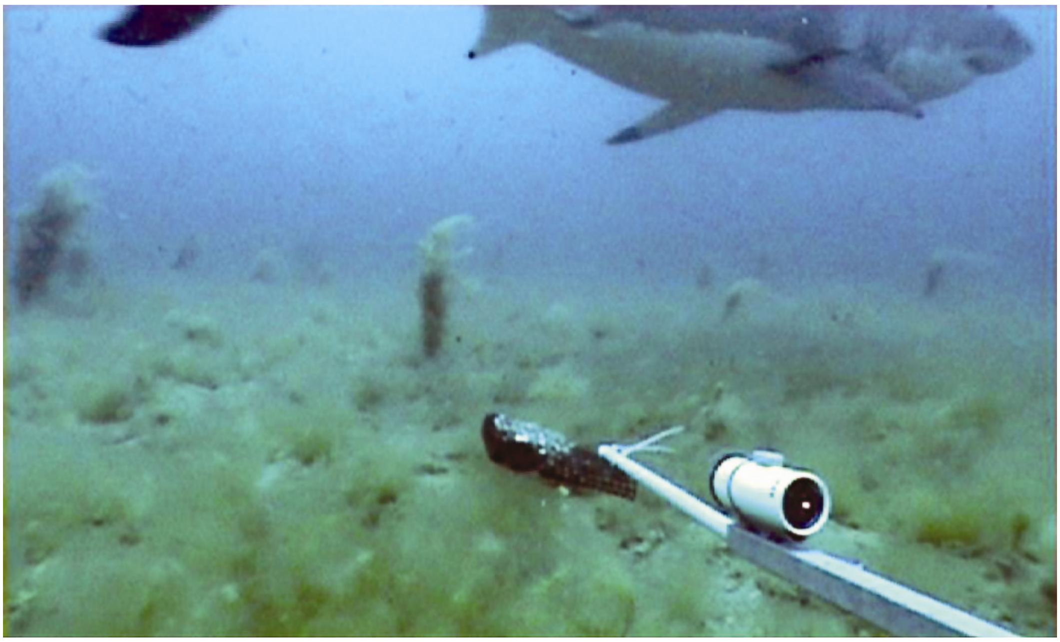
An assessment of fish assemblages adjacent to Port Stanvac

A report to Adelaide Aqua for the Adelaide desalination plant project 2009 - 2011



Prepared by the Marine Parks Branch
Department of Environment and Natural Resources
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Cover photo: Great white shark (*Carcharodon carcharias*) ~4.5m long recorded off Hallett Cove in 20m of water.

Photography: DENR , Marine Parks

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Contents

Summary

As part of an environmental monitoring program associated with construction and operation of a seawater desalination plant at Port Stanvac, the Department of Environment and Natural Resources (DENR) was commissioned to undertake a study to collect baseline data on fish assemblages within two major habitat types (reef and soft sediment) present in the vicinity of the proposed saline outfall.

Baited remote underwater video systems (BRUVS) were used to collect data at seasonal intervals over the period of two years (8 seasons in total) to capture spatial and seasonal variation in fish assemblages prior to the plant producing any saline discharge. Stereo video footage was analysed to provide data on species types, relative abundances and lengths of each of the fish species present.

Throughout the two years of this study, 9463 fish were counted and 75 species identified. Data from this study suggests that fish assemblages at the Port Stanvac site are complex and variable both spatially and temporally.

Overall, relative abundances and the number of species observed were higher in summer and lowest in winter. In the second year, of the project abundance and numbers of species were also higher relative to the first. Similarly, more difference between seasons, habitats and treatments (distance from the outfall) was observed in year two.

Observed annual differences were linked to seasonal variability and further complexity was evident in statistical interactions between seasons, habitat type and treatments (near and distant from the saline outfall). Some differences were observed between the ‘near’ sites (which potentially may be influenced by the hypersaline outfall in the future) and the distant (control) sites, however these were not consistent across seasons or habitat types. As such these differences form part of the ‘background noise’.

Patterns in the fish assemblages observed over the two years of this study represent the background spatial and temporal variability of the area. Any potential future observed effect of the saline concentrate needs to be assessed against this inherent variability.

During the study a total of 1598 fish were measured. At this stage fish length data provides little information that is interpretable in the context of the potential for impact from the hypersaline inputs. It does however provide a baseline for the assessment of any future change. Observations of the lengths of Port Jackson sharks (*Heterodontus portusjacksoni*) suggest that the study area may be a nursery and breeding area for this species. However, this is currently an observation only and further investigation would be required to confirm its validity.

Introduction

In December 2007, as part of the South Australian Government's commitment to securing a future water supply for Adelaide, plans to build a $1.83 billion desalination plant on the former Mobil oil refinery site at Port Stanvac were announced. This plan would provide the state with a water supply independent of the climate by producing up to 100 billion litres of water per year (approximately half Adelaide's annual water needs).

A major Environmental Impact Assessment (EIA) process forms a key component of this project and includes potential impacts on the marine environment. In late 2009 as part of that process, the Department of Environment and Natural Resources (DENR), Marine Parks Project (then known as the Department for Environment and Heritage's, Coast and Marine Conservation Branch) was contracted by Adelaide Aqua to conduct a baseline survey of fish assemblages in the area using Baited Remote Underwater Video Systems (BRUVS).

Previously, Thiel and Tanner (2009) conducted seasonal diver surveys of fish at Port Stanvac as part of their contribution to the Desalination Plant EIS. Their report concluded that alternative methods for conducting fish surveys should be investigated. DENR proposed the use of Baited Underwater Video Systems (BRUVS), which can be deployed remotely to collect stereo video footage of fish in the study area. BRUVS have been widely used to monitor changes in fish assemblages (Langloise *et al.* 2006; Malcolm *et al*. 2007; Kleczkowski *et al.* 2008), and advances in underwater videometric measurement can provide more accurate length measurements than divers doing underwater visual census (Harvey *et al*. 2004; Watson *et al.* 2005; Shortis *et al.* 2007). Furthermore, BRUVS is a non-extractive, non-destructive, repeatable method for quickly gathering data and building a permanent record.

Aims

Using BRUVS, this study assesses the relative abundance, number of species and size of fishes in the Port Stanvac marine area. It also examines spatial and temporal variability of fish assemblages through winter, spring, summer and autumn over two years (from mid 2009 to mid 2011) across the two habitat types present in the area (unconsolidated sediment and low reef). Surveys were conducted in these two habitat types; both within and outside the predicted zone of influence of the saline outfall. This two year dataset will form a baseline against which potential future effects from the hypersaline discharge via outfall can be assessed.

Materials and methods

Study area

Two sites were selected within ("Near" sites), and two outside ("Distant" sites), the predicted zone of influence of the saline concentrate (South Australian Water Corporation, 2008). The location of these sites was based on saline plume-dispersion models detailed in the Adelaide Desalination Plant Environmental Statement (South Australian Water Corporation 2008). Site selection also considered habitat and depth (Figure 1).

Modelling of the predicted saline concentrate suggests that the Near sites should experience dilution rates of less than 50:1 while dilution rates at the Distant sites should be greater than 100:1 (South Australian Water Corporation 2008).

Data was collected in habitats consisting of patchy sparse algae on soft sediment, or patchy low profile reef (referred to hereon as "Soft-bottom", and "Reef", respectively) within the Near and Distant sites. These sites were chosen using existing habitat maps (Figure 1; DEH 2008a, b) and combined to form the four distinct study areas: Distant Soft; Distant Reef; Near Soft and Near Reef (Figure 1).

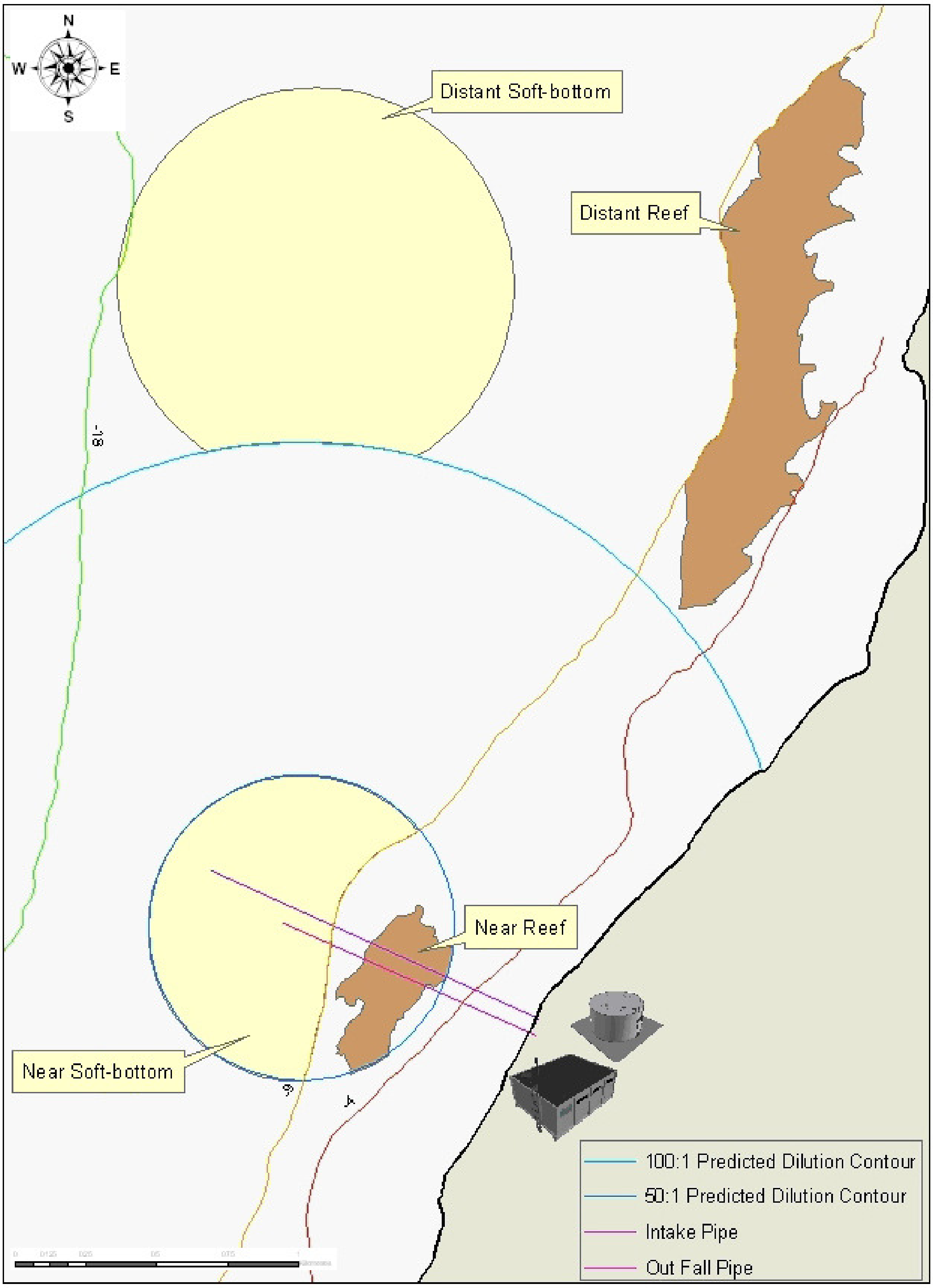


Figure 1: **Port Stanvac survey area showing BRUVS sampling sites and predicted dilution contours, 50:1 (inner dark blue circle) and 100:1 (outer light blue circle), in relation to the outfall, and intake pipes.**

BRUV systems

Each BRUV system (Figure 2) consists of two video cameras orientated along a horizontal plane relative to the sea-floor. The cameras are fitted with 0.5x wide-angle lenses and attached to a steel frame. The BRUVS are linked to the sea-surface via a floating rope and buoy system. Canon HV30 high definition and Sony DCR-HC52 standard definition camcorders are mounted within custom made high-density PVC housings with clear acrylic viewing ports. A bait bag containing ~ 800 grams of mashed pilchards (*Sardinops* spp.) was mounted on a pole, 1.5 m in front of the cameras. The pilchards create an odour plume which serves as an attractant. However, comparative studies by Watson *et al* (2010), Harvey *et al* (2007) and Watson *et al* (2005) show little difference in species composition between baited and unbaited systems, and, although a greater number of predators and scavengers are attracted to baited BRUVS, the relative abundance of omnivorous and herbivorous species is similar.

