02	0.03	7	0.07	32	7	3290	< 0.05	< 2	5.2	0.4	10
CMSS-03	< 0.01	< 5	< 0.05	7	< 2	728	< 0.05	< 2	1.3	< 0.2	< 2
CMSS-04	0.04	< 5	0.09	24	8	2930	< 0.05	< 2	7.6	0.5	18
CMSS-05	0.02	< 5	0.05	21	5	2070	< 0.05	< 2	3.9	0.3	8
CMSS-06	< 0.01	< 5	0.07	13	3	1360	< 0.05	< 2	1.7	< 0.2	4
CMSS-07	0.03	7	0.10	32	16	3200	< 0.05	< 2	4.8	0.4	16
CMSS-08	0.02	8	0.07	36	7	3540	< 0.05	< 2	4.2	0.3	9
CMSS-09	0.04	< 5	0.09	21	6	2460	< 0.05	< 2	6.9	0.5	14

APPENDIX 7: Sediment particle size distribution analysis (see Fig. 1 for sample locations)

Result Analysis Report

Sample Name:
ALW004542_CMSS_01

SOP Name:

Measured:
Wednesday, March 6, 2019 1:39:05 PM

Sample Source & type:

Measured by:
Brad

Analysed:
Wednesday, March 6, 2019 1:39:07 PM

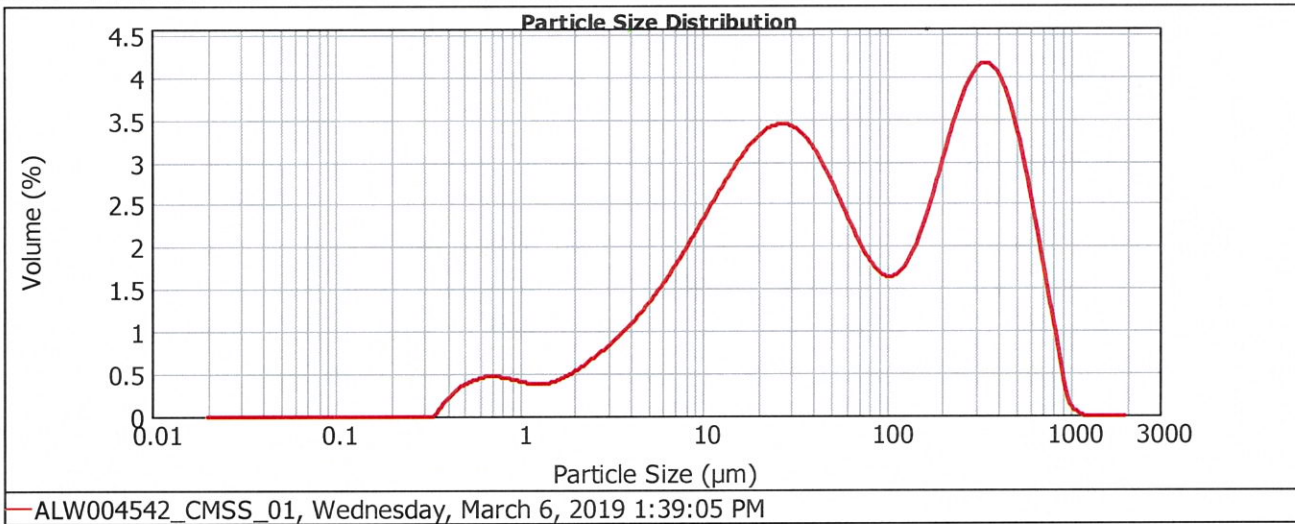
Sample bulk lot ref:

Result Source:
Edited

Particle Name: Default	Accessory Name: Hydro 2000S (A)	Analysis model: General purpose	Sensitivity: Normal
Particle RI: 1.520	Absorption: 0.1	Size range: 0.020 to 2000.000 um	Obscuration: 16.03 %
Dispersant Name: Water	Dispersant RI: 1.330	Weighted Residual: 0.667 %	Result Emulation: Off

Concentration: 0.0283 %Vol	Span : 9.224	Uniformity: 2.82	Result units: Volume
Specific Surface Area: 0.604 m ² /g	Surface Weighted Mean D[3,2]: 9.932 um	Vol. Weighted Mean D[4,3]: 156.379 um	

d(0.1): 5.172 um d(0.5): 49.210 um d(0.9): 459.079 um



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.010	0.00	0.105	0.00	1.096	0.34	11.482	2.40	120.226	1.62	1258.925	0.00
0.011	0.00	0.120	0.00	1.259	0.34	13.183	2.59	138.038	1.87	1445.440	0.00
0.013	0.00	0.138	0.00	1.445	0.37	15.136	2.76	158.489	2.22	1659.587	0.00
0.015	0.00	0.158	0.00	1.660	0.42	17.378	2.91	181.970	2.63	1905.461	0.00
0.017	0.00	0.182	0.00	1.905	0.49	19.953	3.02	208.930	3.03	2187.762	0.00
0.020	0.00	0.209	0.00	2.188	0.57	22.909	3.08	239.883	3.39	2511.886	0.00
0.023	0.00	0.240	0.00	2.512	0.66	26.303	3.09	275.423	3.64	2884.032	0.00
0.026	0.00	0.275	0.00	2.884	0.76	30.200	3.04	316.228	3.74	3311.311	0.00
0.030	0.00	0.316	0.01	3.311	0.87	34.674	2.93	363.078	3.68	3801.894	0.00
0.035	0.00	0.363	0.17	3.802	0.99	39.811	2.75	416.869	3.43	4365.158	0.00
0.040	0.00	0.417	0.27	4.365	1.13	45.709	2.53	478.630	3.01	5011.872	0.00
0.046	0.00	0.479	0.35	5.012	1.27	52.481	2.27	549.541	2.46	5754.399	0.00
0.052	0.00	0.550	0.40	5.754	1.43	60.256	2.01	630.957	1.81	6606.934	0.00
0.060	0.00	0.631	0.42	6.607	1.61	69.183	1.77	724.436	1.16	7585.776	0.00
0.069	0.00	0.724	0.41	7.586	1.80	79.433	1.58	831.764	0.48	8709.636	0.00
0.079	0.00	0.832	0.39	8.710	1.99	91.201	1.48	954.993	0.07	10000.000	0.00
0.091	0.00	0.955	0.36	10.000	2.20	104.713	1.49	1096.478	0.00		
0.105	0.00	1.096	0.36	11.482	2.20	120.226	1.49	1258.925	0.00		

Operator notes:

Result Analysis Report

Sample Name:
ALW004542_CMSS_02

Sample Source & type:

Sample bulk lot ref:

SOP Name:

Measured by:
Brad

Result Source:
Edited

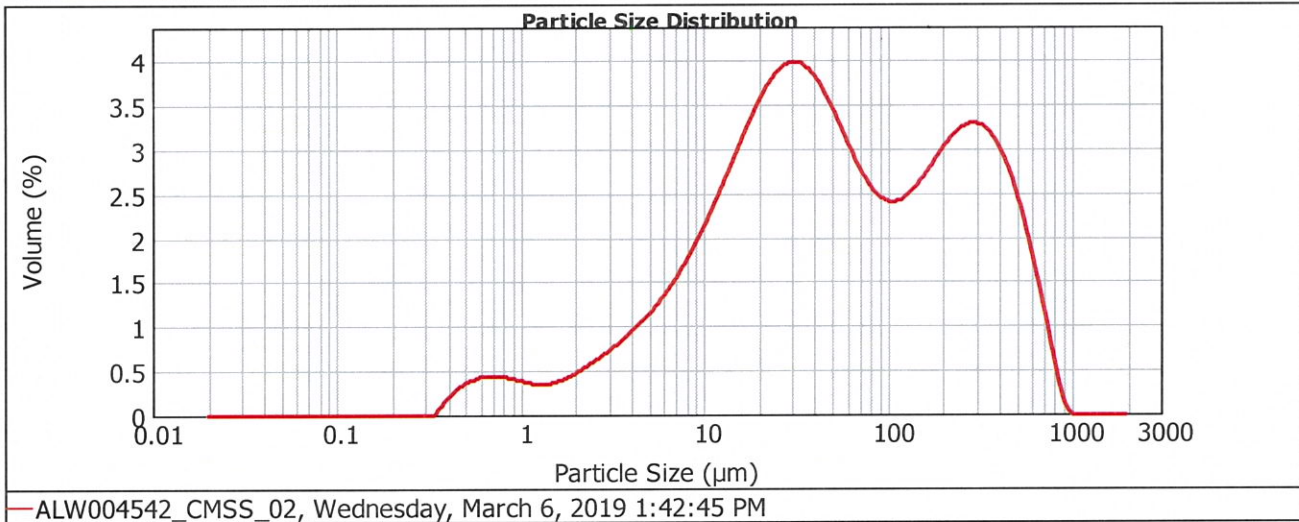
Measured:
Wednesday, March 6, 2019 1:42:45 PM

Analysed:
Wednesday, March 6, 2019 1:42:47 PM

Particle Name: Default	Accessory Name: Hydro 2000S (A)	Analysis model: General purpose	Sensitivity: Normal
Particle RI: 1.520	Absorption: 0.1	Size range: 0.020 to 2000.000 um	Obscuration: 17.32 %
Dispersant Name: Water	Dispersant RI: 1.330	Weighted Residual: 0.611 %	Result Emulation: Off

Concentration: 0.0327 %Vol	Span : 8.161	Uniformity: 2.37	Result units: Volume
Specific Surface Area: 0.571 m ² /g	Surface Weighted Mean D[3,2]: 10.506 um	Vol. Weighted Mean D[4,3]: 129.262 um	

d(0.1): 5.885 um d(0.5): 46.676 um d(0.9): 386.813 um



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.010	0.00	0.105	0.00	1.096	0.31	11.482	2.30	120.226	2.24	1258.925	0.00
0.011	0.00	0.120	0.00	1.259	0.31	13.183	2.57	138.038	2.36	1445.440	0.00
0.013	0.00	0.138	0.00	1.445	0.33	15.136	2.83	158.489	2.52	1659.587	0.00
0.015	0.00	0.158	0.00	1.660	0.38	17.378	3.09	181.970	2.69	1905.461	0.00
0.017	0.00	0.182	0.00	1.905	0.44	19.953	3.30	208.930	2.83	2187.762	0.00
0.020	0.00	0.209	0.00	2.188	0.51	22.909	3.47	239.883	2.93	2511.886	0.00
0.023	0.00	0.240	0.00	2.512	0.58	26.303	3.57	275.423	2.97	2884.032	0.00
0.026	0.00	0.275	0.00	2.884	0.67	30.200	3.58	316.228	2.92	3311.311	0.00
0.030	0.00	0.316	0.01	3.311	0.76	34.674	3.51	363.078	2.77	3801.894	0.00
0.035	0.00	0.363	0.16	3.802	0.86	39.811	3.36	416.869	2.53	4365.158	0.00
0.040	0.00	0.417	0.26	4.365	0.97	45.709	3.15	478.630	2.18	5011.872	0.00
0.046	0.00	0.479	0.33	5.012	1.10	52.481	2.90	549.541	1.74	5754.399	0.00
0.052	0.00	0.550	0.38	5.754	1.24	60.256	2.65	630.957	1.23	6606.934	0.00
0.060	0.00	0.631	0.39	6.607	1.41	69.183	2.43	724.436	0.68	7585.776	0.00
0.069	0.00	0.724	0.39	7.586	1.60	79.433	2.27	831.764	0.17	8709.636	0.00
0.079	0.00	0.832	0.36	8.710	1.81	91.201	2.18	954.993	0.00	10000.000	0.00
0.091	0.00	0.955	0.33	10.000	2.05	104.713	2.17	1096.478	0.00		
0.105	0.00	1.096	0.33	11.482	2.05	120.226	2.17	1258.925	0.00		

Operator notes:

Result Analysis Report

Sample Name:
ALW004542_CMSS_03

SOP Name:

Measured:
Wednesday, March 6, 2019 1:46:52 PM

Sample Source & type:

Measured by:
Brad

Analysed:
Wednesday, March 6, 2019 1:46:53 PM

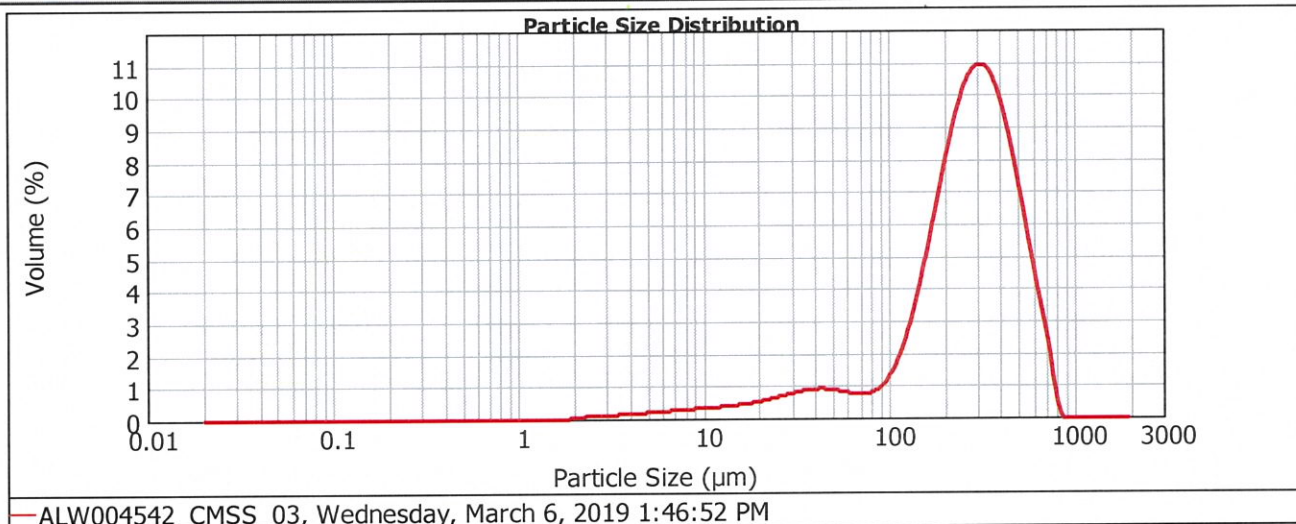
Sample bulk lot ref:

Result Source:
Edited

Particle Name: Default	Accessory Name: Hydro 2000S (A)	Analysis model: General purpose	Sensitivity: Normal
Particle RI: 1.520	Absorption: 0.1	Size range: 0.020 to 2000.000 um	Obscuration: 16.16 %
Dispersant Name: Water	Dispersant RI: 1.330	Weighted Residual: 0.789 %	Result Emulation: Off

Concentration: 0.2387 %Vol	Span : 1.635	Uniformity: 0.478	Result units: Volume
Specific Surface Area: 0.0604 m ² /g	Surface Weighted Mean D[3,2]: 99.370 um	Vol. Weighted Mean D[4,3]: 294.822 um	

d(0.1): 70.868 um d(0.5): 277.935 um d(0.9): 525.252 um



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.010	0.00	0.105	0.00	1.096	0.00	11.482	0.32	120.226	2.50	1258.925	0.00
0.011	0.00	0.120	0.00	1.259	0.00	13.183	0.35	138.038	3.71	1445.440	0.00
0.013	0.00	0.138	0.00	1.445	0.00	15.136	0.39	158.489	5.15	1659.587	0.00
0.015	0.00	0.158	0.00	1.660	0.00	17.378	0.44	181.970	6.70	1905.461	0.00
0.017	0.00	0.182	0.00	1.905	0.02	19.953	0.50	208.930	8.12	2187.762	0.00
0.020	0.00	0.209	0.00	2.188	0.06	22.909	0.57	239.883	9.22	2511.886	0.00
0.023	0.00	0.240	0.00	2.512	0.08	26.303	0.65	275.423	9.79	2884.032	0.00
0.026	0.00	0.275	0.00	2.884	0.10	30.200	0.73	316.228	9.73	3311.311	0.00
0.030	0.00	0.316	0.00	3.311	0.11	34.674	0.79	363.078	9.02	3801.894	0.00
0.035	0.00	0.363	0.00	3.802	0.13	39.811	0.81	416.869	7.76	4365.158	0.00
0.040	0.00	0.417	0.00	4.365	0.16	45.709	0.81	478.630	7.76	5011.872	0.00
0.046	0.00	0.479	0.00	5.012	0.18	52.481	0.80	549.541	6.16	5754.399	0.00
0.052	0.00	0.550	0.00	5.754	0.21	60.256	0.68	630.957	2.83	6606.934	0.00
0.060	0.00	0.631	0.00	6.607	0.23	69.183	0.66	724.436	0.93	7585.776	0.00
0.069	0.00	0.724	0.00	7.586	0.26	79.433	0.76	831.764	0.00	8709.636	0.00
0.079	0.00	0.832	0.00	8.710	0.28	91.201	1.05	954.993	0.00	10000.000	0.00
0.091	0.00	0.955	0.00	10.000	0.30	104.713	1.62	1096.478	0.00		
0.105	0.00	1.096	0.00	11.482	0.30	120.226		1258.925	0.00		

Operator notes:

Result Analysis Report

Sample Name:
ALW004542_CMSS_04

SOP Name:

Measured:
Wednesday, March 6, 2019 1:50:19 PM

Sample Source & type:

Measured by:
Brad

Analysed:
Wednesday, March 6, 2019 1:50:20 PM

Sample bulk lot ref:

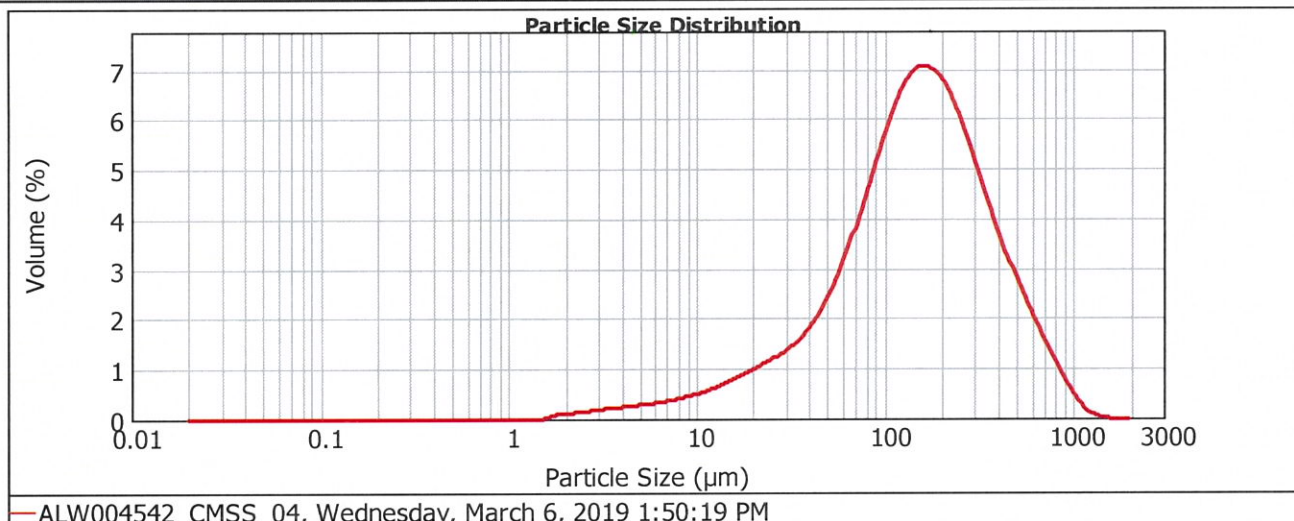
Result Source:
Edited

Particle Name: Default	Accessory Name: Hydro 2000S (A)	Analysis model: General purpose	Sensitivity: Normal
Particle RI: 1.520	Absorption: 0.1	Size range: 0.020 to 2000.000 um	Obscuration: 16.38 %
Dispersant Name: Water	Dispersant RI: 1.330	Weighted Residual: 0.401 %	Result Emulation: Off

Concentration: 0.1421 %Vol	Span : 2.738	Uniformity: 0.844	Result units: Volume
--------------------------------------	------------------------	-----------------------------	--------------------------------

