A baseline assessment of fish and benthic communities at the site of a proposed desalination plant expansion, Penneshaw, Kangaroo Island

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Department for Environment and Water
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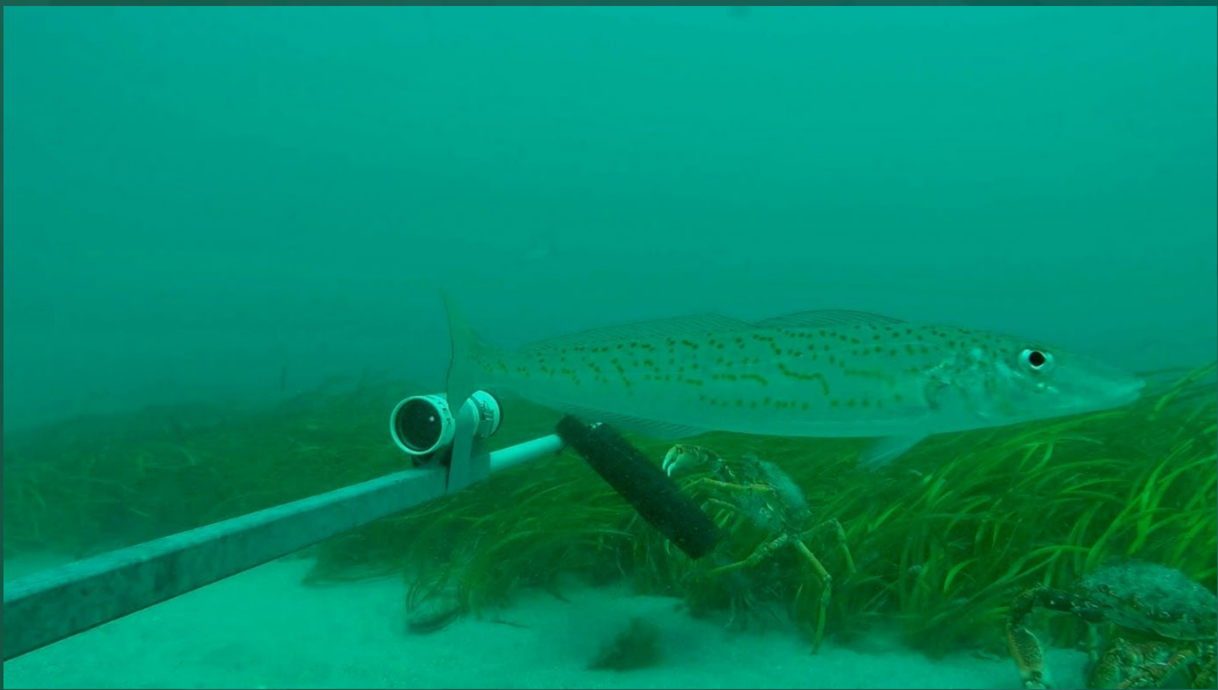

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Acknowledgment of Country

We acknowledge and respect the Traditional Custodians whose ancestral lands we live and work upon and we pay our respects to their Elders past and present. We acknowledge and respect their deep spiritual connection and the relationship that Aboriginal and Torres Strait Islanders people have to Country. We also pay our respects to the cultural authority of Aboriginal and Torres Strait Islander people and their nations in South Australia, as well as those across Australia.

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Summary

Security of water supplies is a key state government priority for regional communities in South Australia. To ensure water security for the township of Penneshaw and surrounds, a seawater desalination plant was constructed in Penneshaw in 1999. SA Water has identified that demand for water on Kangaroo Island is increasing and to ensure the continued water security of Kangaroo Island, a proposed expansion of the desalination plant is forecast. The proposed expansion is planned for the Penneshaw area to take advantage of the existing infrastructure and ocean currents that will aid in the rapid dilution of hypersaline outfall water.

As part of the approvals process a development is required to ensure environmental impacts are minimised and monitored. As the proposed development is located in the Encounter Marine Park, the Department for Environment and Water (DEW) was contracted in 2018 to conduct a preliminary assessment of the marine environment in the vicinity of the hypersaline outfall location from the proposed desalination plant expansion. A monitoring program was designed and implemented in 2018 and 2019 to characterise benthic habitats and fish assemblages that with ongoing monitoring would enable detection of any potential impacts of the hypersaline outfall on the marine environment. Monitoring sites were established at the proposed impact site and two control sites, and surveys were conducted using towed video to assess benthic habitats and baited remote underwater video systems (BRUVS) to assess fish communities. The report provides a baseline assessment of fish and plant communities in the direct area of the proposed desalination outfall as well as similar surrounding areas, and will be used to assess any potential future changes to the aquatic ecosystems.

All three sites monitored were dominated by seagrass and sand habitats with only very minor contributions to the overall habitat by mixed algae and invertebrate cover types. The impact site had the highest percentage of seagrass cover (59%-69%) compared to the control sites (50%-65%). Total seagrass cover was higher in autumn across all three sites. The most dominant habitat type across all three sites was *Posidonia* seagrass. Cover at the impact site consisted of mostly *Posidonia* while at the control sites *Posidonia* and some *Zostera tasmanica* were the most common seagrass species.

A total of 1057 fish were counted and 39 species identified (comprising 33 fish, 4 crustaceans, 1 mollusc and 1 echinoderm). All sites were dominated by benthic invertivores (e.g. trevally) in spring. In autumn, Control site 1 was dominated by browsing herbivores (leatherjackets) while Control site 2 was dominated by higher carnivores (Australian herring, Western Australian salmon). At the impact site both seasons were dominated by benthic invertivores (trevally, King George whiting).

It is recommended where practicable to repeat the surveys as soon as possible post construction and then annually for three years and at the five year post construction mark. Given the seasonal variation in fish communities it is recommended to include seasonal sampling as part of the ongoing monitoring program, however, the frequency and timing of repeat surveys will depend somewhat on the legislated requirements specified for the construction and post operation phase in the development application.

1 Background

1.1 Introduction

Security of water supplies is a key priority for regional communities in South Australia. SA Water has identified that regional communities on Kangaroo Island (KI) will need to be supplemented with additional water production due to uncertainty around ground water reserves and increasing populations. SA Water proposes to expand the desalination plant at Penneshaw on KI to ensure long term water security for this regional area. The proposed site for this development occurs in the state's Encounter Marine Park (General Managed Use Zone GMUZ 5).

Desalination has been used for many years in the Middle East and Mediterranean and is becoming more common in Europe, America and Australia. The hypersaline waste product of the desalination process has the potential to increase salinity, temperature, metals, hydrocarbons and toxic anti-fouling compounds in the waters immediately surrounding the outfall. The selection of adequate outfall sites with high water exchange is paramount to minimising ecological impacts and monitoring is required to assess what impacts are occurring (Roberts et al. 2010, Clark et al. 2018).

As part of the development application process, SA Water were committed to a thorough assessment and management of potential risks to the marine environment. To achieve this and given the location of the proposed site inside a state marine park, the Department for Environment & Water (DEW) was engaged in 2018 to conduct a preliminary assessment of benthic habitats and associated fish communities and design an ongoing monitoring program at the proposed site of the desalination outfall location to assess potential impacts on the marine environment. The collection of data on benthic habitats and associated fish communities in this report was undertaken in 2018 and 2019.

This project, in addition to satisfying the development assessment requirements for desalination plant construction will also improve the knowledge and understanding of benthic habitats and fish communities in the state managed Encounter Marine Park. This report documents the baseline benthic habitats and fish assemblages at the proposed location and environs of the proposed hypersaline outfall prior to establishment of any desalination plant expansion.

1.2 Objectives

The aim of this project was to establish an ecological monitoring program to assess the potential impacts of hypersaline discharge to the benthic marine habitats and fish assemblages at the proposed site of the Penneshaw desalination plant outfall site on KI. The objectives of this project were:

1. Design a Before-After, Control-Impact (BACI) monitoring program to assess the impact of the desalination outfall on benthic habitats and fish assemblages at the Penneshaw outfall site.
2. Map the benthic habitats in the vicinity of the outfall location.
3. Provide an assessment of the benthic habitats and associated fish communities at the outfall site (impact) and two nearby comparative sites (controls) in spring 2018 and autumn 2019.
4. Provide a report to SA Water on the observed plant and animal diversity at the proposed outfall site (impact site) and assess how the control sites compare to the impact site.

2 Methods

2.1 Study Site

The location of the desalination plant and outfall was proposed to be 1.5km west of Penneshaw on KI in the vicinity of the existing desalination plant (Figure 1). The benthic habitats of the area are characterised by seagrass meadows (mainly *Posidonia*) at depths of 3-15m with fringing shallow reef. The area falls inside a General Managed Use Zone (GMUZ) of the Encounter Marine Park (Figure 1).

