A baseline assessment of fish and benthic communities at a proposed desalination site, Sleaford Bay, Eyre Peninsula

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Acknowledgement 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. SA Water has identified that regional communities on the Eyre Peninsula will need to be supplemented with additional water production due to uncertainty around ground water reserves and increasing populations (SA Water 2008). SA Water proposed to build a desalination plant at Sleaford Bay on the Eyre Peninsula to ensure long term water security for this regional area. One of the proposed sites for this development was situated in the state's Thorny Passage Marine Park, adjacent to the Sleaford Bay Sanctuary Zone. While the location of the desalination plant was ultimately relocated, this report presents the findings from benthic habitat and fish communities surveyed in Sleaford Bay and surrounding areas in 2019.

While this site was under consideration, SA Water contracted the Department for Environment and Water (DEW) to conduct a preliminary assessment of the marine environment in the vicinity of the hypersaline outfall location of the proposed desalination plant. To do this, benthic habitats were characterised using towed video camera methods and fish assemblages were assessed using baited remote underwater video systems (BRUVS). Towed video / still cameras were used to create benthic habitat maps, while (BRUVS) were employed to capture fish and large mobile invertebrate assemblage data. The Impact site and two control sites were assessed.

Surveys of fish and benthic habitats were conducted in autumn and spring 2019. The habitat analysis revealed the Impact site contained about 50% bare substrate. Canopy forming macroalgae and the algal functional groups brown and red understory were the most prominent benthic habitat types contributing just over 40% cover of the site. Small amounts of seagrass (*Posidonia*, *Amphibolis.* and *Zostera tasmanica*), green understory, turfing algae and sessile invertebrates made up the remaining habitat cover. Control site 1 had a similar composition to the Impact site (slightly more canopy forming macroalgae and less brown and red understory), while Control 2 had less bare substrate and a higher percentage of total cover consisting primarily of canopy forming macroalgae.

A total of 2035 fish were counted, and 52 species identified during the 2019 monitoring. Results indicated that fish assemblages at the proposed outfall location (Impact site) site were primarily benthic invertivores (91% e.g. trevally, Southern school whiting, Blue throat wrasse) with higher carnivores (6% e.g. Australian herring), and browsing herbivores, omnivores and planktivores (3% combined e.g. leatherjacket spp, Sea sweep, Barber perch) making up the rest of the population structure. Control site 1 had a similar composition of species whereas Control site 2 differed in that it contained more browsing herbivores (35%) and less benthic invertivores (39%) than the other two sites.

Control site 1 contained the highest abundance of fish (1038) and was dominated by large schools of trevally. This site also contained high numbers of Australian herring, Bluethroat wrasse and leatherjacket species, but had the lowest species diversity (28). The Impact site had the second highest abundance (566) and was also dominated by trevally species, Southern school whiting, Blue throat wrasse, and Australian herring. The Impact site contained 31 species. Control site 2 had the highest number of species unique to its site and the highest amount of fish species (36) but had the lowest abundance (431). Control site 2 was dominated by leatherjacket species as well as Barber perch and Bluethroat wrasse. This difference in fish communities between Control site 2 and the other sites is likely due to its slightly different habitat composition.

The report provided a baseline assessment of fish and plant communities in the direct area of the proposed outfall as well as similar surrounding areas and was to be used to assess any potential future changes to the aquatic ecosystems. While the desalination plant was relocated the report still provides important baseline information for the Thorny Passage Marine Park and surrounding areas that can be used in temporal assessments of benthic habitat and fish communities in the future.

1 Background

1.1 Introduction

The majority of freshwater for human use on the Eyre Peninsula comes from 54 bores drawing water from underground basins. Population and industry continue to grow in this region placing increasing pressure on the water supply. In addition, there have been a number of low rainfall years resulting in low recharge of the groundwater supply. To ensure future water security for the townships of the Eyre Peninsula, a seawater desalination plant was proposed for construction in Sleaford Bay. As part of the development application process, SA Water 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 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. This work was completed in 2020 and while the proposed site of the desalination plant was relocated away from this site in Sleaford Bay, the research contains important baseline information on benthic habitats and fish communities in the Thorny Passage Marine Park and surrounding areas and is presented in this report.

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 critical to minimise ecological impacts and monitoring is required to assess what impacts are occurring (Roberts et al. 2010, Clark et al. 2018).

The proposed desalination plant was to extract sea water from Sleaford Bay, south of Lincoln National Park and have an operational capacity of around 4GL/year. The site was to be operated in combination with a bulk water storage facility located 14km from the plant to assist in maintaining water security for the region. It will also be situated in the state's Thorny Passage Marine Park, and will be situated adjacent to the Sleaford Bay Sanctuary Zone (SZ-8, Figure 1). Sleaford Bay's close proximity to the existing water supply network, strong ocean currents that minimise environmental impact, and ready accessibility to electricity and transport infrastructure made this site a suitable location.

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 Sleaford Bay outfall site. This data would have assisted in plant design, to minimise any potential impacts to the marine environment from construction and operation of the desalination plant, and forms a baseline to compare operational performance. The objectives of this project were:

1. Design a Before-After, Control-Impact (BACI) monitoring program to assess the potential impact of the desalination outfall on benthic habitats and fish assemblages at the Sleaford Bay site.