Specific Surface Area: 0.102 m ² /g	Surface Weighted Mean D[3,2]: 58.943 um	Vol. Weighted Mean D[4,3]: 203.619 um
--	---	---

d(0.1): 32.991 um d(0.5): 150.102 um d(0.9): 443.921 um



—ALW004542_CMSS_04, Wednesday, March 6, 2019 1:50:19 PM

Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.010	0.00	0.105	0.00	1.096	0.00	11.482	0.54	120.226	6.05	1258.925	0.03
0.011	0.00	0.120	0.00	1.259	0.00	13.183	0.63	138.038	6.31	1445.440	0.00
0.013	0.00	0.138	0.00	1.445	0.01	15.136	0.72	158.489	6.36	1659.587	0.00
0.015	0.00	0.158	0.00	1.660	0.07	17.378	0.82	181.970	6.19	1905.461	0.00
0.017	0.00	0.182	0.00	1.905	0.09	19.953	0.93	208.930	5.84	2187.762	0.00
0.020	0.00	0.209	0.00	2.188	0.11	22.909	1.04	239.883	5.33	2511.886	0.00
0.023	0.00	0.240	0.00	2.512	0.14	26.303	1.16	275.423	4.74	2884.032	0.00
0.026	0.00	0.275	0.00	2.884	0.16	30.200	1.31	316.228	4.12	3311.311	0.00
0.030	0.00	0.316	0.00	3.311	0.19	34.674	1.51	363.078	3.52	3801.894	0.00
0.035	0.00	0.363	0.00	3.802	0.21	39.811	1.76	416.869	2.95	4365.158	0.00
0.040	0.00	0.417	0.00	4.365	0.24	45.709	2.10	478.630	2.44	5011.872	0.00
0.046	0.00	0.479	0.00	5.012	0.26	52.481	2.53	549.541	1.97	5754.399	0.00
0.052	0.00	0.550	0.00	5.754	0.29	60.256	3.07	630.957	1.54	6606.934	0.00
0.060	0.00	0.631	0.00	6.607	0.32	69.183	3.69	724.436	1.14	7585.776	0.00
0.069	0.00	0.724	0.00	7.586	0.36	79.433	4.36	831.764	0.76	8709.636	0.00
0.079	0.00	0.832	0.00	8.710	0.41	91.201	5.02	954.993	0.42	10000.000	0.00
0.091	0.00	0.955	0.00	10.000	0.47	104.713	5.61	1096.478	0.17		
0.105	0.00	1.096	0.00	11.482		120.226		1258.925			

Operator notes:

Result Analysis Report

Sample Name:
ALW004542_CMSS_05

SOP Name:

Measured:
Wednesday, March 6, 2019 1:53:52 PM

Sample Source & type:

Measured by:
Brad

Analysed:
Wednesday, March 6, 2019 1:53:54 PM

Sample bulk lot ref:

Result Source:
Edited

Particle Name:
Default

Accessory Name:
Hydro 2000S (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.520

Absorption:
0.1

Size range:
0.020 to 2000.000 um

Obscuration:
17.88 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.531 %

Result Emulation:
Off

Concentration:
0.0718 %Vol

Span :
4.555

Uniformity:
1.39

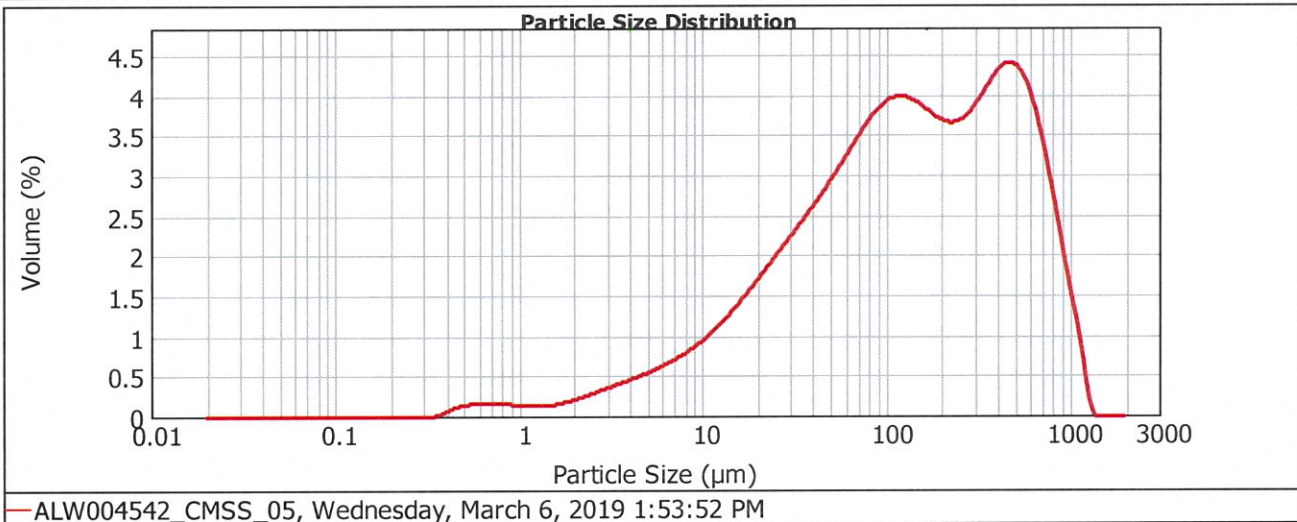
Result units:
Volume

Specific Surface Area:
0.258 m²/g

Surface Weighted Mean D[3,2]:
23.218 um

Vol. Weighted Mean D[4,3]:
239.518 um

d(0.1): 15.068 um d(0.5): 134.587 um d(0.9): 628.057 um



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.010	0.00	0.105	0.00	1.096	0.11	11.482	1.02	120.226	3.59	1258.925	0.01
0.011	0.00	0.120	0.00	1.259	0.11	13.183	1.15	138.038	3.52	1445.440	0.00
0.013	0.00	0.138	0.00	1.445	0.13	15.136	1.30	158.489	3.43	1659.587	0.00
0.015	0.00	0.158	0.00	1.660	0.16	17.378	1.45	181.970	3.34	1905.461	0.00
0.017	0.00	0.182	0.00	1.905	0.19	19.953	1.61	208.930	3.30	2187.762	0.00
0.020	0.00	0.209	0.00	2.188	0.23	22.909	1.77	239.883	3.33	2511.886	0.00
0.023	0.00	0.240	0.00	2.512	0.28	26.303	1.93	275.423	3.46	2884.032	0.00
0.026	0.00	0.275	0.00	2.884	0.32	30.200	2.10	316.228	3.46	3311.311	0.00
0.030	0.00	0.316	0.00	3.311	0.37	34.674	2.26	363.078	3.65	3801.894	0.00
0.035	0.00	0.363	0.04	3.802	0.41	39.811	2.44	416.869	3.84	4365.158	0.00
0.040	0.00	0.417	0.10	4.365	0.46	45.709	2.62	478.630	3.93	5011.872	0.00
0.046	0.00	0.479	0.13	5.012	0.51	52.481	2.82	549.541	3.71	5754.399	0.00
0.052	0.00	0.550	0.15	5.754	0.57	60.256	3.02	630.957	3.27	6606.934	0.00
0.060	0.00	0.631	0.15	6.607	0.63	69.183	3.22	724.436	2.67	7585.776	0.00
0.069	0.00	0.724	0.15	7.586	0.71	79.433	3.39	831.764	1.98	8709.636	0.00
0.079	0.00	0.832	0.13	8.710	0.80	91.201	3.52	954.993	1.31	10000.000	0.00
0.091	0.00	0.955	0.12	10.000	0.90	104.713	3.59	1096.478	0.63		
0.105	0.00	1.096		11.482		120.226		1258.925			