The desalination plant outfall site is subject to water quality criteria that should achieve a dilution rate of 40:1 above ambient within a certain radius. Modelling and studies from other sites suggest that target dilution is achieved in a relatively short distance from the discharge site. At the site of a proposed desalination plant at Sleaford Bay, Eyre Peninsula, modelling results suggest that target dilution may be achieved at around 16.5m from the discharge site under a scenario with no water current, and that the increase in salinity on the seafloor in the direct vicinity of the outfall was predicted to be up to 0.52 g/l and dilute to 0.1-0.2 g/l within a few hundred metres depending on currents and plant size (Sadeghian 2019). Other studies in Australia also suggest the impact from the proposed plant at Penneshaw is likely to extend less than 100m from the outfall before falling within normal ambient salinity fluctuations (Clarke et al. 2018).

To assess the potential impacts of the hypersaline discharge; three monitoring sites were chosen, one 'impact' site centred on the outfall location and two 'control' sites situated beyond the expected impact of the outfall in similar habitats and depths (7-18m). The Impact site and control sites measured approximately 500m by 250m which will encompass the expected radius of impact from the hypersaline discharge.

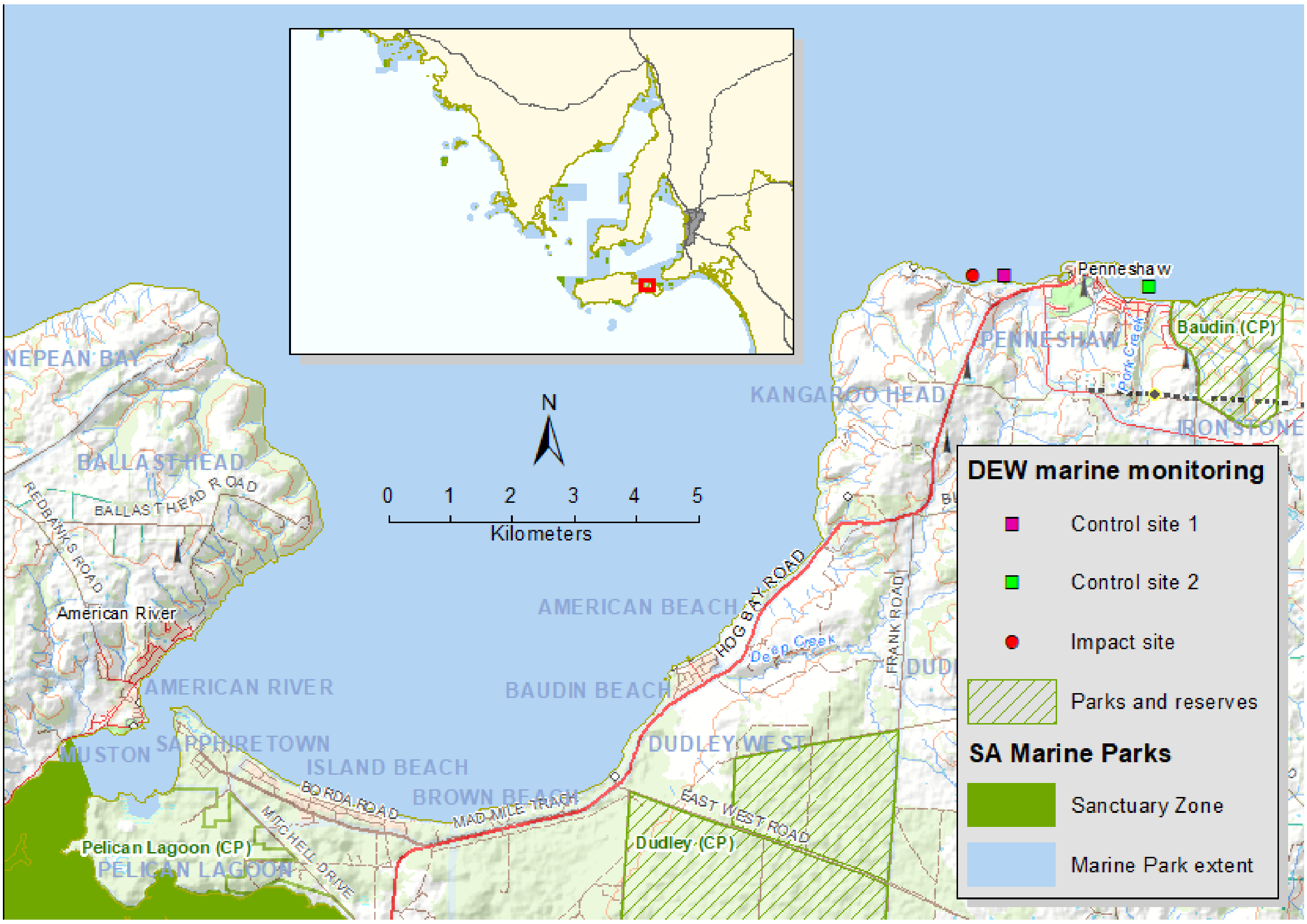

Figure 1. Map showing location of Control and Impact monitoring sites.

2.2 Benthic habitat mapping of impact site

Benthic habitats at the proposed Impact site were mapped over an area measuring 1000m by 500m (double the size of the planned monitoring sites) using a combination of towed video and multibeam swath sonar. A multibeam swath sonar survey of the area was carried out by Hydrographic Services – SA Water between the 2nd and 5th of October 2018 using a Norbit wbms multibeam sonar with 0.5deg high resolution array. Ground truthing and habitat classification were carried out in conjunction with the spring monitoring surveys in October 2018 using a Scielex towed video system (with an additional downfacing GoPro Hero 3+ taking a still image every 2 seconds). Video sample drops consisted of 25m drift transects captured along with GPS data on a video hard-drive recorder (Lawmate). Over the monitoring site (250 x 500m), 50 drift transects were recorded (50m separation) and approximately 40 additional transects were spread evenly over the remainder of the broader habitat mapping area (further detail included in the next section). Each video drop was classified based on the dominant habitat type across the whole transect (including estimates of density and patchiness as per previous regional habitat mapping in SA (e.g. see Department for Environment and Heritage 2009). Classifications were made to genus for seagrasses and broad habitat types for the remainder (e.g. sand and macro-algae). ArcGIS was used to collate information collected in the field along with aerial imagery to produce a digitised layer/map of benthic habitats with a minimum mapping unit of 25 x 25m. The map comprised the habitat classes shown in Table 1, based on previous SA benthic habitat mapping but using a higher resolution for identification of seagrass as used for the monitoring assessment described below (Table 2).

Table 1. Habitat classifications used for mapping of the broader proposed Impact area (note 'dense', 'medium' & 'sparse' classes are a qualitative assessment based on imagery (as per Department for Environment and Heritage 2009), sonar and video.

Habitat Classes	Description
Posidonia/Zostera; dense; patchy	Dense *Posidonia* patches (10-50% cover) with *Zostera* interspersed
Posidonia/Zostera; medium; patchy	Medium density *Posidonia* patches (10-50% cover) with *Zostera* interspersed
Posidonia; dense	Dense *Posidonia* (> 50% cover)
Posidonia; dense; patchy	Dense *Posidonia* patches (10-50% cover)
Posidonia; medium	Dense *Posidonia* (> 50% cover)
Posidonia; medium; patchy	Medium density *Posidonia* patches (10-50% cover)
Posidonia; Sparse; patchy	Sparsely vegetated *Posidonia* patches (10-50% cover)
Reef; low profile	Reef with little to slight profile
Sand	Bare sandy substrate
Zostera; medium	Medium density *Zostera* (> 50% cover)
Zostera; medium; patchy	Medium density *Zostera* patches (10 - 50% cover)
Zostera; sparse; patchy	Sparsely vegetated *Zostera* patches (10 - 50% cover)

2.3 Benthic habitat monitoring

Baseline data for assessing the potential impact of hypersaline discharge on benthic habitats was also collected using the towed video system described above at each of the three study locations, the proposed Impact site, Control 1 and Control 2 (Figure 2). At each site, 50 evenly spaced 25m drift video samples were captured on a portable hard drive recorder along with concurrent GPS tracks. A downward facing GoPro Hero 7 captured habitat images for later analysis. Ten evenly spaced still images were subsampled from each drift transect and used to represent the recorded habitats on that transect. Each image was overlaid with five sample points and biota under each point scored to provide an overall percent cover (based on a total of 50 points) for each drift transect. Biota were scored according to classes in Table 2 which represent three dominant habitat forming seagrass species, two broad classes and bare substrate.

Table 2. Biota classes used for scoring images at the three monitoring sites.