2. Document the benthic habitats and associated fish communities at the outfall site (impact) and two nearby comparative sites (controls) in spring and autumn 2019.

3. 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 proposed desalination plant outfall was at a depth of 10m, 2km from the shore in Sleaford Bay on the southern tip of the Eyre Peninsula (Figure 1 inset). The benthic habitats of the general Sleaford Bay area are characterised by sparse seagrass meadows, sand, and patchy low to medium profile reef at depths of 5-20m (Figure 1, DEW 2019). The proposed outfall area is adjacent the Sleaford Bay Sanctuary Zone within the Thorny Passage Marine Park (Figure 1).

Ambient salinity at the outfall site is reported at 35.5 g/l. The desalination plant outfall site was subject to water quality criteria that should achieve a dilution rate of 40:1 above ambient salinity within a certain radius. Near and far field modelling results showed that target dilution is 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 0.52 g/l and disperse to 0.1-0.2 g/l within a few hundred meters depending on currents and plant size (Sadeghian 2019). Therefore the impact of the outfall from the proposed plant was likely to extend less than 100m from the outfall before falling within normal ambient salinity fluctuations as observed with other desalination plants in Australia (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 site 1 measured approximately 500m by 250m which encompassed the expected radius of impact from the hypersaline discharge. Finding an accessible analogous second Control site proved difficult and as a result Control site 2 comprised of two neighbouring shoals of similar total area.

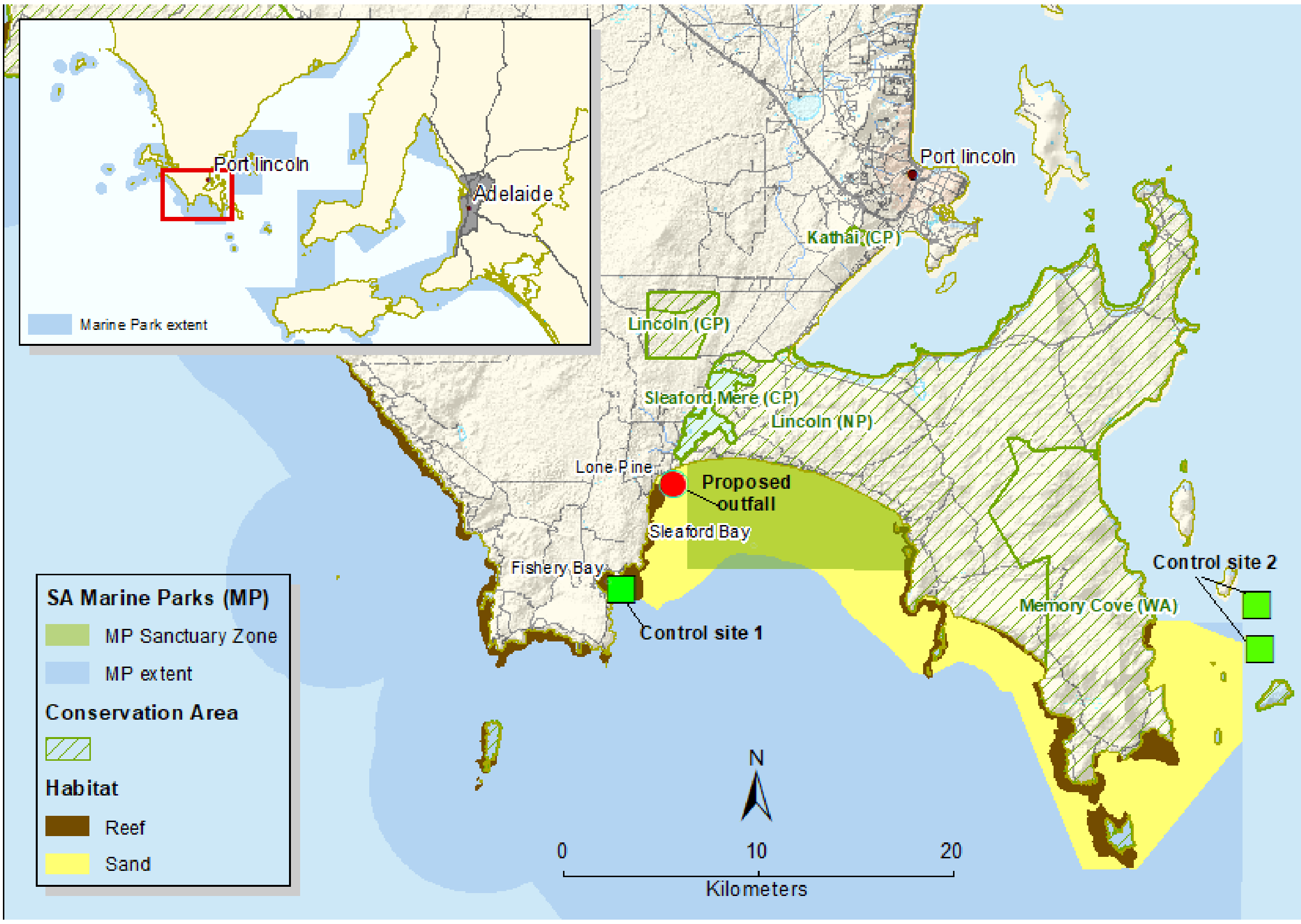


Figure 1. Map showing the location of Control and Impact (Proposed outfall) monitoring sites.