Operator notes:

Result Analysis Report

Sample Name:
ALW004542_CMSS_06

SOP Name:

Measured:
Wednesday, March 6, 2019 1:59:28 PM

Sample Source & type:

Measured by:
Brad

Analysed:
Wednesday, March 6, 2019 1:59:30 PM

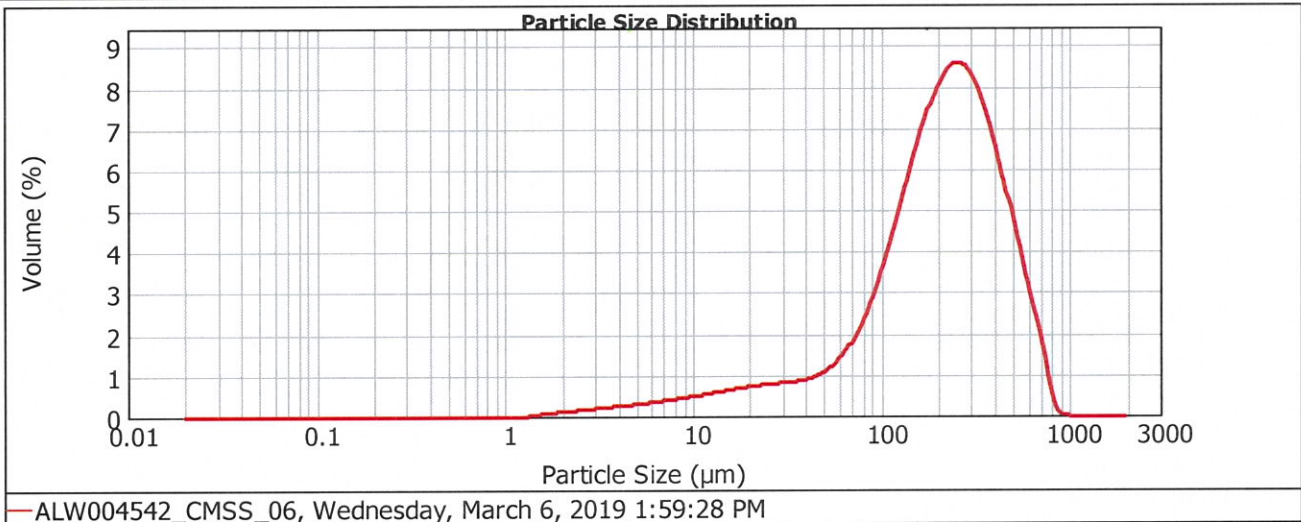
Sample bulk lot ref:

Result Source:
Edited

Particle Name: Default	Accessory Name: Hydro 2000S (A)	Analysis model: General purpose	Sensitivity: Normal
Particle RI: 1.520	Absorption: 0.1	Size range: 0.020 to 2000.000 um	Obscuration: 16.04 %
Dispersant Name: Water	Dispersant RI: 1.330	Weighted Residual: 0.516 %	Result Emulation: Off

Concentration: 0.1537 %Vol	Span : 2.027	Uniformity: 0.607	Result units: Volume
Specific Surface Area: 0.0913 m ² /g	Surface Weighted Mean D[3,2]: 65.725 um	Vol. Weighted Mean D[4,3]: 243.526 um	

d(0.1): 44.005 um d(0.5): 214.279 um d(0.9): 478.410 um



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.010	0.00	0.105	0.00	1.096	0.00	11.482	0.50	120.226	4.71	1258.925	0.00
0.011	0.00	0.120	0.00	1.259	0.00	13.183	0.54	138.038	5.62	1445.440	0.00
0.013	0.00	0.138	0.00	1.445	0.00	15.136	0.59	158.489	6.45	1659.587	0.00
0.015	0.00	0.158	0.00	1.660	0.05	17.378	0.63	181.970	7.15	1905.461	0.00
0.017	0.00	0.182	0.00	1.905	0.08	19.953	0.66	208.930	7.60	2187.762	0.00
0.020	0.00	0.209	0.00	2.188	0.10	22.909	0.69	239.883	7.75	2511.886	0.00
0.023	0.00	0.240	0.00	2.512	0.12	26.303	0.69	275.423	7.56	2884.032	0.00
0.026	0.00	0.275	0.00	2.884	0.15	30.200	0.72	316.228	7.56	3311.311	0.00
0.030	0.00	0.316	0.00	3.311	0.17	34.674	0.75	363.078	7.03	3801.894	0.00
0.035	0.00	0.363	0.00	3.802	0.20	39.811	0.78	416.869	6.22	4365.158	0.00
0.040	0.00	0.417	0.00	4.365	0.23	45.709	0.84	478.630	5.21	5011.872	0.00
0.046	0.00	0.479	0.00	5.012	0.25	52.481	0.95	549.541	4.11	5754.399	0.00
0.052	0.00	0.550	0.00	5.754	0.28	60.256	1.12	630.957	3.00	6606.934	0.00
0.060	0.00	0.631	0.00	6.607	0.31	69.183	1.40	724.436	2.01	7585.776	0.00
0.069	0.00	0.724	0.00	7.586	0.34	79.433	1.80	831.764	0.81	8709.636	0.00
0.079	0.00	0.832	0.00	8.710	0.38	91.201	2.34	954.993	0.06	10000.000	0.00
0.091	0.00	0.955	0.00	10.000	0.41	104.713	3.02	1096.478	0.00		
0.105	0.00	1.096	0.00	11.482	0.45	120.226	3.83	1258.925	0.00		

Operator notes:

Result Analysis Report

Sample Name:
ALW004542_CMSS_07

SOP Name:

Measured:
Wednesday, March 6, 2019 2:03:34 PM

Sample Source & type:

Measured by:
Brad

Analysed:
Wednesday, March 6, 2019 2:03:36 PM

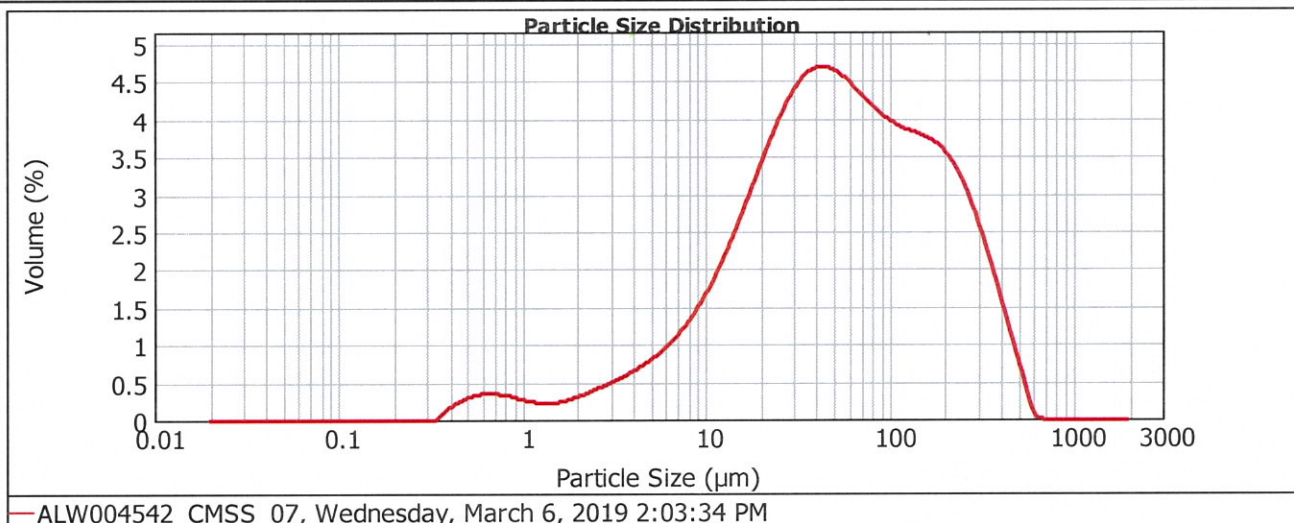
Sample bulk lot ref:

Result Source:
Edited

Particle Name: Default	Accessory Name: Hydro 2000S (A)	Analysis model: General purpose	Sensitivity: Normal
Particle RI: 1.520	Absorption: 0.1	Size range: 0.020 to 2000.000 um	Obscuration: 13.80 %
Dispersant Name: Water	Dispersant RI: 1.330	Weighted Residual: 0.656 %	Result Emulation: Off

Concentration: 0.0319 %Vol	Span : 4.570	Uniformity: 1.37	Result units: Volume
Specific Surface Area: 0.46 m ² /g	Surface Weighted Mean D[3,2]: 13.042 um	Vol. Weighted Mean D[4,3]: 95.006 um	

d(0.1): 8.681 um d(0.5): 52.577 um d(0.9): 248.979 um



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.010	0.00	0.105	0.00	1.096	0.21	11.482	1.91	120.226	3.46	1258.925	0.00
0.011	0.00	0.120	0.00	1.259	0.20	13.183	2.22	138.038	3.42	1445.440	0.00
0.013	0.00	0.138	0.00	1.445	0.21	15.136	2.55	158.489	3.35	1659.587	0.00
0.015	0.00	0.158	0.00	1.660	0.24	17.378	2.90	181.970	3.24	1905.461	0.00
0.017	0.00	0.182	0.00	1.905	0.28	19.953	3.24	208.930	3.06	2187.762	0.00
0.020	0.00	0.209	0.00	2.188	0.34	22.909	3.56	239.883	2.80	2511.886	0.00
0.023	0.00	0.240	0.00	2.512	0.39	26.303	3.84	275.423	2.45	2884.032	0.00
0.026	0.00	0.275	0.00	2.884	0.45	30.200	4.05	316.228	2.04	3311.311	0.00
0.030	0.00	0.316	0.01	3.311	0.52	34.674	4.18	363.078	1.58	3801.894	0.00
0.035	0.00	0.363	0.14	3.802	0.59	39.811	4.23	416.869	1.10	4365.158	0.00
0.040	0.00	0.417	0.21	4.365	0.68	45.709	4.20	478.630	0.64	5011.872	0.00
0.046	0.00	0.479	0.27	5.012	0.77	52.481	4.10	549.541	0.00	5754.399	0.00
0.052	0.00	0.550	0.30	5.754	0.89	60.256	3.97	630.957	0.00	6606.934	0.00
0.060	0.00	0.631	0.31	6.607	1.03	69.183	3.83	724.436	0.00	7585.776	0.00
0.069	0.00	0.724	0.30	7.586	1.20	79.433	3.70	831.764	0.00	8709.636	0.00
0.079	0.00	0.832	0.27	8.710	1.40	91.201	3.60	954.993	0.00	10000.000	0.00
0.091	0.00	0.955	0.23	10.000	1.64	104.713	3.52	1096.478	0.00		
0.105	0.00	1.096	0.23	11.482	1.64	120.226	3.52	1258.925	0.00		

Operator notes:

Result Analysis Report

Sample Name:
ALW004542_CMSS_08

SOP Name:

Measured:
Wednesday, March 6, 2019 2:07:10 PM

Sample Source & type:

Measured by:
Brad

Analysed:
Wednesday, March 6, 2019 2:07:12 PM

Sample bulk lot ref:

Result Source:
Edited

Particle Name:
Default

Accessory Name:
Hydro 2000S (A)