Classification	Description
Sand	Bare sand
Posidonia	*Posidonia* seagrass beds (likely *P. angustifolia* or *P sinuosa*)
Zostera tasmanica	*Zostera tasmanica*
Amphibolis	*Amphibolis* seagrass beds (likely *A. antarctica*)
Algae	Miscellaneous algae on sand
Invertebrates	Non mobile invertebrate communities

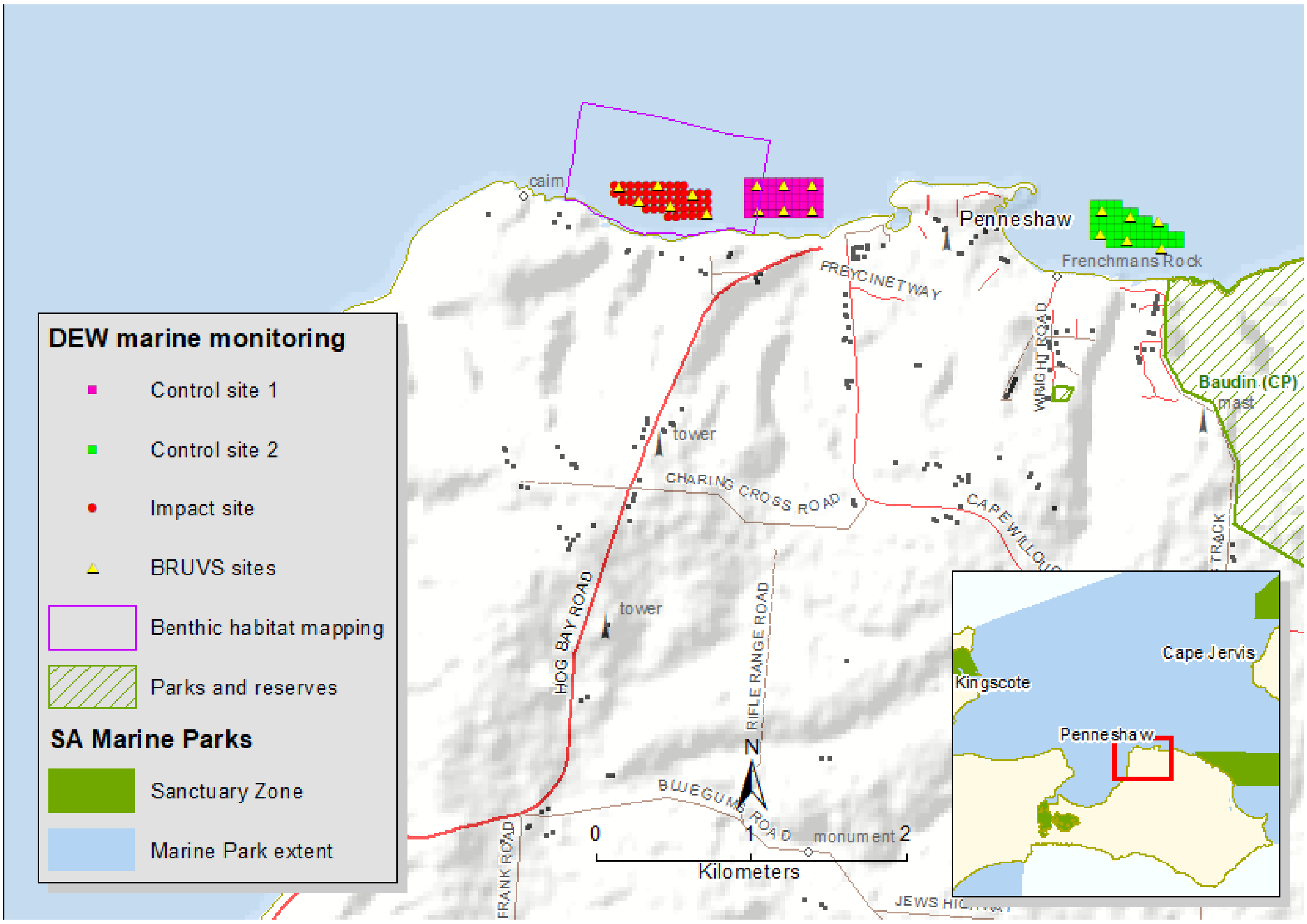

Figure 2. Location and layout of tow camera and BRUVS deployments.

2.4 Fish and mobile invertebrate assemblage monitoring

Fish and mobile invertebrate assemblages were characterised using stereo baited remote underwater video systems (BRUVS). BRUVS are frequently utilised to survey fish and large mobile invertebrates and monitor changes in assemblages (Langlois et al. 2006; Malcolm et al. 2007; Kleczkowski et al. 2008) and are currently used to monitor biodiversity of the South Australian Marine Parks Network (DEWNR 2017).

Six replicate BRUVS drops were undertaken at each site in spring 2018 and autumn 2019. Each BRUVS unit was separated by 150m at depths ranging from 6-10m (Figure 2). Each stereo BRUVS unit consisted of a pair of GoPro Hero 7 cameras housed inside custom-made underwater housings mounted to a steel frame fitted with ballast. A plastic mesh bait bag filled with approximately 750 grams of minced pilchards (*Sardinops* spp.) was mounted on a pole 1.5m in front of the cameras to attract fish into the view of the cameras. The BRUVS were left on the seabed to record for 60 minutes before being retrieved and redeployed. The video footage was interrogated to extract relative abundance (MaxN) and fish length data using EventMeasure software by SeaGIS. For a full description of BRUVS, use and data management, please refer to Miller et al. (2017).

As per benthic habitat monitoring, it is anticipated that if the desalination development goes ahead these sites will be reassessed over time to determine any potential impact on fish and mobile invertebrate communities. It is recommended that future analysis use multivariate techniques to assess potential differences in assemblages over time between treatments.

Community structure of fish was assessed using multivariate statistical techniques to display species assemblages across sites in multidimensional space (Clarke 1993). Comparisons of community structure across different sites at different sampling times were conducted in PRIMER v7 (Clarke and Gorley 2015) and PERMANOVA + (Anderson et al. 2008). A resemblance matrix was generated using Bray-Curtis index of dissimilarity on dispersion weight transformed data. The data was transformed using dispersion weighting to reduce the impact of high abundance schooling fish which can introduce bias into the data (Clarke et. al 2006). A non-metric multidimensional scaling (nMDS) ordination was plotted to visualise the differences between the fish communities at each site. To further test differences between fish assemblages at each site, comparisons using permutational multivariate analysis of variance (PERMANOVA) were conducted using fixed factors of site and season with pairwise tests conducted on significant factors.

2.5 Analysis and change detection

It is anticipated that these sites will be monitored over time to assess any potential impacts of hypersaline discharge and the current sampling layout has been designed to facilitate this. The sampling design in this report captures the "BEFORE" data. The rationale for detecting potential impacts of hypersaline water discharge is to use a multiple lines of evidence approach. The data collected by towed video and BRUVS can be used to assess a range of different components of the ecosystem encompassing both benthic habitats and fish communities. Metrics can be calculated for diversity (e.g. species richness) and abundance (e.g. number of fish, percentage cover of seagrass) while change in community structure over time can be assessed using univariate or multivariate techniques.

As seagrass was the dominant habitat at all sites, percentage cover of seagrass was used to compare "BEFORE" habitats between sites. To compare habitats between sites percentage data was transformed using an arcsine transformation (Sokal & Rohlf 1995) and a standard three factor ANOVA with Site, Season and Treatment as the factors and percentage seagrass cover derived from the towed video as the dependant habitat variable. For epiphyte analysis, data was log transformed to improve normality before conducting a standard three factor ANOVA with Site, Season and Treatment as the factors. Tukey HSD was used as the post hoc analysis.

Fish diversity and abundance metrics were calculated from the BRUVS data and the community structure of fish was assessed using multivariate statistical techniques to display species assemblages across sites in multidimensional space (Clarke 1993). Comparisons of fish community structure across different sites at different sampling times were conducted in PRIMER v7 (Clarke and Gorley 2015) and PERMANOVA + (Anderson et al. 2008). A resemblance matrix was generated using Bray-Curtis index of dissimilarity on raw habitat cover data and dispersion weight transformed fish (and mobile invertebrate) data. The latter was transformed using dispersion weighting to reduce the impact of high abundance schooling fish which can introduce bias into the data (Clarke et. al 2006). An ordination plot using non-metric multidimensional scaling (nMDS) was produced to visualise the differences between habitat types and fish communities at each site. Differences between habitat types and fish assemblages at each site were tested using permutational multivariate analysis of variance (PERMANOVA) using fixed factors of site and time (i.e. sampling season) with pairwise tests conducted on significant factors. Similarity percentages analysis (SIMPER) was used to assess habitat or species contributions to observed differences at different sites and different sampling times.

3 Results

3.1 Habitat mapping of the proposed impact site and surrounding area

Habitat mapping of the proposed Impact site of the Penneshaw desalination plant and the area surrounding it revealed a mix of sand, seagrass (mostly *Posidonia* with small amounts of *Zostera tasmanica*) and some sparse algal cover. Sand habitats made up a significant component of the shallows (to 4-5m depth; adjacent the existing outfall) and some of the deeper areas. Seagrass (mostly *Posidonia*) dominated the medium depths (5-10m: which includes the existing desalination plant intake), while further off shore (10-18m) habitats graded from mixed and patchy seagrass habitats (a mix of *Posidonia* and *Zostera tasmanica* to the west of the intake, and *Zostera tasmanica* and sparse algae and sand to the east of the intake) to sand dominated habitat (with some sparse *Zostera tasmanica* and algae) at the deeper margins of the survey area (Figure 3).