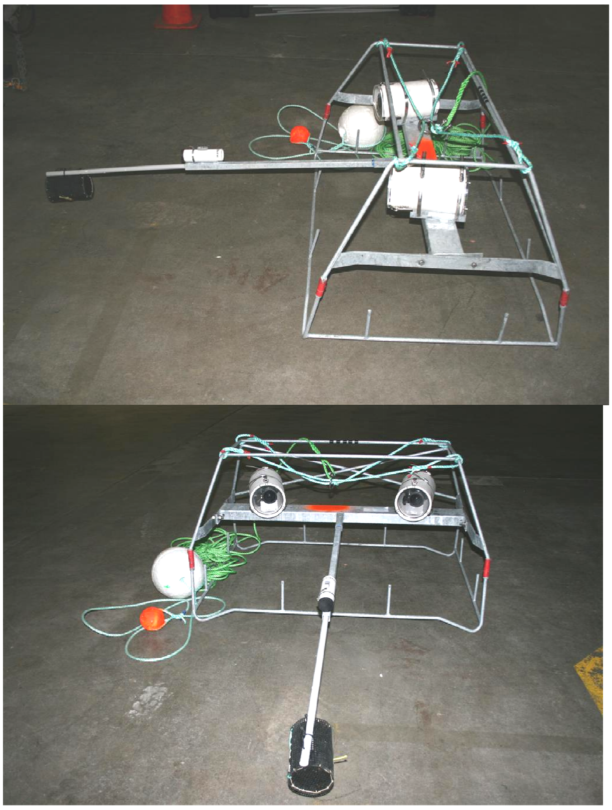


Figure 2: BRUVS unit used for fish surveys (side and front views).

Prior to field use, all stereo BRUVS were calibrated in a swimming pool and the data processed using SeaGIS *Cal* software (http://www.seagis.com.au/bundle.html). Calibration ensures accurate length measurements can be made during video analysis of the stereo images (Harvey *et al*. 2001; 2003; Shortis *et al*. 2007).

Deployment

Sampling was conducted from winter 2009 to autumn 2011 during the months of September (early in the month, nominally considered to be winter), November (spring), February (summer) and May (autumn). During each sampling season, six BRUVS were deployed at each of the four study sites, in daylight hours, over two consecutive days. Three BRUVS were deployed at each site on each day, with the deployment order being reversed on the second day so that sampling times for each site/habitat type were comparable.

BRUVS units were deployed in groups of 3 with an average time separation of between 5 and 10 minutes. Typically, they were placed a minimum of 200m apart where possible to avoid the bait plume from one unit influencing the response of fish at another, and to achieve a level of independence between replicate samples. Each BRUVS was lowered to the seafloor and left to record 60 minutes of footage before retrieval. Recordings with an unobstructed field of view were kept for analysis.

Video analysis

Video footage was analysed to produce species abundance and length data. Footage from the right-side camera was analysed using SeaGIS *EventMeasure* software (http://www.seagis.com.au/event.html) to identify fish and estimate abundance. Fish identification was carried out with the aid of reference books (Gomon *et al.* 2008; Edgar 2008; Kuiter 2001).

The largest number of individual fish (for each species/taxa) observed in a single frame throughout the duration of a single sample recording is given as a *MaxN* value. *MaxN* should be considered a conservative estimate of abundance, particularly where large numbers of fish are present. This technique of estimating abundance has been reviewed in detail by Cappo *et al.* (2003, 2004) and Willis *et al*. (2000).

Fish length measurements were obtained from paired stereo images using SeaGIS *PhotoMeasure* software (http://www.seagis.com.au/photo.html). Associated files from *EventMeasure* software (which is used to provide *MaxN* abundance values) are loaded into *PhotoMeasure*. The time coordinates from the event file are used to locate the point in the video where the *MaxN* event occurred for each species. All length measurements for each species are performed at this point in time for each sample, preventing any one fish being measured twice.

Measurements of *MaxN* and length were only conducted within a range of approximately 4 metres in front of the cameras. This was to ensure a level of standardisation across all samples to allow for any variations in visibility due to water quality. In addition, the precision of length measurements suffered at distances greater than 4m, and at the edges of the field of view due to lenticular distortion.

Fish were measured using fork length rather than total length. Fork length is a more accurate measure which reduces potential errors resulting from fin damage. Some fish such as those belonging to the Labridae and Monacanthidae families do not have a forked tail and so standard length was used. These measures were applied to all fish except for the rays, belonging to the genera *Dasyatis* and *Trygonorrhina,* where the disc length was measured instead.

Statistical analysis

All samples were accepted for statistical analysis with the exception of those from the reef habitat within the predicted zone of influence of the saline concentrate, during winter in year 1 of the project. During this sampling season, visibility was poor and a number of samples were thus unusable. This was the result of a well-defined band of extremely turbid water adjacent the shore which enveloped much of the reef habitat. This turbidity resulted from the combined effect of a period of extended rainfall, high winds, and a discharge of water from a holding pond on the Port Stanvac desalination plant construction site. This resulted in a relative paucity of data for reef sites for the first winter sampling period.

Data for two years (8 seasons) within 2 habitat types inside and outside the zone of influence were examined using a range of multivariate procedures in the *PRIMER* software package (Plymouth Marine Laboratories). Data were combined at genus level, and relative abundance values (*MaxN*) were 4^{th}-root transformed and a similarity matrix constructed using Bray-Curtis similarities. Non-metric Multi Dimensional Scaling (nMDS) ordination plots were used to provide visual representations of the surveyed fish assemblages both spatially and temporally (i.e. four seasons over two years).

Differences between these assemblages were determined statistically using permutational multivariate analysis of variance (PERMANOVA). The PERMANOVA routine has the capacity to explore complex interactions between multiple factors that are associated with sophisticated sampling designs but with fewer assumptions as is usual for a permutation-based test (in contrast to the parametric MANOVA technique used in year one of the project). As a result, all factors including habitat, in the analytical design were examined together in the second year of the project to better scrutinize these interactions. Results from this test were used to define interactions between the various factors, i.e. year, season, habitat type and treatment (distance from saline outfall), and further examination was carried out by conducting individual pairwise tests on the various combinations of factors.

Where differences were observed between fish assemblages, spatially or seasonally, the SIMPER (similarity percentages) routine in *PRIMER* was used to examine the role of specific genera of fish in driving these differences. For a specific pairwise comparison of factors, SIMPER generates a table of genera ranked by their contribution to the overall dissimilarities between the two groups of samples, or the closeness of samples within a group (Clarke and Gorley 2006). It also provides an indication of the consistency with which that genus contributes to those differences by the "Diss/SD" ratio (the ratio of the average contribution from a genus divided by the standard deviation of those contributions across all pairs of samples making up this average; Clarke and Gorley 2006).

Results

Fish Communities in the Pt Stanvac area.

During the course of this survey, a total of 92 types of fish were recorded with 75 of those identified to species level. This comprised 44 species within 28 families in the first year and approximately 68 species of fishes belonging to 35 families in the second year. Over the two years, this could be broken down further to include 7 species of Chondrichthyes (cartilaginous fishes – sharks and rays) in as many families, and 66 species of Actinopterygii (ray-finned fishes) representing 35 families. The most speciose families were Monacanthidae, Labridae, Tetraodontidae and Ostraciidae (see Appendix A).

A total of 6720 fish were recorded in the second year compared to 2743 in the first, from pooled *MaxN* data collected over the 2 year period. It should be noted that this high number can be attributed to the occasional occurrence of large schools of baitfish such as those belonging to the Clupeidae and Engraulidae families, especially in the second year. The most consistently abundant genera over the two years were *Parequula*, *Heterodontus*, *Pseudocaranx*, *Sillago* and *Torquigener*.

Image quality and morphological similarities between species resulted in a number of individuals being identified to genus level. These were:

Pseudocaranx spp. – possibly *P.georgeanus* or *P. wrighti*

Platycephalus spp. – *P. bassensis, P. speculator* or *P. aurimaculatus*

Aracana spp. – *A. aurita* or *A. ornata*

Sillago spp. – probably *S. bassensis* but could also be *S. schomburgkii*

Acanthaluteres sp. – probably *A. spilomelanurus*

Trachurius sp. – possibly *T. declivis*

Meuschenia spp. - many

Notolabrus spp. – probably *N. parilus or N. tetricus*

Pseudorhombus spp. – P. arius or P. jenynsii

Sphyraena spp. probably *S. novaehollandiae*

In addition, the following taxa were only reliably identified to family level:

Monacanthidae (leatherjacktes: sp, sp1, sp2, sp3) – difficult to differentiate using video alone due to morphological similarities.

Clupeidae – many
Sillaginidae – either *Sillaginodes* or *Sillago*
Tetraodontidae – many
Carcharhinidae – probably *Carcharhinus*
Gobiidae – many
Labridae – many
Ostraciidae – *Aracana, Caprichthys,* or *Anoplocapros.*

Total relative abundance and number of species across Seasons, Habitats, Treatments and Years

Overall, summed (for treatment and season) mean relative abundances (*MaxN*) across the study seemed highly variable (Figure 3A). Abundances overall were generally highest for spring and summer and lowest in winter. Very high abundances were recorded in summer of year 2 at all sites except near reef.

Seasonal variation in the total number of species among habitat treatments seemed to vary more in the second year compared to the first (Figure 3B). Species numbers were generally higher in year two of the study, especially for spring, summer and autumn. The total number of species was consistently lower in winter and generally higher at sites located in reef habitat.