Analysis model:
General purpose

Sensitivity:
Normal

Particle RI:
1.520

Absorption:
0.1

Size range:
0.020 to 2000.000 um

Obscuration:
13.94 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.774 %

Result Emulation:
Off

Concentration:
0.0286 %Vol

Span :
3.811

Uniformity:
1.2

Result units:
Volume

Specific Surface Area:
0.521 m²/g

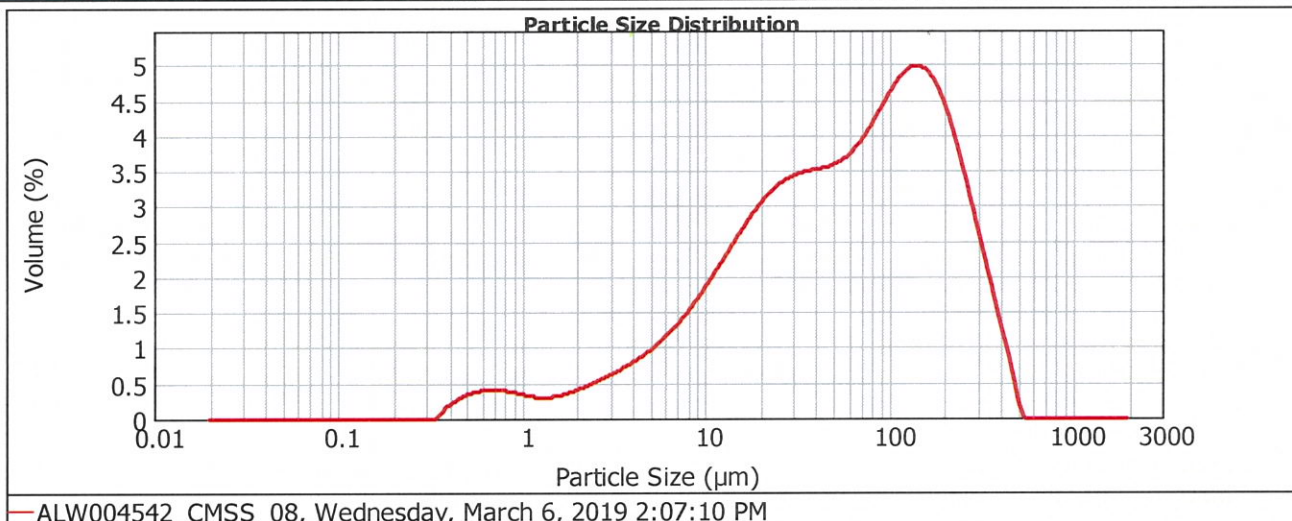
Surface Weighted Mean D[3,2]:
11.524 um

Vol. Weighted Mean D[4,3]:
95.923 um

d(0.1): 6.909 um

d(0.5): 60.779 um

d(0.9): 238.521 um



—ALW004542_CMSS_08, Wednesday, March 6, 2019 2:07:10 PM

Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.010	0.00	0.105	0.00	1.096	0.27	11.482	2.01	120.226	4.46	1258.925	0.00
0.011	0.00	0.120	0.00	1.259	0.27	13.183	2.23	138.038	4.48	1445.440	0.00
0.013	0.00	0.138	0.00	1.445	0.28	15.136	2.45	158.489	4.36	1659.587	0.00
0.015	0.00	0.158	0.00	1.660	0.32	17.378	2.65	181.970	4.07	1905.461	0.00
0.017	0.00	0.182	0.00	1.905	0.37	19.953	2.83	208.930	3.65	2187.762	0.00
0.020	0.00	0.209	0.00	2.188	0.43	22.909	2.96	239.883	3.11	2511.886	0.00
0.023	0.00	0.240	0.00	2.512	0.50	26.303	3.06	275.423	2.52	2884.032	0.00
0.026	0.00	0.275	0.00	2.884	0.57	30.200	3.12	316.228	1.94	3311.311	0.00
0.030	0.00	0.316	0.01	3.311	0.64	34.674	3.16	363.078	1.35	3801.894	0.00
0.035	0.00	0.363	0.16	3.802	0.73	39.811	3.19	416.869	0.80	4365.158	0.00
0.040	0.00	0.417	0.25	4.365	0.82	45.709	3.23	478.630	0.14	5011.872	0.00
0.046	0.00	0.479	0.31	5.012	0.93	52.481	3.30	549.541	0.00	5754.399	0.00
0.052	0.00	0.550	0.35	5.754	1.06	60.256	3.43	630.957	0.00	6606.934	0.00
0.060	0.00	0.631	0.36	6.607	1.21	69.183	3.62	724.436	0.00	7585.776	0.00
0.069	0.00	0.724	0.35	7.586	1.39	79.433	3.85	831.764	0.00	8709.636	0.00
0.079	0.00	0.832	0.33	8.710	1.58	91.201	4.10	954.993	0.00	10000.000	0.00
0.091	0.00	0.955	0.29	10.000	1.79	104.713	4.32	1096.478	0.00		
0.105	0.00	1.096	0.29	11.482	2.01	120.226	4.46	1258.925	0.00		

Operator notes:

Result Analysis Report

Sample Name:
ALW004542_CMSS_09

Sample Source & type:

Sample bulk lot ref:

SOP Name:

Measured by:
Brad

Result Source:
Edited

Measured:
Wednesday, March 6, 2019 2:13:38 PM

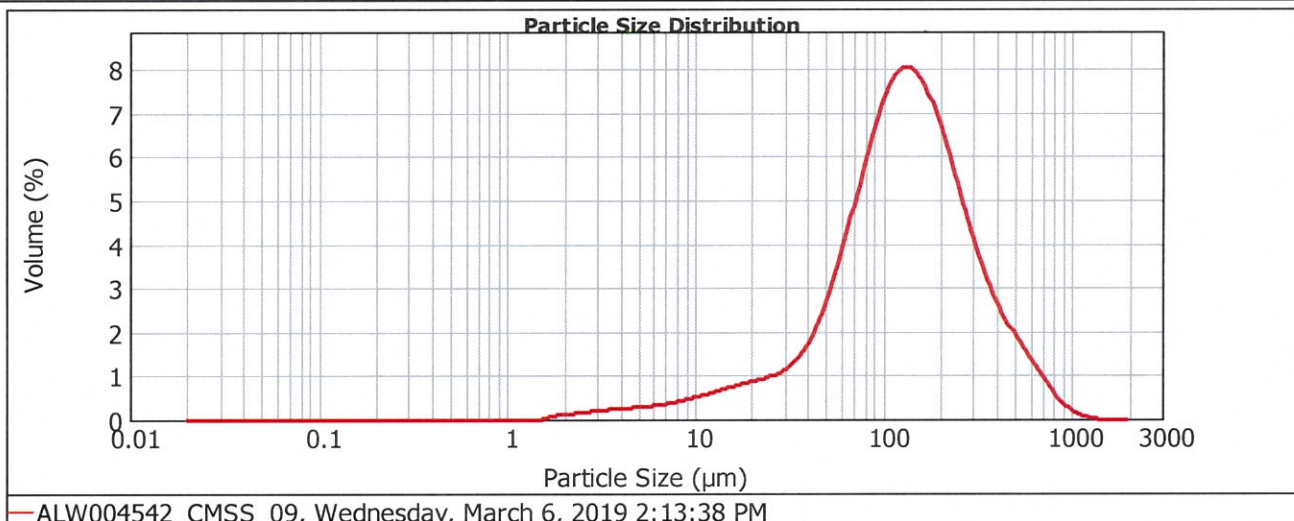
Analysed:
Wednesday, March 6, 2019 2:13:39 PM

Particle Name: Default	Accessory Name: Hydro 2000S (A)	Analysis model: General purpose	Sensitivity: Normal
Particle RI: 1.520	Absorption: 0.1	Size range: 0.020 to 2000.000 um	Obscuration: 16.50 %
Dispersant Name: Water	Dispersant RI: 1.330	Weighted Residual: 0.376 %	Result Emulation: Off

Concentration: 0.1377 %Vol	Span : 2.476	Uniformity: 0.773	Result units: Volume
--------------------------------------	------------------------	-----------------------------	--------------------------------