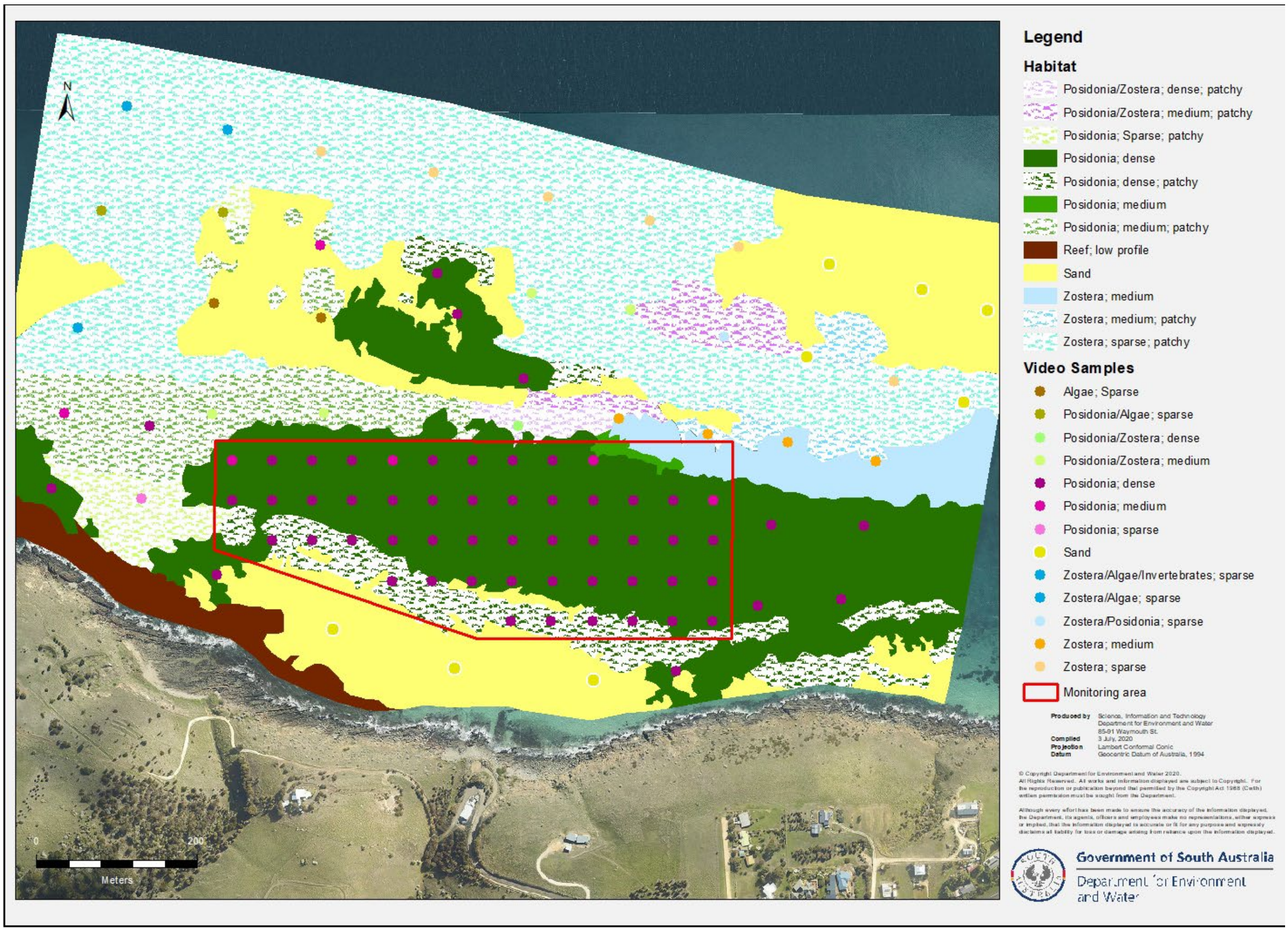

Figure 3. Habitat mapping of the Impact site around the proposed desalination intake and outfall.

In terms of area, the "Sparse, patchy *Zostera*" class (which also has small amounts of algae and *Posidonia* present) covered the greatest area (around 25 ha or almost 30% of the total area), followed by dense *Posidonia* (around 20 ha or approximately 25% of the area) and Sand habitat (covering almost 18 ha or 21% of the area; Table 3).

Table 3. Area and percentage of habitat classification types.

Note the values in table 3 represent the broader area of the proposed Impact site shown in Figure 3 (i.e. includes the area outside of the Impact site in Figure 3, Data in the following section (e.g. 3.2, table 4 and figure 4) is derived from a more vigorous methodology designed to assess the actual monitoring sites (e.g. the area inside the red boundary in Figure 3).

Habitat	Area Hectares (Ha)	Percentage
Posidonia/Zostera; dense; patchy	0.57	0.68
Posidonia/Zostera; medium; patchy	1.50	1.78
Posidonia; dense	20.86	24.77
Posidonia; dense; patchy	4.63	5.50
Posidonia; medium	0.18	0.21
Posidonia; medium; patchy	5.49	6.53
Posidonia; Sparse; patchy	1.69	2.01
Reef; low profile	2.23	2.65
Sand	17.80	21.14
Zostera; medium	2.88	3.41
Zostera; medium; patchy	1.17	1.39
Zostera; sparse; patchy	25.20	29.92

3.2 Baseline monitoring of benthic communities

3.2.1 Community structure and cover

Benthic habitats within the proposed Impact monitoring site were characterized by sand and seagrass habitats (31-41% and 59-68% respectively; Table 4, Figure 4). The vegetative cover was almost entirely *Posidonia* with only very small quantities of *Zostera tasmanica* seagrass. Similarly, at the two control sites the dominant habitat cover was *Posidonia* seagrass (33-40%). Seagrass composition however differed slightly at the control sites with a higher proportion of *Zostera tasmanica* present (between 16-26% of cover). Bare sand habitat contributed to the remaining area (varying between 35 and 50%; Table 4, Figure 4). Seagrass cover was significantly different between seasons and sites (P<0.001, Figure 4, Table 5). Total seagrass cover was significantly higher at the Impact site in both seasons (˜69% in autumn and ˜59% in spring, Figure 4, Appendix 1) and Control site 1 had the lowest seagrass cover overall, but the highest proportion of *Amphibolis* (Table 4). Some seasonal variation in seagrass cover was also evident at all monitoring sites with consistently higher cover in autumn (60-68%) compared to spring (50-59%; Figure 4) however the seasonal difference was only significant at the Impact site (P = 0.02, Appendix 1).

Table 4.Percent cover of all benthic habitats at Control and Impact sites.

Habitat type	Impact site		Control 1		Control 2	
	Spring	Autumn	Spring	Autumn	Spring	Autumn
Sand	41.11	31.32	49.88	38.87	45.58	34.95
***Posidonia* .**	58.81	68.44	33.36	39.80	35.09	38.50
Zostera tasmanica	0.00	0.16	16.27	20.32	18.84	26.31
Amphibolis	0.00	0.00	0.45	0.73	0.04	0.00
Misc Algae	0.08	0.08	0.00	0.28	0.45	0.24
Invertebrates	0.00	0.00	0.04	0.00	0.00	0.00

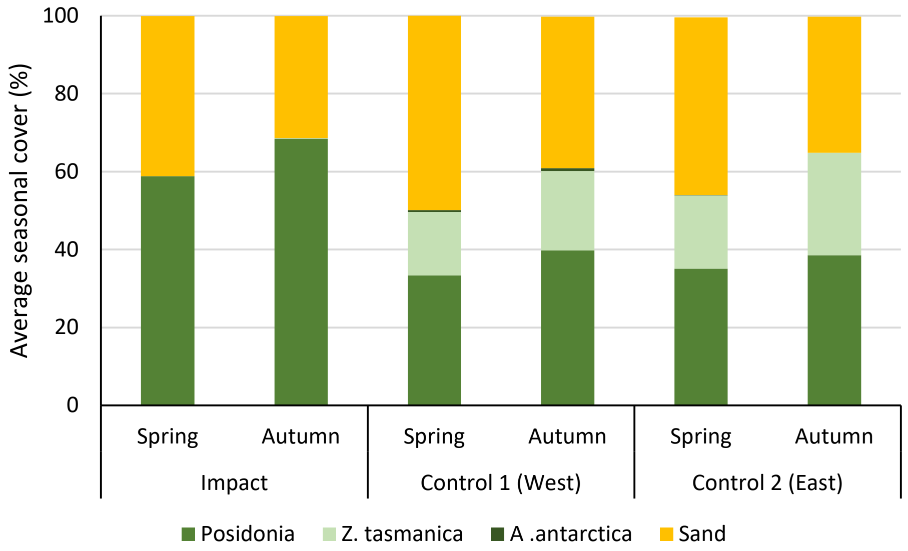

Figure 4. Percentage of seagrass cover and bare sand at three sampling sites in different seasons.

Table 5. ANOVA results for total seagrass cover between sites and seasons.

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Site	1.021418	2	0.510709	7.330899	**0.000782**	3.026465904
Season	1.732841	1	1.732841	24.87381	**1.05E-06**	3.873282557
Site X Season	0.026457	2	0.013228	0.189886	0.827155	3.026465904
Within	20.4816	294	0.069665			
Total	23.26231	299				

3.2.2 Epiphyte cover

Mean epiphyte ratings were found to differ between sites and seasons (P=0.008 and P<0.001 respectively, See Appendix 2). Seasonal differences were detected at each site (P<0.001) with Control site 1 and the Impact site both having higher epiphyte ratings in autumn compared to spring whereas Control site 2 showed the opposite trend with a higher epiphyte rating in spring. Control Site 2 had a significantly lower mean epiphyte rating in autumn and a significantly higher rating in spring (P<0.001) compared with Control site 1 and the Impact site (Figure 5, Appendix 3).