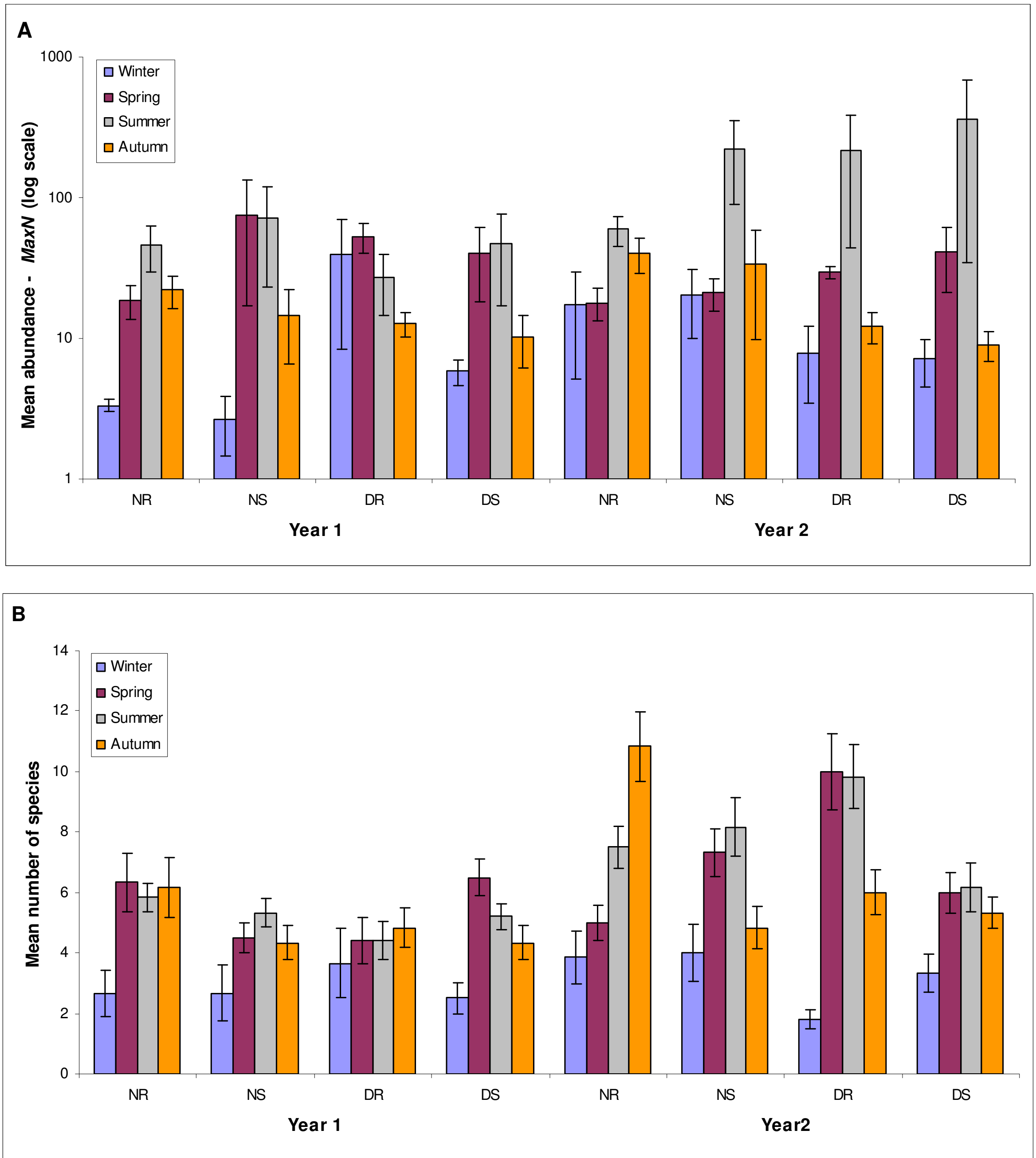


Figure 3. Mean seasonal species richness and relative abundance over two years and across sites. Treatment/Habitat codes: NR = Near Reef, NS = Near Soft, DR = Distant Reef, DS = Distant Soft

Multivariate Analysis of fish community assemblages at Pt Stanvac

Ordination of the data showed no clear separation or grouping overall based on the various factors (Figure 4), although points from year one did ordinate more to the lower half of the plot suggesting the possibility that in the second year fish communities were a little more variable. However, this is likely to result from the higher number of genera sampled in the second year of the project.

From a seasonal perspective, the same plot suggests that, although the spread of points overlap, there is evidence of some grouping based on season (Figure 4A), and this is borne out by statistical testing which indicated an interaction between annual and seasonal effects (Table 1). Results also suggest differences between fish assemblages related to treatment (i.e. near versus distant sites; Figure 4B Table 1); however, the interaction between factors means they cannot be considered independently of one another.

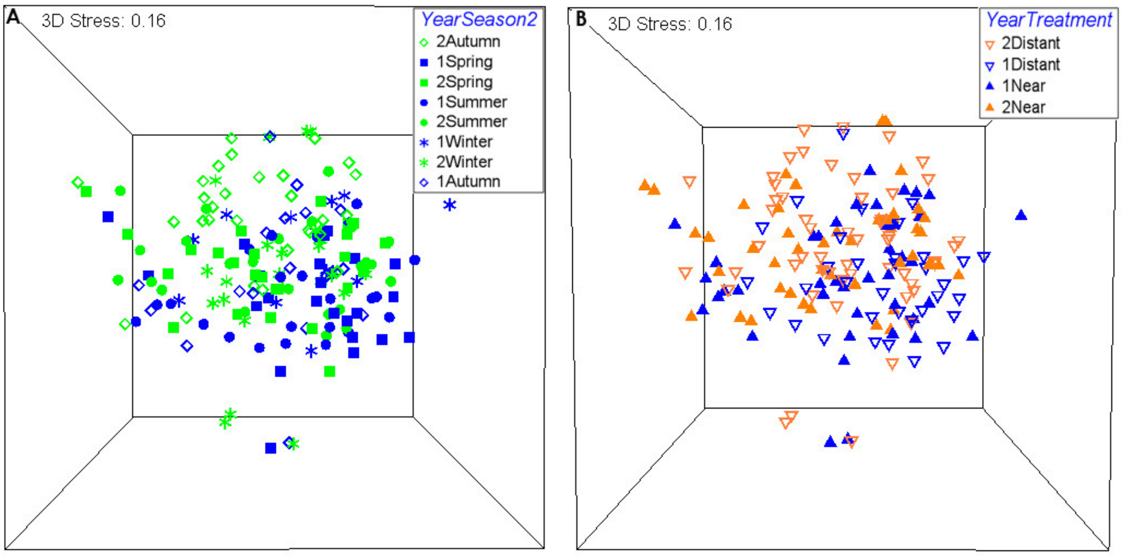


Figure 4. MDS ordination of all BRUVS data over 2 years (8 seasons). A. Blue and green represent samples from yrs 1 and 2, respectively. B. Blue and orange) represent years and filled versus hollow shapes represent Near and Distant sites.

Table 1 PERMANOVA results showing significant differences within all factors and factors interacting with one another (see Appendix B for full Permanova output for the interacting effects shown below in bold)

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms	P(MC)
Ye	1	9141.3	9141.3	3.5943	0.0004	9941	0.0004
Tr	1	2832.4	2832.4	1.24	0.3331	6	0.3752
Ha	1	16393	16393	3.8443	0.0001	6	0.0333
Se(Ye)	6	50673	8445.4	3.3207	0.0001	9848	0.0001
YexTr	1	2284.3	2284.3	0.89817	0.5177	9938	0.5204
YexHa	1	4264.3	4264.3	1.6767	0.0892	9943	0.0966
TrxHa	1	3512	3512	0.27054	0.9609	630	0.9626
Se(Ye)xTr	6	24631	4105.1	1.6141	0.0043	9847	0.0067
Se(Ye)xHa	6	14208	2368	0.93109	0.6069	9844	0.5989
YexTrxHa	**1**	**12982**	**12982**	**5.1043**	**0.0001**	**9956**	**0.0001**
Se(Ye)xTrxHa	**5**	**39635**	**7927**	**3.1168**	**0.0001**	**9864**	**0.0001**
Res	148	3.76E+05	2543.3				
Total	178	5.73E+05					

Pairwise comparisons

The complex interactions observed above were broken down into a series of pair-wise comparisons to test for differences within each factor when under the influence of another. The results were too extensive to include in the text of this report and are provided in Appendix B. The following provides a summary of those results of pairwise comparisons.

Seasonal differences were more common in year 2 than year 1 and were observed at all sites except Near Soft (in year 1) with autumn (both years) and winter (particularly year 1) standing out as being different from the other seasons (Appendix B). Differences observed between autumn and other seasons were most often driven by *Heterodontus* and *Parequula* at the Near sites. A variety of taxa drove differences at the Distant Reef site, including *Sillago*, *Upeneichthys*, *Parequula*, *Aracana* and *Torquigener,* while at the Distant Soft site *Aracana* and *Heterodontus* were important. Differences between winter and other seasons (in year 1) were driven largely by *Pseudocanranx* and *Parequulla*.

Similarly, differences in the fish assemblages between the two habitat types (reef and soft) were observed more often in year 2 than in year 1. In year 1, differences in fish assemblages between habitats were only observed during spring for both treatments and for the near treatment during summer and autumn (Appendix B). The main taxa driving these differences were *Parequula*, *Sillago* and, to a lesser degree, *Heterodontus* (Appendix C). In contrast, differences in the fish assemblages between the two habitat types were observed in all seasons bar spring for both treatments (i.e. Near and Distant). Once again, *Parequula* and *Heterodontus* were important in driving these differences between fish assemblages for the two habitat types.

More differences between treatments (i.e. Near versus Distant sites) were observed in year 2 of the study than in year 1. Differences were also seen more often within the reef habitat, and more often during summer, throughout the study (Appendix B). *Parequulla* were an important driver for these differences across the two years while *Pseudocaranx* was important in year 1 and *Heterodontus* in year 2 (Appendix C).

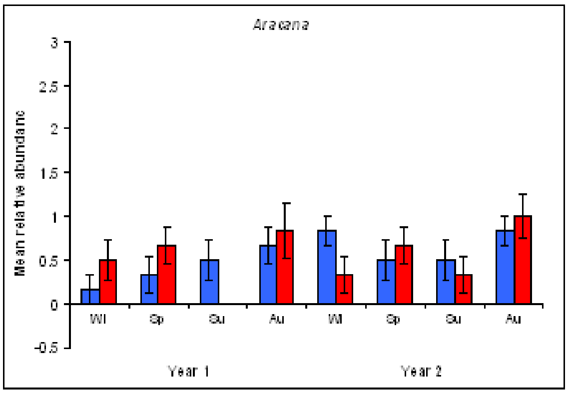
Relative abundance of significant genera

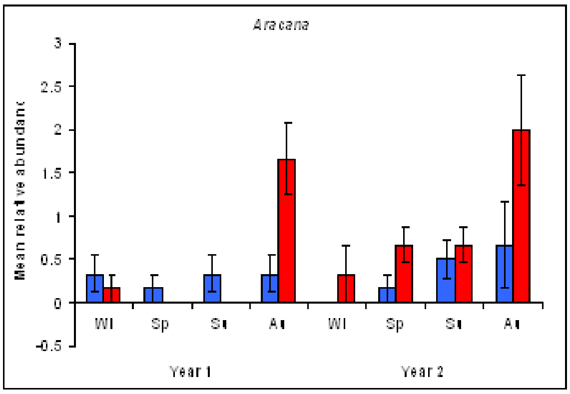
Relative abundances for the main genera driving the statistical differences show no evidence of consistent patterns relating to treatments (Figure 5). This is to be expected at this stage since this dataset represents a ‘pre-effect’ or baseline survey. Some minor patterns were however observed that related to seasonal and habitat differences.