Specific Surface Area: 0.106 m ² /g	Surface Weighted Mean D[3,2]: 56.611 um	Vol. Weighted Mean D[4,3]: 172.410 um
--	---	---

d(0.1): 35.809 um d(0.5): 130.249 um d(0.9): 358.341 um



— ALW004542_CMSS_09, Wednesday, March 6, 2019 2:13:38 PM

Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.010	0.00	0.105	0.00	1.096	0.00	11.482	0.54	120.226	7.24	1258.925	0.00
0.011	0.00	0.120	0.00	1.259	0.00	13.183	0.61	138.038	7.18	1445.440	0.00
0.013	0.00	0.138	0.00	1.445	0.01	15.136	0.68	158.489	6.81	1659.587	0.00
0.015	0.00	0.158	0.00	1.660	0.08	17.378	0.74	181.970	6.20	1905.461	0.00
0.017	0.00	0.182	0.00	1.905	0.10	19.953	0.79	208.930	5.44	2187.762	0.00
0.020	0.00	0.209	0.00	2.188	0.13	22.909	0.86	239.883	4.62	2511.886	0.00
0.023	0.00	0.240	0.00	2.512	0.15	26.303	0.95	275.423	3.83	2884.032	0.00
0.026	0.00	0.275	0.00	2.884	0.18	30.200	1.11	316.228	3.13	3311.311	0.00
0.030	0.00	0.316	0.00	3.311	0.20	34.674	1.36	363.078	2.54	3801.894	0.00
0.035	0.00	0.363	0.00	3.802	0.22	39.811	1.75	416.869	2.06	4365.158	0.00
0.040	0.00	0.417	0.00	4.365	0.24	45.709	2.30	478.630	1.66	5011.872	0.00
0.046	0.00	0.479	0.00	5.012	0.26	52.481	3.00	549.541	0.97	5754.399	0.00
0.052	0.00	0.550	0.00	5.754	0.29	60.256	3.85	630.957	0.63	6606.934	0.00
0.060	0.00	0.631	0.00	6.607	0.32	69.183	4.76	724.436	0.33	7585.776	0.00
0.069	0.00	0.724	0.00	7.586	0.36	79.433	5.66	831.764	0.17	8709.636	0.00
0.079	0.00	0.832	0.00	8.710	0.41	91.201	6.43	954.993	0.06	10000.000	0.00
0.091	0.00	0.955	0.00	10.000	0.48	104.713	6.99	1096.478	0.06		
0.105	0.00	1.096	0.00	11.482	0.54	120.226	7.24	1258.925	0.06		

Operator notes:

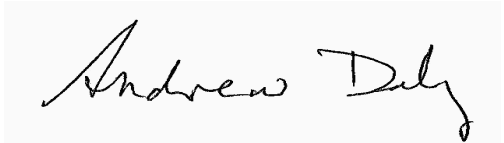
APPENDIX 8: Water sample Results (see Fig. 1 for sample locations)

Analytical Report

Job No: ALW004542A Date Received: 1/03/2019 Date Reported: 3/04/2019 No Of Samples: 3
Client Ref: GJW001

Client: **Aqua Research and Monitoring Services**
Dr Glen Whisson
29 Pine Terrace

DARLINGTON WA 6070

Signature: 
Andrew Daly, Laboratory Manager
03/04/2019

All results refer to samples as received.

Analytical Report

Element	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu
Units	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L
DL	0.05	0.001	0.05	0.05	5	0.05	0.05	0.05	0.05	0.05	0.01	0.02	0.001	0.01	0.1
ClientID\Scheme	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04
Method															
CMSSW-01	< 0.05	< 0.001	24.1	< 0.05	1840	11.3	< 0.05	< 0.05	351	< 0.05	0.01	1.07	0.002	0.18	1.0
CMSSW-02	< 0.05	< 0.001	24.4	< 0.05	1720	11.4	< 0.05	< 0.05	341	< 0.05	0.01	0.78	< 0.001	0.18	1.0
CMSSW-03	< 0.05	< 0.001	21.4	< 0.05	1550	10.8	< 0.05	< 0.05	353	< 0.05	0.01	0.69	0.005	0.17	1.0

Analytical Report

Element	Dy	Er	Eu	Fe	Ga	Gd	Ge	Hf	Hg	Ho	In	K	La	Li	Lu
Units	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L
DL	0.01	0.01	0.01	0.01	0.05	0.01	0.05	0.02	0.1	0.01	0.01	0.05	0.01	0.1	0.01
ClientID\Scheme	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04
Method															
CMSSW-01	0.02	0.02	< 0.01	< 0.01	0.09	0.03	< 0.05	0.05	0.2	< 0.01	0.02	360	0.01	108	0.02
CMSSW-02	0.02	0.02	< 0.01	0.02	< 0.05	0.03	< 0.05	0.06	0.1	< 0.01	0.02	352	0.01	95.5	0.02
CMSSW-03	0.01	0.02	< 0.01	< 0.01	< 0.05	0.03	< 0.05	0.05	0.1	< 0.01	0.02	371	0.01	88.2	0.02

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Element	Mg	Mn	Mo	Na	Nb	Nd	Ni	P	Pb	Pd	Pr	Pt	Rb	Re	Rh
Units	mg/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
DL	0.05	0.05	0.1	0.05	0.01	0.01	0.2	0.02	0.1	0.2	0.01	0.01	0.01	0.01	0.01
ClientID\Scheme	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04
Method															
CMSSW-01	1420	0.31	9.5	11200	0.01	0.08	4.7	< 0.02	< 0.1	< 0.2	< 0.01	0.02	90.6	0.02	< 0.01
CMSSW-02	1410	0.22	9.3	12000	< 0.01	0.10	4.8	< 0.02	< 0.1	< 0.2	< 0.01	0.02	88.0	0.01	< 0.01
CMSSW-03	1430	0.13	8.5	12900	< 0.01	0.09	4.4	< 0.02	< 0.1	< 0.2	< 0.01	0.02	78.7	0.01	< 0.01

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Element	Ru	S	Sb	Sc	Se	Si	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl
Units	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L
DL	0.05	1	0.05	1	0.5	40	0.01	0.05	0.01	0.02	0.01	0.05	0.05	0.01	0.01
ClientID\Scheme	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04
Method															
CMSSW-01	< 0.05	917	0.21	< 1	14.4	123	0.02	< 0.05	6.06	< 0.02	< 0.01	0.59	< 0.05	< 0.01	0.02
CMSSW-02	< 0.05	918	0.26	< 1	24.3	96	0.03	< 0.05	5.94	< 0.02	< 0.01	0.57	< 0.05	< 0.01	0.02
CMSSW-03	< 0.05	946	0.23	< 1	6.3	< 40	0.03	< 0.05	6.16	< 0.02	< 0.01	0.58	< 0.05	< 0.01	0.02

Analytical Report

Element	Tm	U	V	W	Y	Yb	Zn	Zr
Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
DL	0.01	0.02	0.01	0.02	0.01	0.01	0.5	0.02
ClientID\Scheme	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04	ENV04
Method								
CMSSW-01	< 0.01	2.81	1.00	0.24	0.02	0.02	0.6	0.25
CMSSW-02	< 0.01	2.90	1.00	0.22	0.02	0.01	1.1	0.12
CMSSW-03	< 0.01	3.04	1.00	0.20	0.02	0.01	< 0.5	0.06