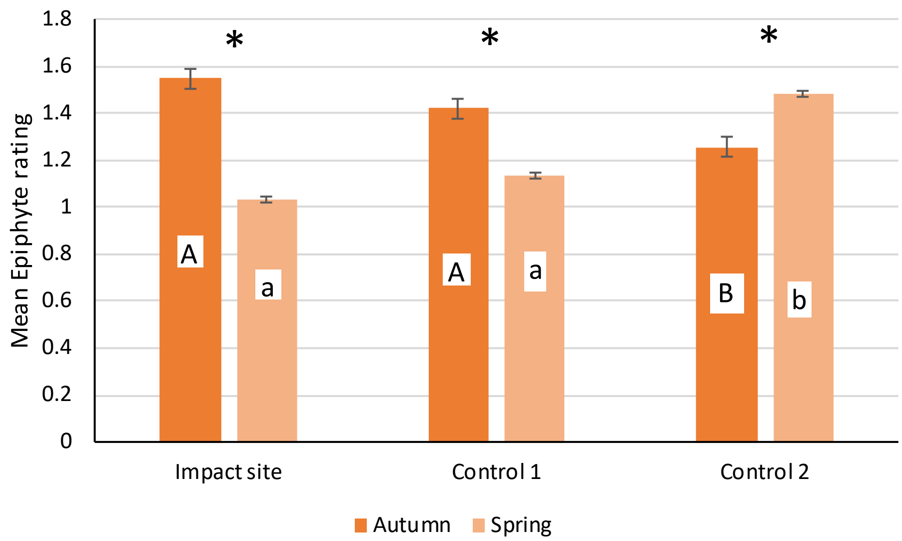

Figure 5. Mean epiphyte rating on *Posidonia* seagrass in autumn and spring 2018 at each site. * represents significant difference between seasons at individual sites. Different capital letters represent significant difference between sites for autumn, whereas differences in lowercase letters represent significant difference between sites for spring.

3.3 Baseline monitoring of fish communities

3.3.1 Community structure

A total of 26 species were observed at the proposed outfall site. The most abundant functional group present in both seasons was benthic invertivores (e.g. trevally, King George whiting, red mullet). Browsing herbivores (e.g. leatherjacket spp.) made up the second largest group in autumn while omnivores (e.g. spinytail leatherjackets) made up a larger proportion in spring (Figure 6). The site contained a typical array of seagrass associated fish species such as southern bluespot flathead, snook, wrasse and leatherjacket species, as well as rough rock crab and great spider crab. Some seasonal difference in species was observed with higher species diversity in autumn (see Appendix 4 for more detail). Similar to the Impact site, Control site 1 had a high proportion of benthic invertivores in spring but a larger seasonal difference in the proportion of browsing herbivores. Control site 2 had a similar proportion of benthic invertivores in spring but also recorded the highest proportion of higher carnivores (Australian herring). The proportion of higher carnivores increased over autumn (Figure 6).

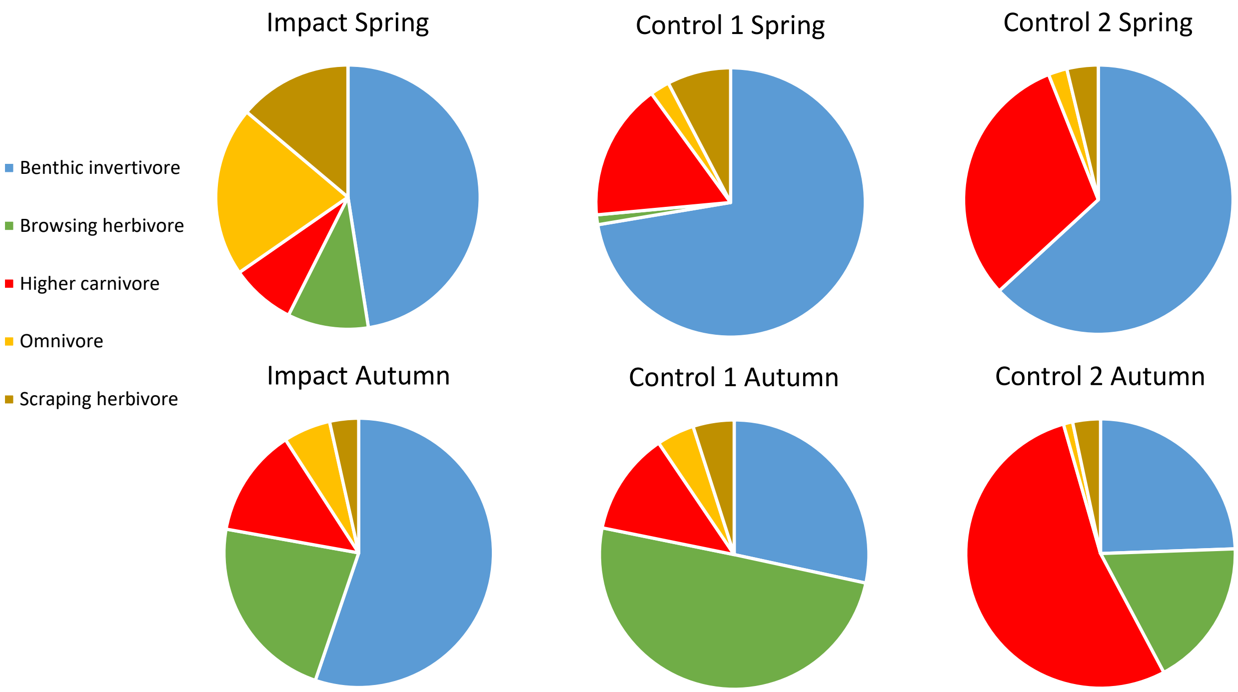

Figure 6. Proportion of fish in various functional groups observed at the Impact and control sites in spring 2018 and autumn 2019.

At the Impact site, the most abundant of families was the monocanthidae comprising around 25% of families at the Impact site. There were seasonal changes in abundance for families of carangidae (i.e trevally, higher in autumn), mullidae and sillaginidae (i.e red mullet and King George and southern school whiting higher in spring, Figure 7). At the control sites, monocanthidae both increased in autumn while Arripidae (Australian herring) were particularly present at Control site 2. Control site 2 also had the highest instance of Polybiidae (common sand crab, Figure 7)

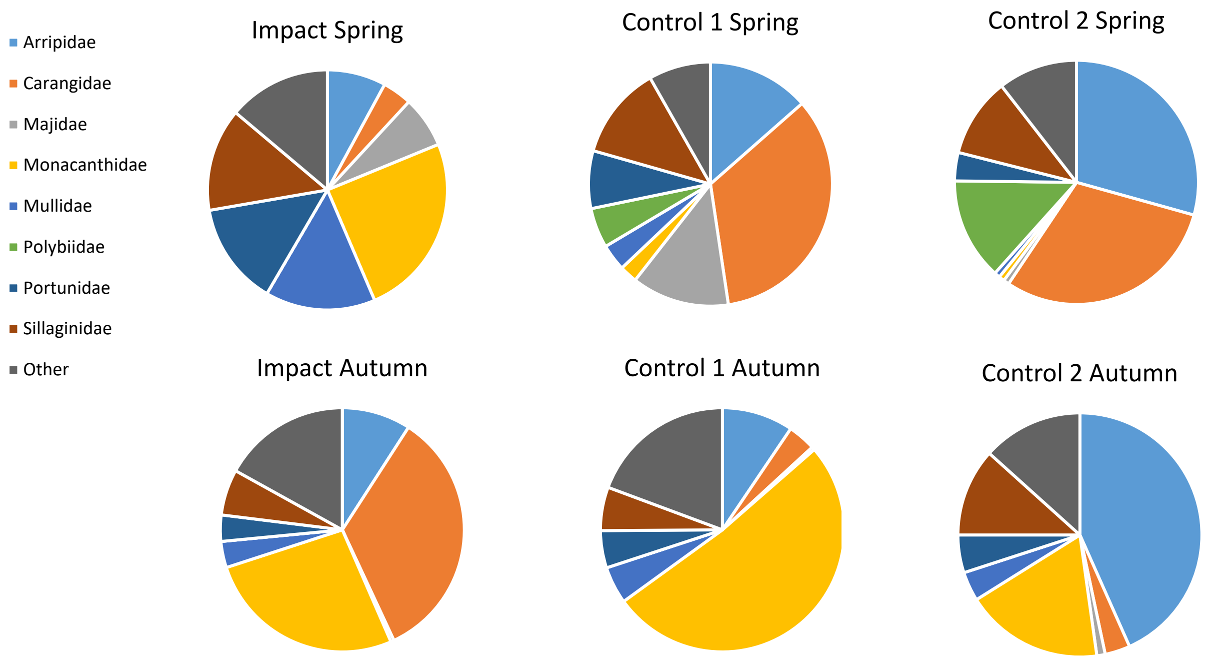

Figure 7. Proportion of species families at the Impact and control sites in spring 2018 and autumn 2019.