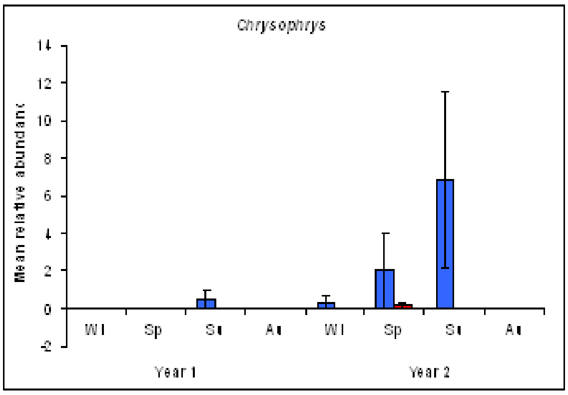
Seasonally, *Aracana* numbers were higher in autumn in both years at the distant reef site. Habitat preferences were observed for *Heterodontus* and *Torquigener*, with the former producing consistently higher abundances at soft-bottom sites and the latter at reef sites (although less consistently).

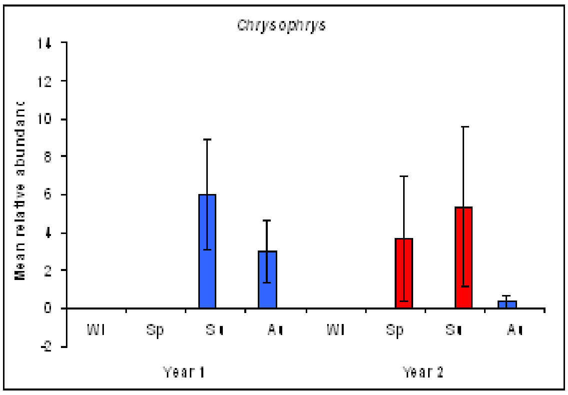
Soft-bottom

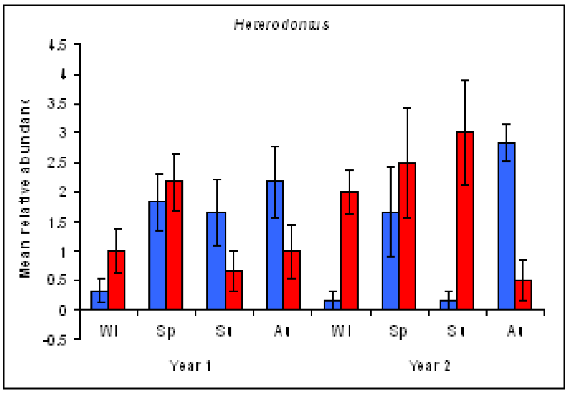
Reef

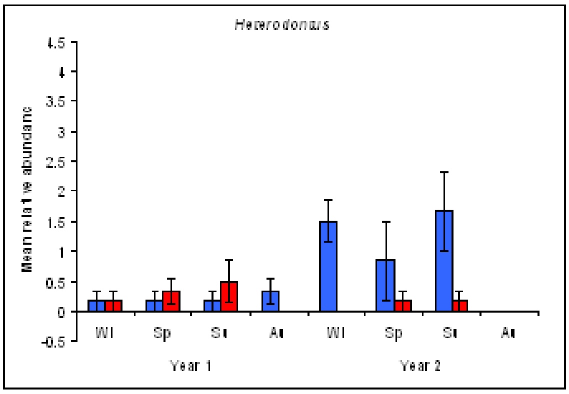


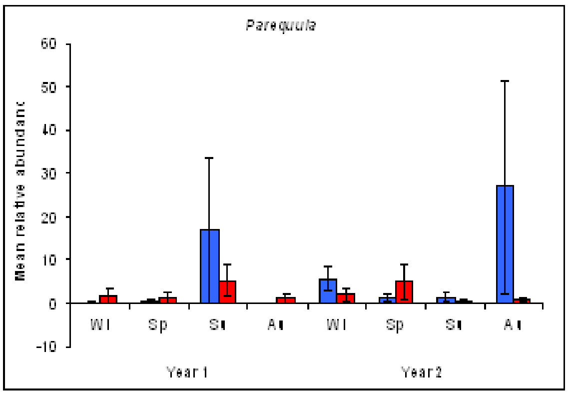


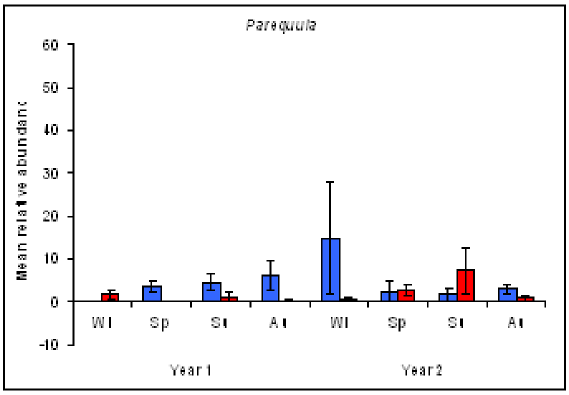












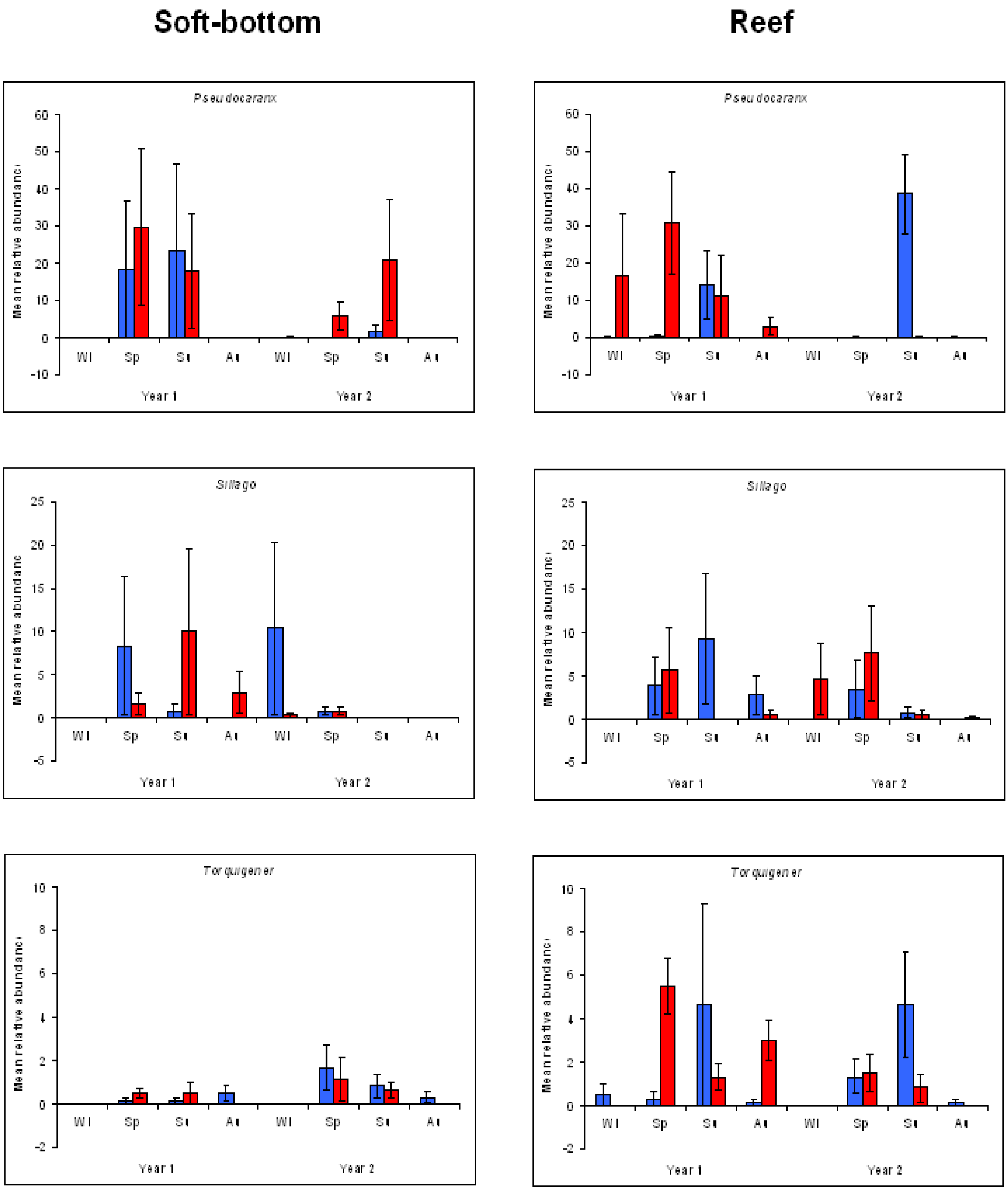


Figure 5. Mean relative abundance of important genera (determined by SIMPER analysis above) across habitats, seasons and treatments for years 1 & 2.

Fish lengths

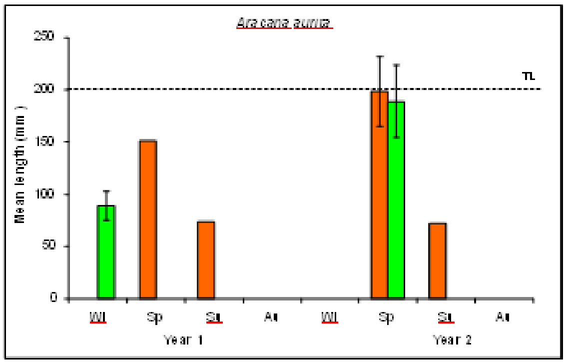
A total of 1615 fish were measured over the course of this 2 year survey (641 in year 1 and 974 in year 2), representing 53 genera. As the study so far represents a baseline, choosing which species to examine for potential effects of saline concentrate is difficult at this stage. For this report, the lengths of eight taxa that were important in driving differences between years, seasons, habitats and treatments (near versus distant from the outfall; (Appendix C) are presented along with an additional species considered to be of commercial and recreational importance (*Chrysophrys auratus*: Snapper).

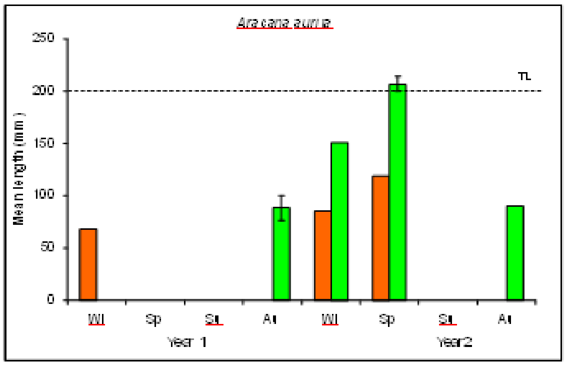
Observations of fish length have remained consistent in the second year of the study. Overall, fish length data were quite variable and no consistent patterns were observed in the length data between ‘Near’ and ‘Distant’ sites. A number of the taxa measured were consistently smaller than their maximum total or standard lengths according to Gomon *et al.* 2008.