3.3.2 Comparison of fish communities across all sites

Fish and mobile invertebrate communities across sites reflected their geographic proximity, with the proposed Impact site and its neighbouring Control site 1 appearing more similar to one another than the more distant Control site 2 (Figure 8). Control site 2 is located in a separate bay from the Impact and Control site 1 so is expected to have a slightly different suite of environmental influences. This is apparent in the higher degree of overlap seen in points from those sites relative to the east Control. Statistical analyses using PERMANOVA found that differences exist both between sites and seasons (Table 6.A) and a pairwise comparison (Table 6.B) suggests this was true for comparisons of all sites in both spring and autumn with exception of the Impact site and Control site 1 in March (autumn).

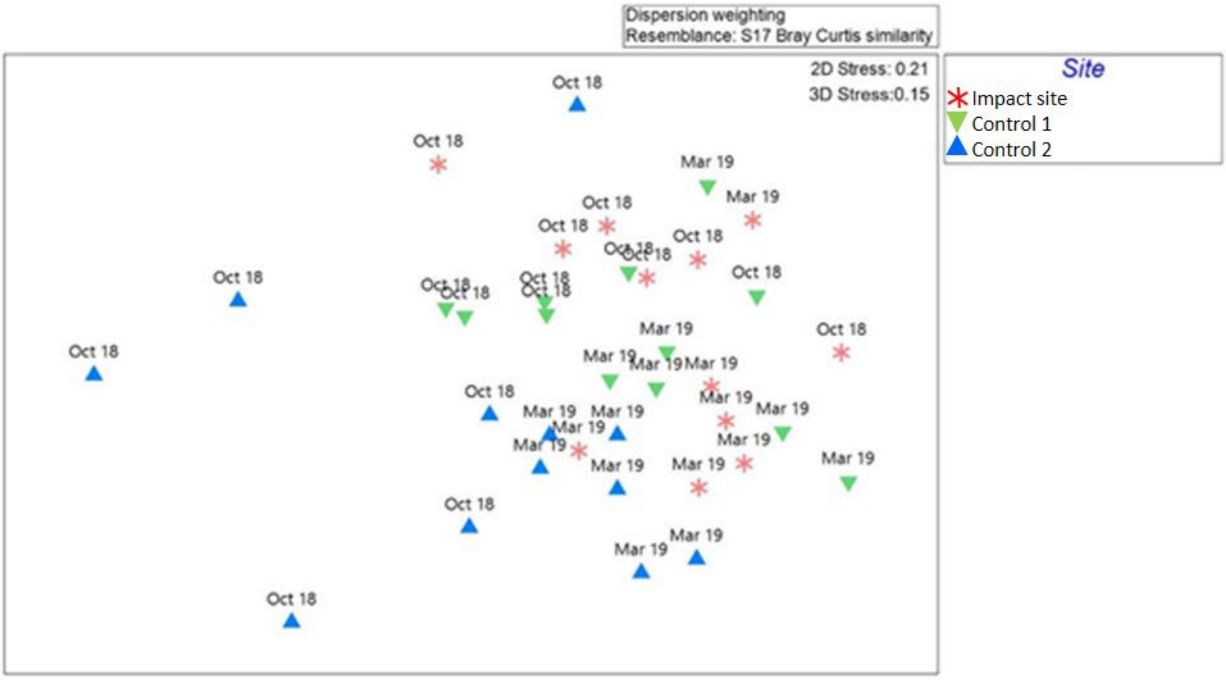

Figure 8. Non-metric multidimensional scaling (nMDS) ordination based on Bray-Curtis dissimilarities of fish and mobile invertebrate assemblages captured on BRUVS at Penneshaw Impact and control sites.

Table 6.A) Two-way permutational multivariate analysis of variance (PERMANOVA) based on Bray-Curtis dissimilarities of fish and invertebrates captured on BRUVS at Penneshaw (Impact) and control sites. B) Pairwise tests for each site x site and season.

A)						
Source	**df**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**perms**
Site	2	9632.6	4816.3	2.8585	**0.0002**	9923
Season	1	12579	12579	7.4658	**0.0001**	9925
Site x Season	2	8584.1	4292	2.5473	**0.0006**	9903
Res	30	50548	1684.9			
Total	35	81344				
B)						
	October 2018			**March 2019**		
	t	**P(perm)**	**Unique Perms**	**t**	**P(perm)**	**Unique Perms**
Penneshaw Impact, Penneshaw Control 1	1.6618	**0.0017**	462	1.2293	0.1368	462
Penneshaw Impact, Penneshaw Control 2	1.7204	**0.0072**	462	1.4561	**0.0295**	462
Penneshaw Control 2, Penneshaw Control 1	1.8106	**0.0029**	462	1.7943	**0.0102**	462

Overall the fish and mobile invertebrate assemblages at the three sites appeared heterogenous/variable (Table 7) except perhaps for Control site 1 in spring and Control site 2 in Autumn. Control site 2, however, was found to be most variable of all in spring (October). Similarity between sites was also lowest in spring, particularly for comparisons with Control site 2.

Table 7. Similarity within and between sites for both seasons (high values indicate homogeneity with values <50 being relatively heterogeneous). Bold values indicate within site similarity.

Average Similarity between/within sites			
October 2018	Penneshaw Impact	Penneshaw Control 2	Penneshaw Control 1
Penneshaw Impact	**40.73**		
Penneshaw Control 2	20.27	**22.476**	
Penneshaw Control 1	40.565	26.368	**56.696**
March 2019	Penneshaw Impact	Penneshaw Control 2	Penneshaw Control 1
Penneshaw Impact	**44.869**		
Penneshaw Control 2	43.826	**51.572**	
Penneshaw Control 1	44.411	41.524	**48.894**

3.3.3 Diversity

Overall, six broad taxonomic groups were identified including a range of bony fish species, sharks, crustaceans, a cephalopod (southern calamari) and an echinoderm (sea urchin, Table 8). In total, there were 39 individual species identified. Seventeen species were common to all three sites. Four species were unique to Control site 1, 7 species were unique to Control site 2 and 5 were unique to the Impact site (Figure 9; See Appendix 4 for a full species list).

Table 8. Number of taxa per broad taxonomic grouping.

Broad taxonomic group	Impact site	Control site 1	Control site 2
Sharks	0	0	2
Rays	0	1	0
Bony fishes	25	22	20
Crustacean	1	2	3
Cephalopods	1	1	1
Echinoderm	0	0	1

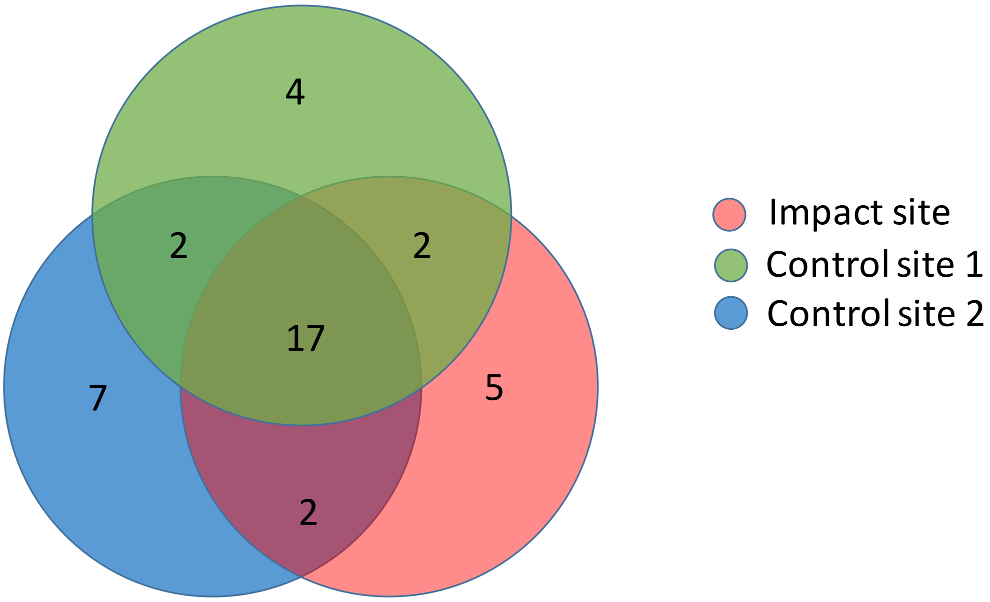

Figure 9. Venn diagram showing species overlap between Impact and control sites.

Control site 2 had the highest number of identified species overall (a total of 28 species across both sampling seasons; 20 in autumn 20, in spring). Control site 1 and the Impact site both recorded a total of 26 species across both seasons. The highest number of species observed in one season was at the Impact site with 23 species observed in autumn. Species abundance was higher in autumn for both the Impact site and Control site 1 but was the same each season for Control site 2 (Figure 10). There were some differences in the species seen at each site between seasons. (See Appendix 4 for full results).

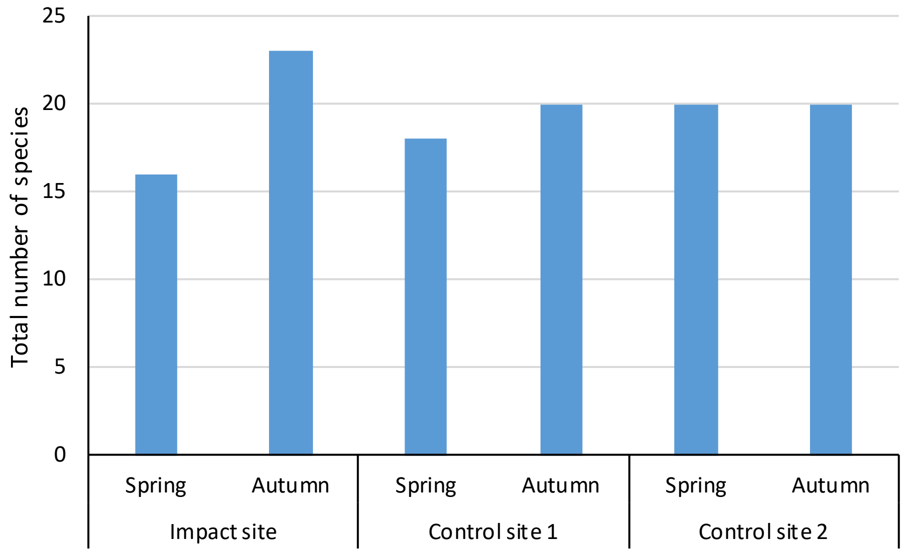

Figure 10. Total number of fish and mobile invertebrate species observed in autumn and spring at each site.

3.3.4 Overall fish and mobile invertebrate abundance

Total combined abundance of fish and mobile invertebrates varied seasonally at all sites with higher numbers observed in autumn than spring (Figure 11). This is particularly true for the Impact site which provided the largest difference with more than twice the abundance in autumn. This difference was due to the number of trevally recorded. Trevally are a schooling species which can heavily impact MaxN/abundance if a large school aggregates in the bait plume from the BRUVS. The seasonal difference at both control sites is attributed to leatherjacket species.

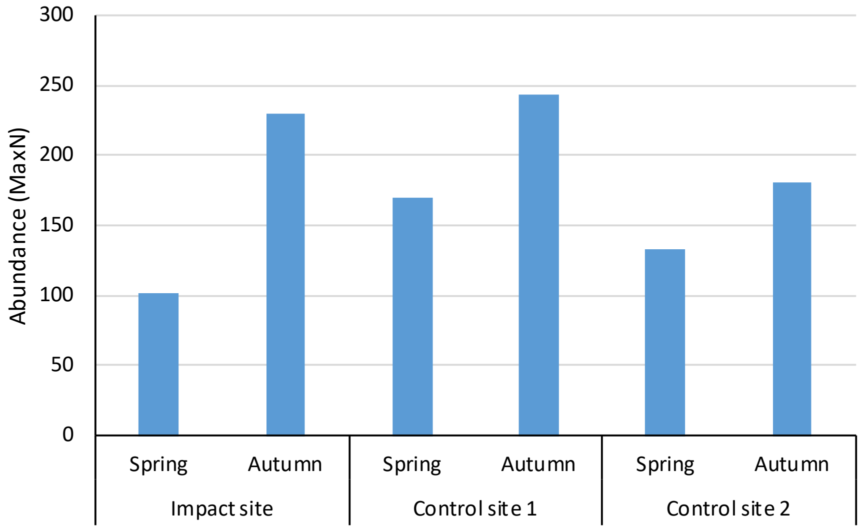

Figure 11. Total number of fish and mobile invertebrates (MaxN) observed in autumn and spring at each site.

3.3.5 Fish size

The Impact site averaged the highest number of fish over 200mm across both seasons (20 in autumn, 21 in spring). Control site 2 had the highest number of fish over 200mm observed in a season with 30 recorded in spring. Control site 2 also had the lowest seasonal number of fish over 200mm in autumn recording a total of 9 (Figure 12). Species observed exceeding 200mm included snook, trevally, King George whiting, southern school whiting, southern bluespotted flathead, southern calamari, rough leatherjackets, bronze whaler shark and fiddler rays. For more information on fish size see Appendix 5.

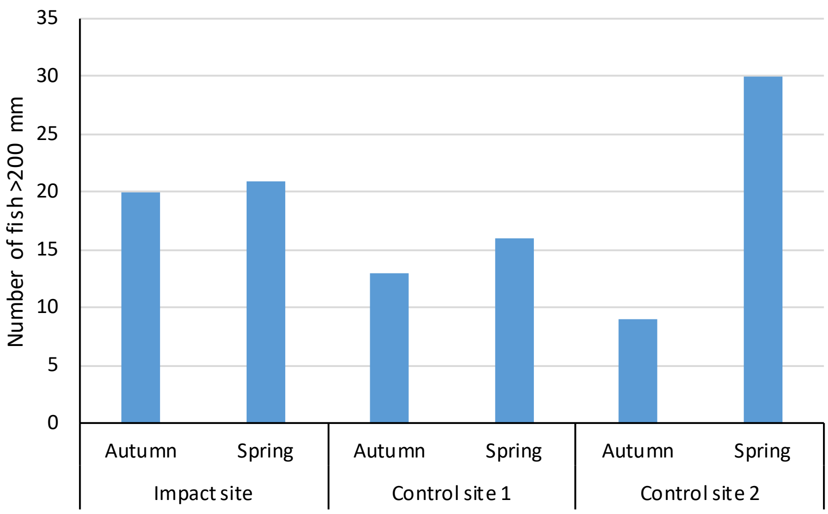

Figure 12. Number of fish larger than 200mm recorded at each site.

4 Discussion

4.1 Impact and Control Site biological characteristics

The proposed outfall site at Penneshaw is an open coastline with relatively good tidal movement and it is expected that the hypersaline discharge from the outfall will be dispersed quickly. Modelling and studies from other sites suggest that target dilution is achieved in a relatively short distance (10s to <100m) from the discharge site (Clark *et. al.* 2018, Roberts *et. al.* 2009, Sadeghian 2019). This expectation guided the design of this study, in particular, the size and location of the Impact and two control sites. The extent of the study sites (500m x 250m) will encompass the area where elevated salinity is expected to occur while the control sites are more than adequate distances from the Impact site to be outside of this potential impact area.

This project aimed to describe (and set a baseline) for benthic habitats and associated fish communities present at the proposed Penneshaw desalination plant outfall site and two control sites for comparison. The information collected over two seasons (spring 2018 and autumn 2019) provides a baseline against which any future changes resulting from the desalination outfall at the Impact site can be assessed. This report also outlines the recommended approach for ongoing monitoring of the site should the desalination plant commence operation.

This study found that the proposed Impact site and two controls were primarily seagrass and sand habitats with *Posidonia* being the dominant habitat forming species. The Impact site had on average almost twice as much *Posidonia* cover as the two control sites, while *Zostera tasmanica* made up a significant proportion of the seagrass habitat at the two control sites but was absent at the Impact site. *Posidonia* are a late successional species that can take years to recover once disturbed and will need to be considered in the context of any construction associated with the outfall.

Consistent seasonal differences in seagrass cover were detected with seagrass cover lower in spring than in autumn sampling. This is typical of seagrass habitats where species such as *Posidonia* are known to shed leaves (above ground biomass) during the winter months when day length and sun angles make light less available. This factor needs to be taken into account in future analysis as the Impact site has a higher proportion of *Posidonia* habitat.

Fish communities were diverse with a mix of species typical to seagrass/sand habitats and a number of more mobile species. In general fish assemblages were variable in both time and space with differences detected both seasonally and between sites, with the exception of the Impact site and Control site 1 in autumn. Fish associated with seagrass communities are often highly mobile with large home ranges (e.g. trevally), migration patterns or seasonal inshore/offshore movements (e.g. King George whiting) which can result in variable assemblages at any point in time. This may make detection of small changes over time difficult. The detection of seasonal differences implies that seasonal sampling should be continued however it should be noted that if only one season is chosen for ongoing monitoring it should be autumn as fish communities were less variable at this sampling time.

4.2 Ongoing Monitoring

The habitat and fish assessment methods used in this study (towed video with high definition stills and BRUVS) are recommended for the ongoing monitoring program in the event of construction of the desalination plant. Several standard ecological metrics can be derived from the data collected by these methods including the following;

- Benthic habitat cover and composition
- Fish community structure
- Fish abundance and size distribution
- Diversity indices

These metrics are commonly used to detect changes in benthic habitats (including macroalgal and seagrass communities) and fish assemblages and information collected by repeat surveys using these methods will generate datasets suitable for assessing the potential impacts of hypersaline discharges on ecological communities in the area.

The way the baseline data collection has been designed and the type of data collected will enable a range of biological characteristics to be assessed at different temporal and spatial scales. While there were differences detected in the habitats and fish assemblages between the Impact and control sites, it is any unusual change within the Impact site (e.g. loss of seagrass, dramatic change in fish species) relative to the control sites that is of interest here.