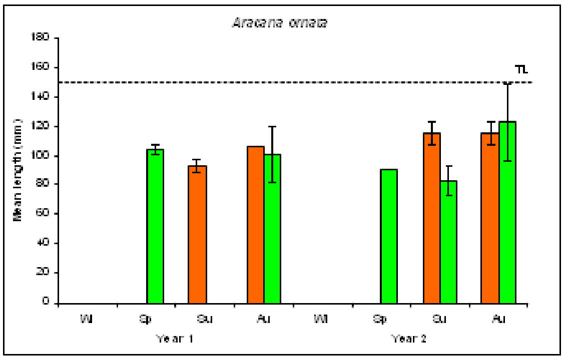
The most interesting pattern observed in the fish length data was observed for *Heterodontus portusjacksoni* (Port Jackson shark). Over the two years of the study, measurements of individuals in the soft sediment habitats were consistently below the size of sexual maturity (approximately 600 mm, Rodda pers. comm. 2010), at around 300 – 400 mm (approximately 6-8 months old). On reef sites, lengths were highly variable (although individuals were not measured for all seasons). Of note, was a spike in size in the summer of year 1, which was the only set of measurements taken that reached and exceeded the size of sexual maturity.

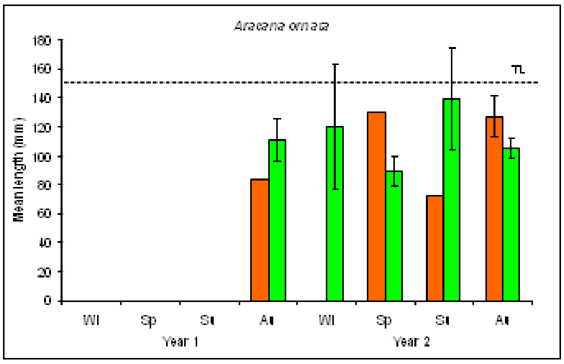
Soft-bottom

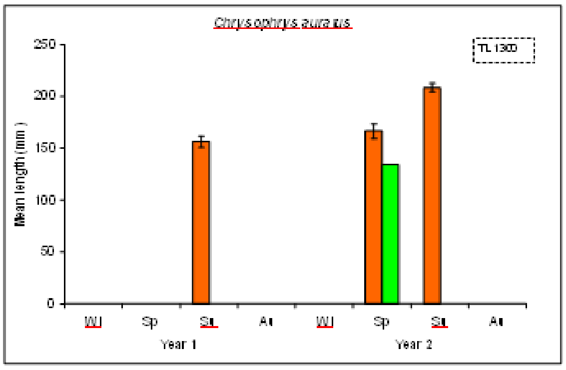
Reef

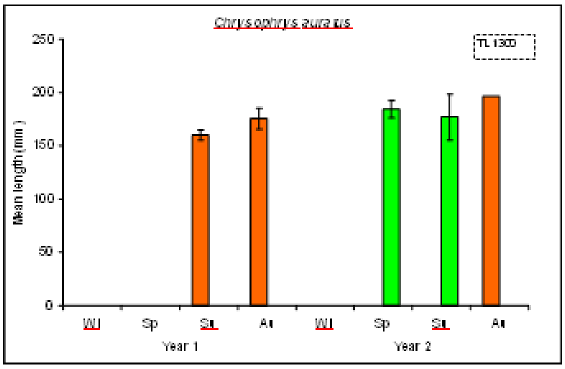


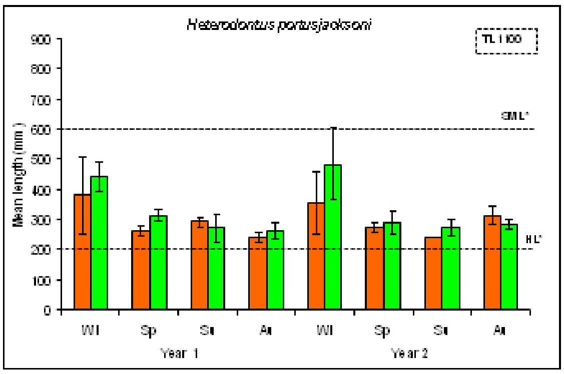


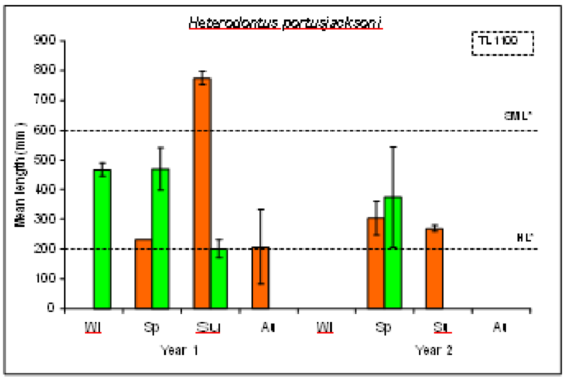












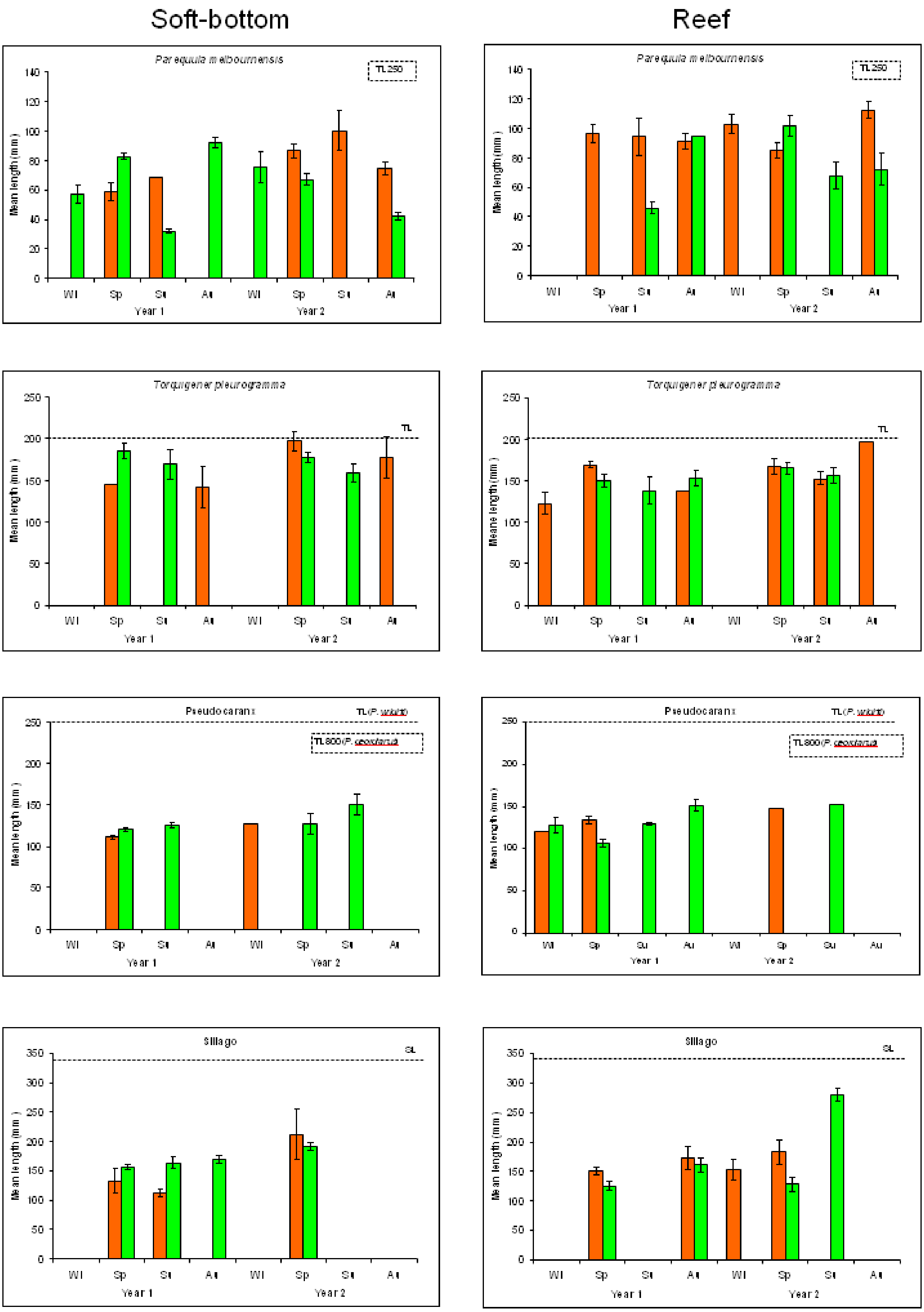


Figure 6. Mean lengths of species / genera identified by SIMPER and maximum adult length as per Gomon *et al,* (2008) shown as a horizontal limit line or, if much larger, given in a dashed box. Green = Distant site, orange = Near site. TL = total length, SL = standard length. TL* = total length, SML* = sexually mature length, HL* = Hatchling length (* apply to *H. portusjacksoni* only and are based on pers comm. K Rodda of SARDI)

Discussion

This study has produced a two-year dataset describing both the spatial and temporal variability of fishes in the area. The resultant dataset forms a baseline against which potential future changes in the fish assemblages at the site can be assessed once the desalination plant is fully operational and hence saline concentrate is discharging.

A diverse range of taxa were recorded, and a high degree of variability in fish assemblages was evident, both spatially and temporally. Annual differences were evident in higher abundances, species numbers and a higher proportion of differences between treatments observed during the second year. However, interactions between these annual differences and other factors such as season, habitat type and treatment (near versus distant from the saline outfall) were complex and, as a result, no factor could be examined in isolation from the others.

In addition, some of the background variability in fish assemblages was not driven evidently by year, season, habitat or treatment, suggesting that other factors may be influencing the fish assemblages in the area. Several possible reasons were proposed in the preceding report (Colella *et al.* 2010) including tide and currents, variability of the habitat in the area, and high variability in fish datasets that results from their great mobility (eg Miller *et al.* 1998).

Overall, abundances and the number of species observed were higher in summer and lowest in winter. In the second year of the project, larger numbers of species and more differences between season, habitat and treatment were observed relative to the first year. Overall, a similar list of taxa (compared to year 1, see Colella *et al.* 2010) driving differences was observed during the second year. These include *Heterodontus* (Port Jackson shark), *Parequula* (Melbourne silverbelly), *Sillago* (Whiting), *Aracana* (Boxfish), *Torquigener* (Toadfish) and *Pseudocaranx* (Trevally). A significant proportion of the higher numbers observed could be attributed to schooling taxa such as the Clupiedae family (sardines and pilchards), which also occasionally contributed to differences between seasons, habitats and treatments, although not consistently and never as the main driver.

In the second year, more differences were observed between the sites within and outside the proposed zone of influence of the saline outfall, than was observed in the first year. As in the first year these were more often on the reef sites. In summer and winter of the second year differences between the treatments were observed in both reef and soft habitats. Assuming no impact on the area has occurred to date (i.e. from the construction process), this difference could be ascribed to naturally-occurring background differences between the sites which is not unexpected in nature. Without sampling before any impact, those pre-existing differences might have been misconstrued as an impact of the outfall once it is operational.

The design of this survey was dictated by the location and nature of the two habitat types found within the predicted zone of influence. At the Near site (i.e. within the zone of influence), the reef habitat was small relative to the soft-bottom habitat. Similarly at the control site (i.e. Distant), the same was true but there was more separation between the sites. Fish are relatively mobile, and as a result the relative proximity of sites, more overlap of species in each habitat would not be unexpected at the near sites. Other factors such as the difference in scale and patchiness of the sites could also cause some of these background differences.

Overall, data from this study indicate that fish assemblages at the Port Stanvac site are complex and highly variable. This is not unusual in studies of fish communities since fish are so mobile and such variability has been found in a number of previous studies (Miller *et al.* 1998). As a result, the detection of the potential impact of hypersaline discharge in the area can only be achieved by overlaying any new states of the fish assemblages in the area over this dataset representing the ‘background noise’. The patterns observed over two years prior to the commencement of desalination operations thus represent the background spatial and temporal patterns against which any potential future observed effect of the saline concentrate can be assessed.