It is recommended where practicable to repeat the surveys as soon as possible post construction and then annually for three years and at the five year post construction mark. Given the seasonal variation in fish communities it is recommended to include seasonal sampling as part of the ongoing monitoring program, however, the frequency and timing of repeat surveys will depend somewhat on the legislated requirements specified for the construction and post operation phase in the development application.

5 Appendices

Appendix 1. Post hoc analysis of total seagrass cover.

	diff	**lwr**	**upr**	**p adj**
Spring:Control 1 X Autumn:Control 1	-0.07275	-0.23119	0.085678	0.775306
Autumn:Control 2 X Arc Autumn:Control 1	-0.02223	-0.18066	0.136206	0.998633
Spring:Control 2 X Arc Autumn:Control 1	-0.06564	-0.22408	0.092789	0.84214
Autumn:Impact X Autumn:Control 1	0.406635	0.248203	0.565068	**2.80E-11**
Spring:Impact X Autumn:Control 1	0.231585	0.073152	0.390017	**5.18E-04**
Autumn:Control 2 X Spring:Control 1	0.050529	-0.1079	0.208961	0.942514
Spring:Control 2 X Spring:Control 1	0.007112	-0.15132	0.165544	0.999995
Autumn:Impact X Spring:Control 1	0.47939	0.320958	0.637823	**7.58E-13**
Spring:Impact X Spring:Control 1	0.304339	0.145907	0.462772	**1.16E-06**
Spring:Control 2 X Autumn:Control 2	-0.04342	-0.20185	0.115015	0.96973
Autumn:Impact X Autumn:Control 2	0.428861	0.270429	0.587294	**2.80E-12**
Spring:Impact X Autumn:Control 2	0.25381	0.095378	0.412243	**9.33E-05**
Autumn:Impact X Spring:Control 2	0.472278	0.313846	0.630711	**7.65E-13**
Spring:Impact X Spring:Control 2	0.297227	0.138795	0.45566	**2.24E-06**
Spring:Impact X Autumn:Impact	-0.17505	-0.33348	-0.01662	**0.020737**

Appendix 2. ANOVA analysis of epiphyte rating between site and season.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0.061622	2	0.030811	4.865354	**0.008354**	3.027111
Columns	0.337895	1	0.337895	53.35712	**2.74E-12**	3.87395
Interaction	0.706543	2	0.353272	55.78524	**3.33E-21**	3.027111
Within	1.82382	288	0.006333			
Total	2.92988	293				

Appendix 3. Post hoc analysis of epiphyte rating between site and season.

	diff	lwr	upr	p adj
Spring...3:Control 1 X Autumn...2:Control 1	-0.101284431	-0.147410224	- 0.055158638	**1.66E-08**
Autumn...2:Control 2 X Autumn...2:Control 1	-0.050939522	-0.097065315	- 0.004813729	**0.020842**
Spring...3:Control 2 X Autumn...2:Control 1	0.014525322	-0.031600471	0.060651115	0.945408262
Autumn...2:Impact X Autumn...2:Control 1	0.036953455	-0.009172338	0.083079248	0.198012839
Spring...3:Impact-Autumn...2:Control 1	-0.130635184	-0.176760977	- 0.084509391	**8.38E-13**
Autumn...2:Control 2 X Spring...3:Control 1	0.050344908	0.004219115	0.096470701	**0.02334559**
Spring...3:Control 2 X Spring...3:Control 1	0.115809753	0.06968396	0.161935546	**7.79E-11**
Autumn...2:Impact X Spring...3:Control 1	0.138237886	0.092112092	0.184363679	**6.39E-13**
Spring...3:Impact X Spring...3:Control 1	-0.029350753	-0.075476546	0.01677504	0.450907248
Spring...3:Control 2 X Autumn...2:Control 2	0.065464845	0.019339052	0.111590638	**8.48E-04**
Autumn...2:Impact X Autumn...2:Control 2	0.087892977	0.041767184	0.13401877	**1.48E-06**
Spring...3:Impact X Autumn...2:Control 2	-0.079695662	-0.125821455	- 0.033569869	**1.80E-05**
Autumn...2:Impact X Spring...3:Control 2	0.022428132	-0.023697661	0.068553926	0.730053944
Spring...3:Impact X Spring...3:Control 2	-0.145160506	-0.191286299	- 0.099034713	**6.31E-13**
Spring...3:Impact X Autumn...2:Impact	-0.167588639	-0.213714432	- 0.121462846	**6.28E-13**

Appendix 4. Raw BRUVS data showing the full list of species and sum of MaxN (Abundance).

	Impact site			Control 1			Control 2			Grand total
Common Name	**Autumn**	**Spring**	**Total**	**Autumn**	**Spring**	**Total**	**Autumn**	**Spring**	**Total**	
Australian herring	21	8	29	18	23	41	58	34	92	162
Barred toadfish	1		1			0			0	1
Blue swimmer crab			0			0	3		3	3
Blue weed whiting	1	4	5			0		1	1	6
Bluethroat wrasse	1	2	3		1	1			0	4
Boxfish unidentified	1		1			0			0	1
Bronze whaler			0			0	1		1	1
Brownspotted wrasse	1	2	3	1	1	2	1	2	3	8
Carcharhinidae sp			0			0		1	1	1
Common sand crab			0		9	9		18	18	27
Degen's leatherjacket	2		2			0			0	2
Dusky morwong			0			0		1	1	1
Fiddler ray			0	3		3			0	3
Flounder sp			0			0		1	1	1
Great spider crab	1	7	8	1	22	23	2	1	3	34
Horseshoe leatherjacket			0		1	1			0	1
King George whiting	14	13	27	14	12	26	14	6	20	73
Leatherjacket sp	51	7	58	119	1	120	31		31	209
Longsnout boarfish		1	1	1		1			0	2
Old wife	1		1			0			0	1
Ornate cowfish	1		1	5	1	6	1		1	8
Prickly toadfish			0	1		1			0	1
Red mullet	8	15	23	12	6	18	7	1	8	49
Ringed toadfish			0		1	1			0	1
Rough leatherjacket	1	3	4	2		2	1		1	7
Rough rock crab	8	14	22	12	13	25	6	5	11	58
Sea urchin Sp			0			0	1		1	1
Shaw's cowfish	2		2			0			0	2
Slender weed-whiting	1		1	1		1			0	2
Smooth toadfish			0			0		1	1	1
Snook	6		6	4	1	5	6		6	17
Southern bluespotted flathead	3		3	3	4	7	6	1	7	17
Southern calamary	6	2	8	1	3	4	1	1	2	14
Southern school whiting		1	1		9	9	7	8	15	25
Southern silverbelly	10	1	11	20		20	6	4	10	41
Spinytail leatherjacket		15	15		2	2		1	1	18
Toothbrush leatherjacket	7		7	4		4	1		1	12
Trevally	78	4	82	9	58	67	1	40	41	190
Weedy whiting	4	2	6	6	2	8		1	1	15
Western Australian salmon			0	5		5	20	5	25	30
Wrasse sp			0	1		1	1		1	2
Yellowtail scad			0			0	5		5	5
Grand total	230	101	331	243	170	413	180	133	313	1057

Appendix 5. Average fish length per species.

Average of Length (mm)	Impact site		Control 1		Control 2	
Species	***Spring***	***Autumn***	***Spring***	***Autumn***	***Spring***	***Autumn***
Australian herring	160.02	158.57	115.76	138.82	113.47	134.24
Barred toadfish		170.70				
Blue weed whiting	235.69					
Bluethroat wrasse	130.42		146.07			
Boxfish unidentified		99.74				
Bronze whaler						1925.22
Brownspotted wrasse	129.35	270.51			238.76	
Degen's leatherjacket		178.28				
Dusky morwong					374.59	
Fiddler ray				748.72		
Flounder sp					244.45	
Horseshoe leatherjacket			279.86			
King George whiting	323.73	337.19	299.10	357.98	299.12	367.75
Leatherjacket sp	90.30	131.26		138.75		145.48
Longsnout boarfish	197.73					
Old wife		112.45				
Ornate cowfish		104.48	90.35	90.71		77.23
Prickly toadfish				146.36		
Red mullet	193.10	139.36	226.72	165.21	235.79	169.02
Rough leatherjacket	251.62			150.19		222.63
Shaw's cowfish		93.52				
Slender weed-whiting		104.59		60.98		
Snook		418.46	427.50	509.45		434.23
Southern bluespotted flathead		411.14	296.67	392.52		336.51
Southern calamary	172.52	236.16	161.08			362.07
Southern school whiting			155.40		174.34	224.96
Southern silverbelly	115.32	90.72		94.98		91.65
Spinytail leatherjacket	205.68		254.54		267.17	
Toothbrush leatherjacket		153.50		154.92		168.89
Trevally	116.60	131.29	126.98	280.48	103.19	144.89
Weedy whiting	137.67	119.22	92.21	88.81		
Western Australian salmon				161.84	234.42	195.33
Wrasse sp						164.45
Yellowtail scad						180.26

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