Fish length data provides little information at this stage that is interpretable in the context of potential impacts resulting from saline inputs. Currently this data set only provides a baseline for assessment of any future change that may eventuate following commencement of saline input to the local marine environment. In this report, the authors focussed upon species that were found to be important in driving differences between seasons, habitats and treatments; however, we recognise that this may have little relevance to fish length data.

A number of the taxa measured were consistently smaller than their maximal total or standard lengths, which may indicate that in some instances the study area may be home to sub adults and juveniles. However, it should also be kept in mind that a number of these are targeted species in an area subject to high recreational fishing effort, which would skew the size distributions of these species toward the smaller end of the scale (because larger individuals of each species are more prized).

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Appendix A: Species identified and counted using BRUVS over two years adjacent to Port Stanvac

Summed abundance codes: A = 1-10, B = 11-50, C = 51-100, D = 101+, * = many hundreds to thousands (sporadic large schools)

Class	Family	Genus	Species	Common name	CAAB code	Total count Year 1	Total count Year 2
Chondrichthyes	Alopiidae	*Alopias*	*vulpinus*	Thresher shark	37012001	A	
	Carcharhinidae	Carcharhinidae Unk	spp	Whaler shark		A	
	Lamnidae	*Carcharodon*	*carcharias*	Great white shark	37010003		A
	Dasyatidae	*Dasyatis*	*brevicaudata*	Smooth ray	37035001	B	B
	Heterodontidae	*Heterodontus*	*portusjacksoni*	Port Jackson shark	37007001	C	D
	Hexanchidae	*Notorynchus*	*cepedianus*	Broadnose sevengill shark	37005002	A	A
		Heptranchius	*perlo*	Sharpnose sevengill shark	37005001		A
	Rhinobatidae	*Trygonorrhina*	*fasciata*	Southern fiddler ray	37027006	B	B
Actinopterygii	Arripidae	*Arripis*	*georgianus*	Australian herring	37344001	A	A
		Arripis	*truttaceus*	West Australian salmon	37 344004	D	A
	Callionymidae	*Eocallionymus*	*papilio*	Painted stinkfish	37 427014		A
	Carangidae	Carangidae Unk	spp	Trevally	37 337000	D	
		Pseudocaranx	wrighti	Skipjack trevally	37 337063		D
		Pseudocaranx	spp	Trevally	37 337000	D*	D
		Trachurus	spp	Mackerel or Scad	37 337907	B	
	Chaetodontidae	*Chelmonops*	*curiosus*	Western talma	37 365066		A
	Cheilodactylidae	*Cheilodactylus*	*nigripes*	Magpie perch	37377001		A
		Dactylophora	*nigricans*	Dusky morwong	37 377005	A	B
	Clupeidae	Clupeidae Unk	spp	Anchovie or Pilchard	37 085000	D	D
		Hyperlophus	*vittatus*	Sandy sprat	37 085005		D
		Sardinops	*sagax*	Australian pilchard	37 085903		D*
		Spratelloides	*robustus*	Blue sprat	37 085003		A
	Dinolestidae	*Dinolestes*	*lewini*	Longfin pike	37327002	B	C
	Engraulidae	*Engraulis*	*australis*	Australian anchovy	37 086001		D*
	Enoplosidae	*Enoplosus*	*armatus*	Old wife	37 366001		A

	Gerridae	*Parequula*	*melbournensis*	Melbourne silverbelly	37349001	D	D*
	Gobiidae	*Gobiidae Unk*	spp	Goby	37 428000		A
	Kyphosidae	*Kyphosus*	*sydneyanus*	Silver drummer	37 361001		A
	Labridae	*Austrolabrus*	*maculatus*	Blackspotted wrasse	37384025	A	B
		Dotalabrus	*aurantiacus*	Castelnau's wrasse	37 384018		A
		Notolabrus	*parilus*	Brown-spotted wrasse	37384022	A	B
		Notolabrus	*tetricus*	Bluethroat wrasse	37 384003		A
		Ophthalmolepis	*lineolata*	Southern Maori wrasse	37384040	A	
		Pictilabrus	*laticlavius*	Senator wrasse	37384020	A	A
		Labridae Unk	spp	Wrasse	37 384000		A
	Monacanthidae	*Acanthaluteres*	*brownii*	Spinytail leatherjacket	37465001	A	B
		Acanthaluteres	*spilomelanurus*	Bridled leatherjacket	37 465043		A
		Acanthaluteres	spp	Leatherjacket	37 465901	A	A
		Acanthaluteres	vittiger	Toothbrush leatherjacket	37 465002		B
		Brachaluteres	*jacksonianus*	Southern pygmy leatherjacket	37465025	A	B
		Meuschenia	*flavolineata*	Yellowstriped leatherjacket	37 465035		A
		Meuschenia	*freycineti*	Sixspine leatherjacket	37465036	A	B
		Meuschenia	*galii*	Bluelined leatherjacket	37 465040		A
		Meuschenia	*hippocrepis*	Horseshoe leatherjacket	37465004	A	A
		Meuschenia	*venusta*	Stars & Stripes leatherjacket	37 465060		A
		Meuschenia	spp	Leatherjacket	37 465902	A	B
		Monacanthidae Unk	spp	Leatherjacket	37 465903	B	
		Monacanthidae Unk	spp1	Leatherjacket	37 465903	A	
		Monacanthidae Unk	spp2	Leatherjacket	37 465903	A	
		Monacanthidae Unk	spp3	Leatherjacket	37 465903	A	
		Nelusetta	*ayraud*	Ocean jacket	37465006	B	B
		Scobinichthys	*granulatus*	Rough leatherjacket	37465007	A	B
		Thamnaconus	*degeni*	Bluefin leatherjacket	37 465037		A
	Mugilidae	*Aldrichetta*	*forsterii*	Yelloweye mullet	37 381001		B
	Mullidae	*Upeneichthys*	*vlamingii*	Bluespotted goatfish	37355029	B	C

	Neosebastidae	*Neosebastes*	*scorpaenoides*	Common gurnard perch	37287005	A	A
	Odacidae	*Neoodax*	*balteatus*	Little weed whiting	37 385005		A
		Olisthops	*cyanomelas*	Herring cale	37 385001		A
		Siphonognathus	*attenuatus*	Slender weed whiting	37385004	B	A
		Siphonognathus	*beddomei*	Pencil weed whiting	37385006	A	B
	Ostraciidae	*Aracana*	*aurita*	Shaw's cowfish	37466003	B	B
		Aracana	*ornata*	Ornate cowfish	37466001	B	B
		Aracana	spp	Cowfish	37 466000	A	B
		Ostraciidae Unk	spp	Boxfish	37 466000		A
	Paralichthyidae	*Pseudorhombus*	*jenynsii*	Smalltooth flounder	37 460002		A
		Pseudorhombus	spp	Flounder	37 460000		A
	Pempherididae	*Parapriacanthus*	*elongatus*	Elongate bullseye	37 357002		A
		Pempheris	*multiradiata*	Bigscale bullseye	37 357001		A
	Pentacerotidae	*Pentaceropsis*	*recurvirostris*	Long-snout boarfish	37367003	A	A
	Pinguipedidae	*Parapercis*	*haackei*	Wavy grubfish	37390004	A	C
		Parapercis	*ramsayi*	Spotted grubfish	37 390002		A
	Platycephalidae	*Platycephalus*	*aurimaculatus*	Toothy flathead	37296035	A	
		Platycephalus	*bassensis*	Southern sand flathead	37296003	B	B
		Platycephalus	*speculator*	Southern bluespotted flathead	37 296037		A
		Platycephalus	spp	Flathead	37 296000	A	B
	Plesiopidae	*Trachinops*	*noarlungae*	Noarlunga hulafish	37 316017		D
	Pomacentridae	*Parma*	*victoriae*	Scalyfin	37 372006		A
	Scombridae	*Scomber*	*australasicus*	Blue mackerel	37441001	A	
	Scorpididae	*Tilodon*	*sexfasciatus*	Moonlighter	37361003	A	A
	Sillaginidae	Sillaginidae Unk	spp	Whiting	37 330000	A	A
		Sillaginodes	*punctata*	King George whiting	37330001	B	D
		Sillago	*bassensis*		37 330901		A
		Sillago	spp	Whiting	37 330000	B	D
	Sparidae	*Chrysophrys*	*auratus*	Snapper	37353001	C	D
	Sphyraenidae	*Sphyraena*	*novaehollandiae*	Snook	37382002	A	A
		Sphyraena	spp		37 382000		A

	Syngnathidae	*Histiogamphelus*	*cristatus*	Rhino pipefish	37 282081	A	
	Terapontidae	*Pelates*	*octolineatus*	Western striped grunter	37321020	A	B
		Pelsartia	*humeralis*	Sea trumpeter	37321021	A	
	Tetraodontidae	*Omegophora*	*armilla*	Ringed toadfish	37467002	A	A
		Tetractenos	*glaber*	Smooth toadfish	37467003	A	A
		Tetraodontidae Unk	spp	Toadfish	37 467000	A	
		Torquigener	*pleurogramma*	Weeping toadfish	37467030	D	C
	Tetrarogidae	*Gymnapistes*	*marmoratus*	Cobbler	37 287018		A

Appendix B. PERMANOVA Results

Pair-wise tests (bold text indicates a statistically significant result)

Source: Year x Treatment x Habitat

	Pair of levels of factor Year	t	p	Pair of levels of factor Treatment	t	p	Pair of levels of factor Habitat	t	p
Within Factors	**Distant, Reef**	**2.1218**	**0.0001**	**Year1, Soft**	**1.461**	**0.033**	**Year1, Near**	**2.6434**	**0.0001**
	Distant, Soft	1.1259	0.2727	Year1, Reef	1.2192	0.1529	Year2, Near	1.2719	0.1173
	Near, Reef	**1.5792**	**0.0164**	**Year2, Soft**	**1.6805**	**0.0077**	**Year1, Distant**	**1.4446**	**0.0434**
	Near, Soft	**2.1913**	**0.0001**	**Year2, Reef**	**1.9932**	**0.0001**	**Year2, Distant**	**2.2598**	**0.0001**

Source: Season (within Year) x Treatment x Habitat

Pairs of levels of	Year	Within levels	Groups	t	p
Season	1	Distant, Reef	**Sp, Wi**	**2.1791**	**0.0181**
			Sp, Su	1.3334	0.112
			Su, Wi	1.3564	0.1272
		Distant, Soft	**Su, Wi**	**1.5973**	**0.0249**
			Sp, Wi	**1.4826**	**0.0159**
			Su, Wi	**1.7034**	**0.0124**
			Au, Sp	1.2062	0.2079
			Au. Wi	1.1902	0.2131
			Sp, Su	1.4493	0.0878
		Near, Reef	**Au, Wi**	**1.4636**	**0.0375**
			Au, Sp	0.6639	0.877
			Au, Su	0.7996	0.6875
			Sp, Su	0.9266	0.5459
			Sp, Wi	1.1582	0.231
			Su, Wi	1.4542	0.0967
		Near, Soft	Au, Sp	0.9390	0.5772
			Au, Su	1.0621	0.3676
			Au, Wi	0.9821	0.4796
			Sp, Su	1.3919	0.0941
			Sp, Wi	0.9075	0.6133
			Su, Wi	1.2157	0.1806
	2	Distant, Reef	**Au, Sp**	**1.7297**	**0.0025**
			Au, Su	**1.7427**	**0.0053**
			Au, Wi	**1.9184**	**0.0049**
			Sp, Su	0.7317	0.7911
			Sp, Wi	1.2745	0.1367
			Su, Wi	1.4372	0.0822
		Distant, Soft	**Au, Su**	**1.9755**	**0.0029**
			Au, Wi	**2.3815**	**0.0093**

			Su, Wi	**1.7797**	**0.0023**
			Au, Sp	1.4305	0.0962
			Sp, Su	1.1605	0.2261
			Sp, Wi	1.2882	0.1588
		Near, Reef	**Au, Sp**	**1.6739**	**0.0218**
			Au, Su	**2.4717**	**0.0017**
			Au, Wi	**2.3161**	**0.0013**
			Sp, Su	**1.4689**	**0.0226**
			Sp, Wi	1.2559	0.1607
			Su, Wi	**2.3569**	**0.0012**
		Near, Soft	**Au, Su**	**1.8568**	**0.0057**
			Au, Sp	1.3758	0.0963
			Au, Wi	**2.0919**	**0.0064**
			Sp, Su	0.8625	0.5997
			Sp, Wi	1.1496	0.27
			Su, Wi	1.2917	0.1329
Treatment	1	**Spring, Reef**	Distant, Near	**1.7676**	**0.0031**
		Spring, Soft		0.2297	0.988
		Autumn, Soft		1.3081	0.1322
		Summer, Reef		**1.6694**	**0.0218**
		Summer, Soft		**1.7997**	**0.0164**
		Winter, Reef		1.2626	0.2005
		Winter, Soft		0.5086	08883
	2	**Autumn, Reef**		**1.9596**	**0.0003**
		Autumn, Soft		1.5759	0.0771
		Spring, Reef		1.1017	0.2996
		Spring, Soft		0.8128	0.6811
		Summer, Reef		**2.0595**	**0.0027**
		Summer, Soft		**1.5483**	**0.0238**
		Winter, Reef		**2.0165**	**0.0086**
		Winter, Soft		**2.4693**	**0.0049**
Habitat	1	**Autumn, Near**	Reef, Soft	**2.107**	**0.0023**
		Spring, Distant		**1.8216**	**0.0144**
		Spring, Near		**1.3844**	**0.0465**
		Summer, Distant		1.3404	0.1264
		Summer, Near		**2.0236**	**0.0106**
		Winter, Distant		1.3346	0.1498
		Winter, Near		0.6635	1
	2	**Autumn, Distant**		**1.5721**	**0.0106**
		Autumn, Near		**2.1304**	**0.0025**
		Spring, distant		1.0379	0.4
		Spring, Near		0.67011	0.8402
		Summer, Distant		**1.8752**	**0.005**
		Summer, Near		**1.7001**	**0.0172**
		Winter, Distant		**1.9458**	**0.0196**
		Winter, Near		**1.9344**	**0.0193**

Appendix C: SIMPER results

Top ranked taxa responsible for driving differences between: 1. Seasons, 2. Treatments and 3. Habitats. **Bold** numerals indicates those taxa consistently contributing to differences (Diss/SD >1), * = Diss/SD >2. (Generally ranks 1 to 3 are included, however where differences between contributions was small, subsequent ranks were also added)

1. Seasons

Year 1	Near Reef	Distant Reef	Distant Soft		**Year 2**	Distant Reef			Distant Soft		Near Reef			Near Soft	
Genera	Au,Wi	Sp, Wi	Su, Wi	Sp, Wi		Au, Sp	Au,Su	Au, Wi	Au,Su	Au,Wi	Au, Sp	Au,Su	Au, Wi	Au,Su	Au,Wi
Acanthaluteres											**2**	**5**	**2**		
Aracana								**1***	**2**	**2**					
Heterodontus									**1**	**1**	**3**	**2***	**1***	**1**	**1**
Parapercis														**3**	
Parequula	**1**	**3**	2	2		**2**	**1**			**4**	**1**	**4**	**3**	2	2
Platycephalus				**3**						**3**					**3**
Pseudocaranx		**2**	**1**	1								**1**			
Sillaginodes															
Sillago	2		**3**			1		2							
Torquigener		**1***				3	3	3							
Trachurus												**3**			
Upeneichthys	**3**						**2**							**4**	

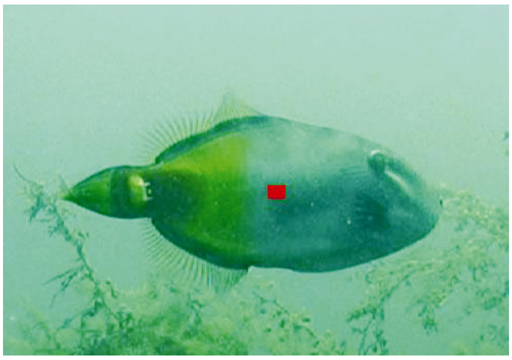
2. Treatment (Near, Distant)

Year 1 **Genera**	Spring Reef	Summer Reef	Summer Soft	**Year 2**	Summer Reef	Winter Reef	Autumn Reef	Summer Soft	Winter Soft
Acanthaluteres							**2**		
Aracana							**3**		2
Arripis			**1***						
Chrysophrys		**1**							
Heterodontus					**3***	**1***		**1**	**1**
Parequula		**2**	**3**		**2**	**3**	**1**		**4**
Platycephalus									**3**
Pseudocaranx	**1**	3	**2**		**1**			2	
Sardinops								3	
Sillago	3					2			
Torquigener	**2**	**4**							

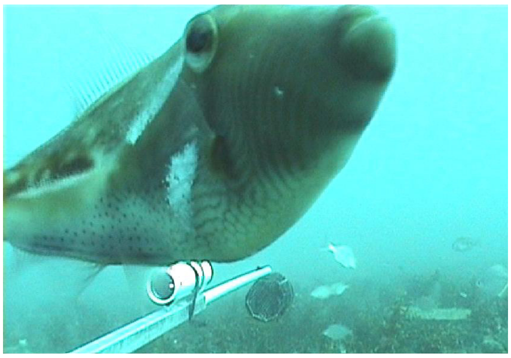
3. Habitat (Reef, Soft)

Year 1 **Genera**	Spring Near	Spring Distant	Summer Near	Autumn Near	**Year 2**	Autumn Distant	Summer Distant	Winter Distant	Autumn Near	Summer Near	Winter Near
Acanthaluteres									**3**		
Arripis			**1***	3							
Chrysophrys			**3**								
Heterodontus	**2**			**4**			**2**	**1***	**1***	**2**	**1**
Parapercis						3					
Parequula	**3**		**2**	**1**			**1**		**2**		**2**
Platycephalus								**3**			**3**
Pseudocaranx		**1**								**1**	
Sillago	1	**3**		2				2			
Torquigener		**2**				1					
Trachurus										**3**	
Upeneichthys						**2**					

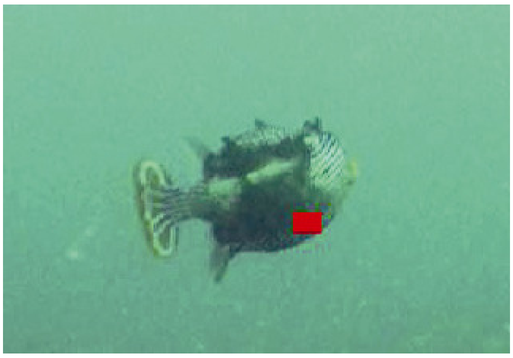
Appendix D. Still images of fish species commonly identified in the Port Stanvac area.



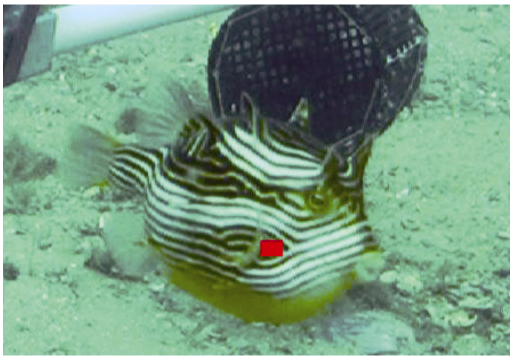
Acanthaluteres brownii



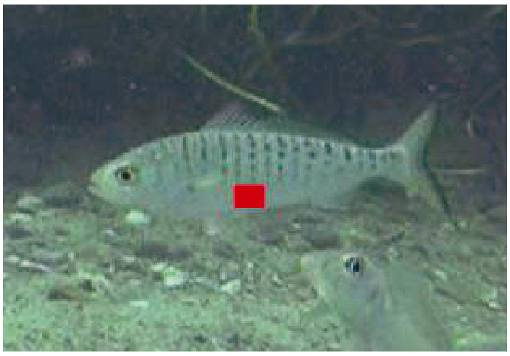
Acanthaluteres vittiger



Aracana ornata

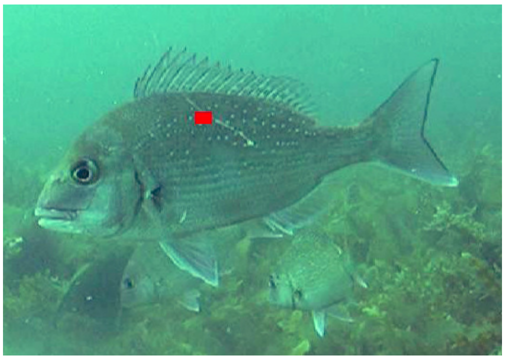


Aracana aurita

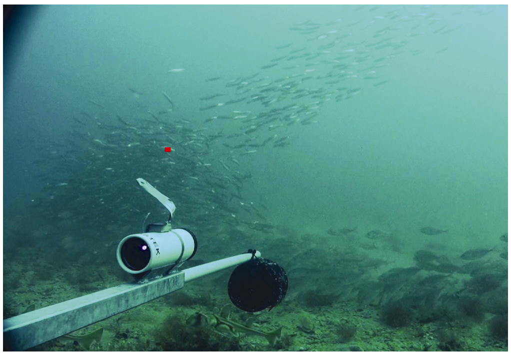


Arripis truttaceus

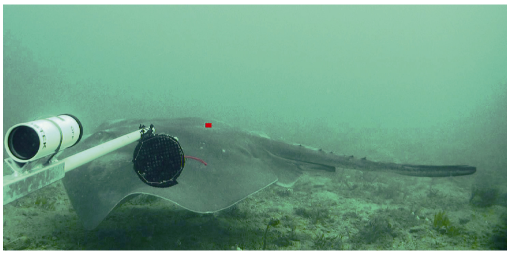
Austrolabrus maculatus

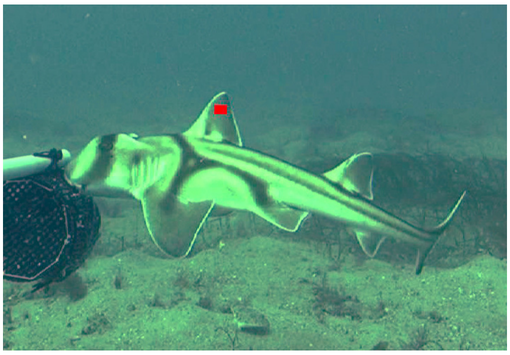


Chrysophrys auratus

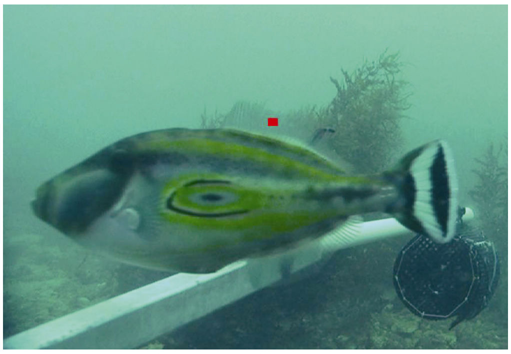


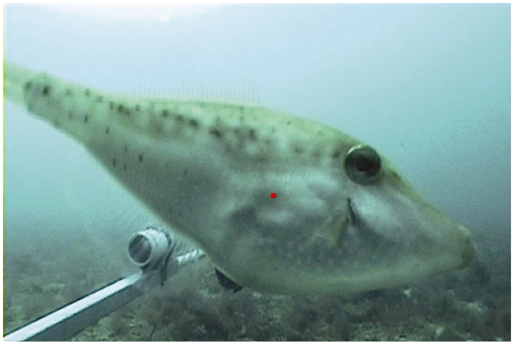
Clupeidae spp.


Dasyatis brevicaudata

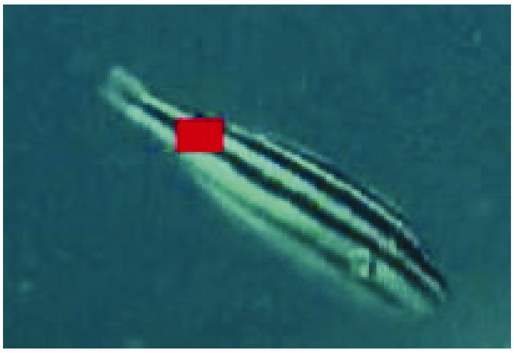

Heterodontus portusjacksoni

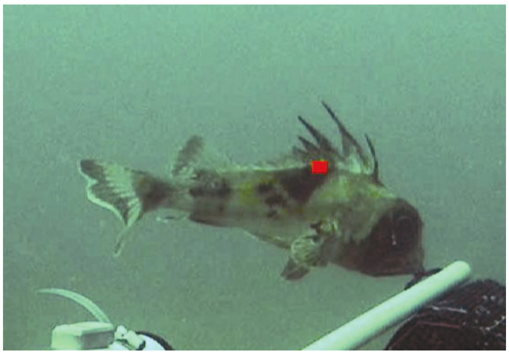

Meuschenia freycineti

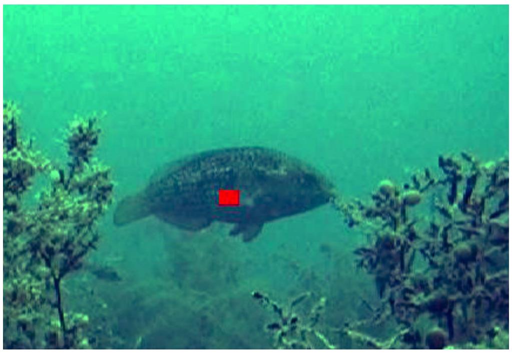

Meuschenia hippocrepis

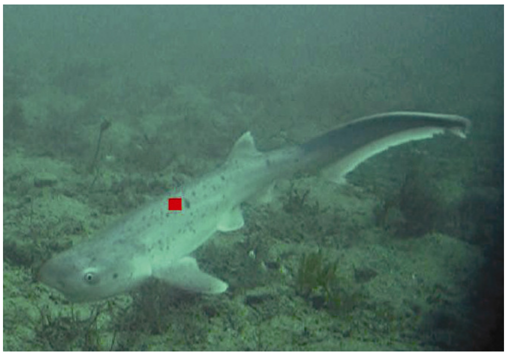

Monacanthidae spp.


Monacanthidae spp.2


Nelusetta ayraud

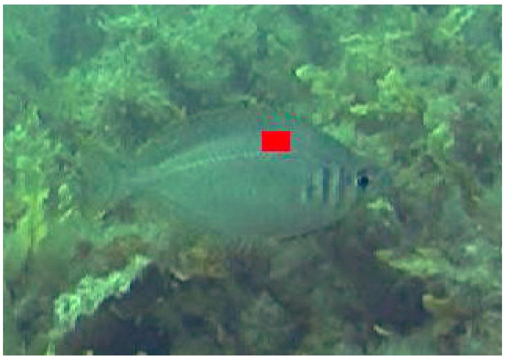

Neosebastes scorpaenoides

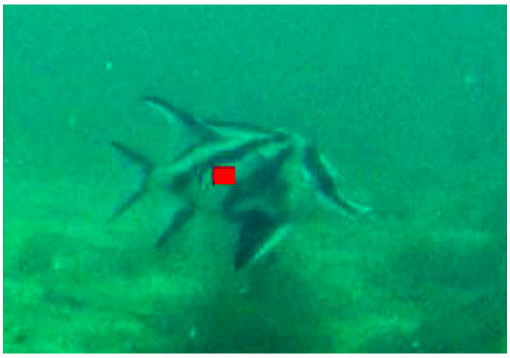

Notolabrus parilus

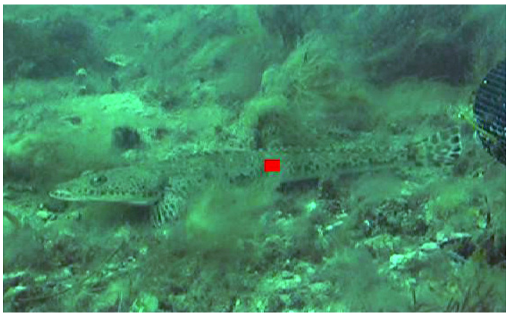

Notorynchus cepedianus

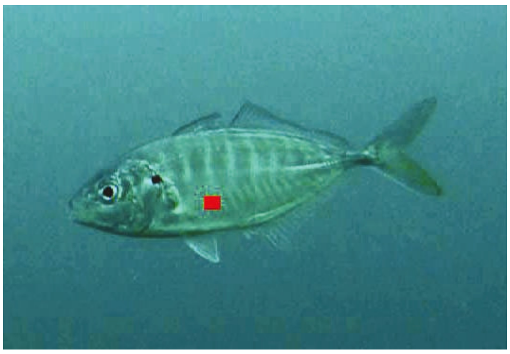

Omegaphora armilla

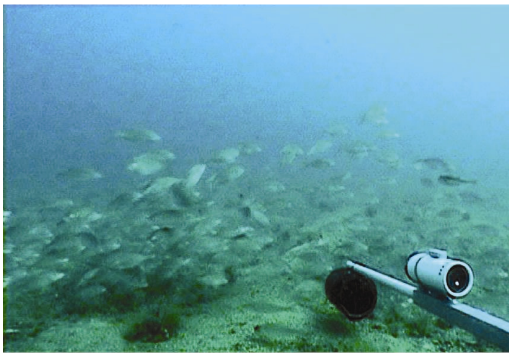

Opthalmolepis lineolata


Parequula melbournensis

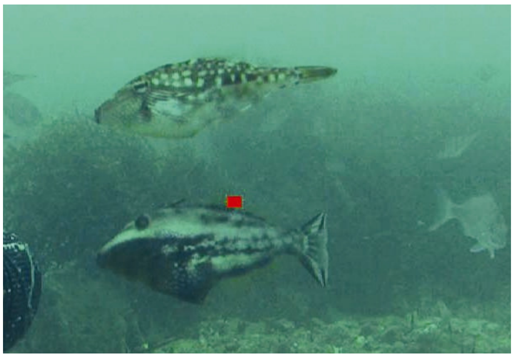

Pentaceropsis recurvirostris


Platycephalus bassensis

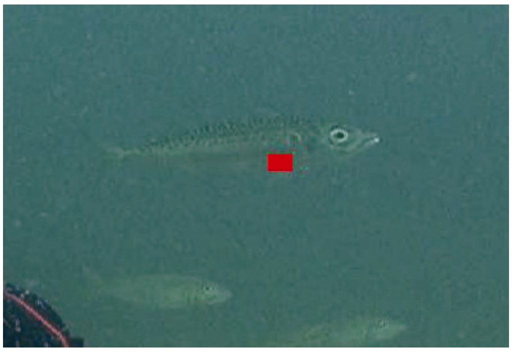

Pseudocaranx spp.



Pseudocaranx spp. (large school)

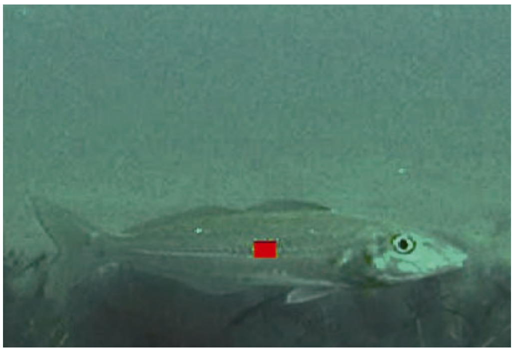


Scobinichthys granulatus



Scomber australasicus

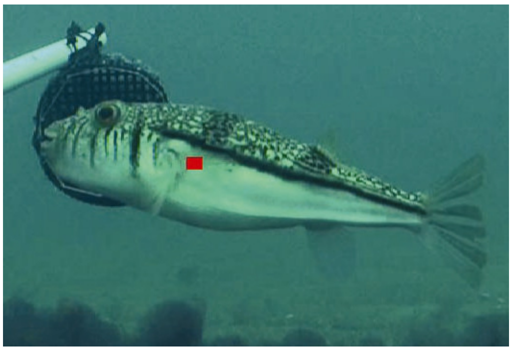
Sillaginodes punctata



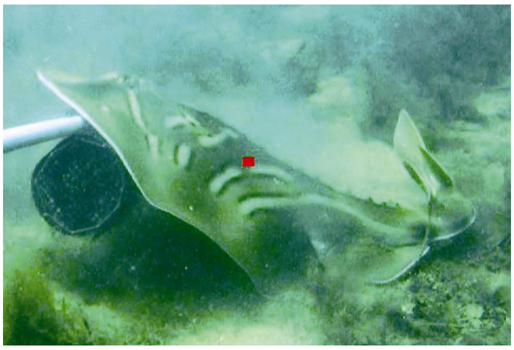
Sillago spp.

Siphonognathus attenuatus

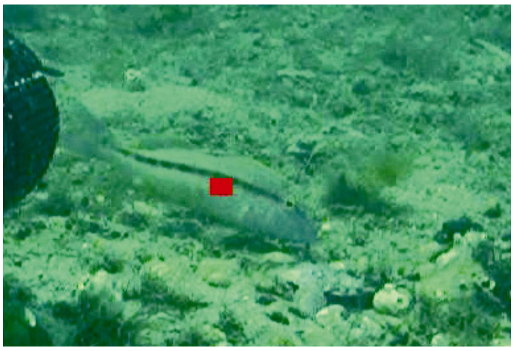
Siphonognathus beddomei



Torquigener pleurogramma



Trygonorrhina fasciata



Upeneicthyes vlamingii