2.2 Benthic habitat monitoring

Towed video was used to characterise benthic habitats at each of the three study locations (Impact Site, Control sites 1 and 2, Figure 2 Figure 3 Figure 4). Surveys were carried out at the 3 sites during autumn and spring of 2019. 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 characterise the recorded habitats. Each image, five sample points were overlayed on each image and scored to provide an overall percent cover (based on a total of 50 points) of each habitat classification for each drift transect. Biota were scored using "Functional groups" (Table 1) loosely based on the CATAMI classification system (Collaborative and Annotation Tools for Analysis of Marine Imagery; Althaus et al. 2013).

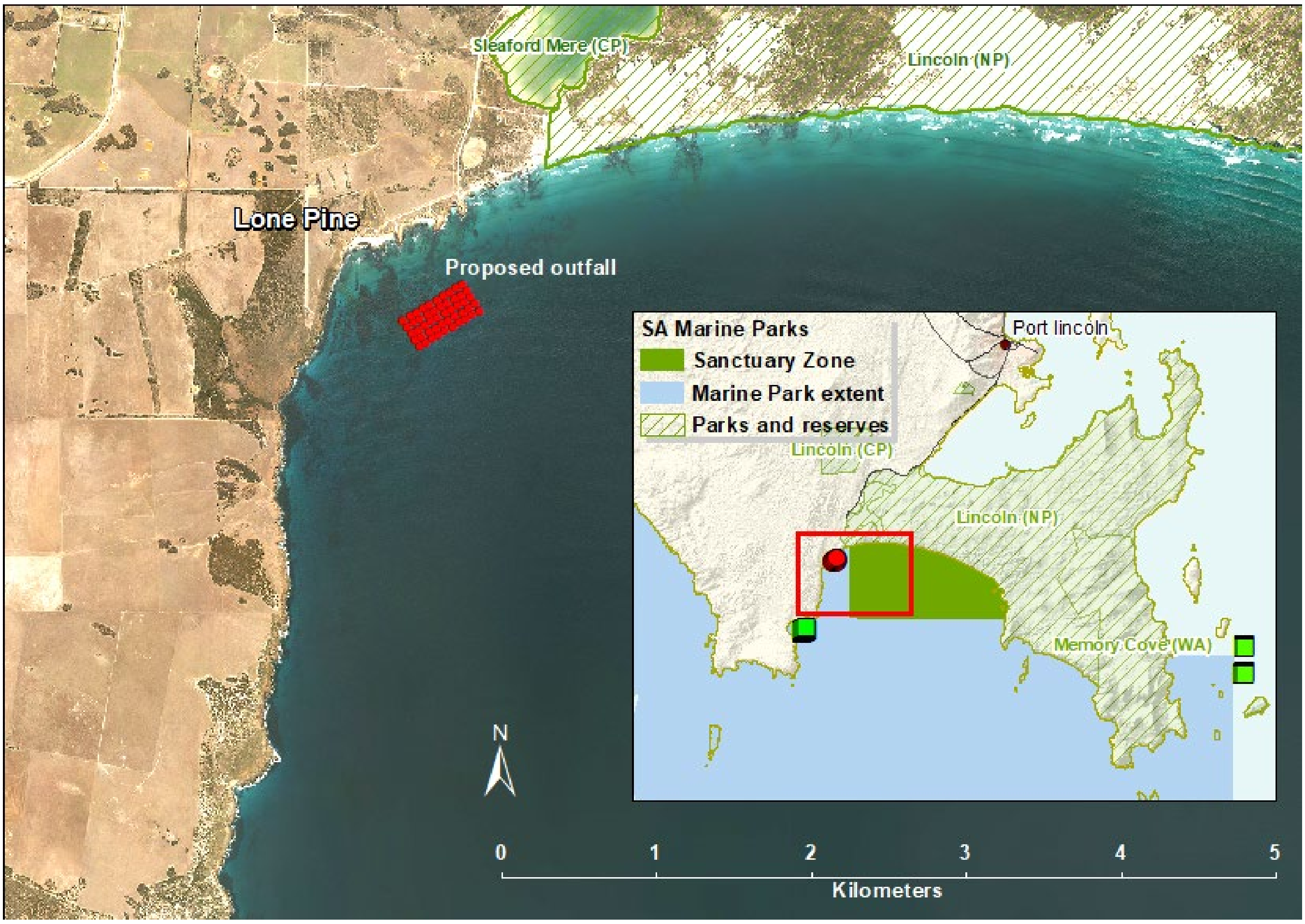


Figure 2. Satellite image showing the location and orientation of towed camera samples at the Impact site at Sleaford Bay.

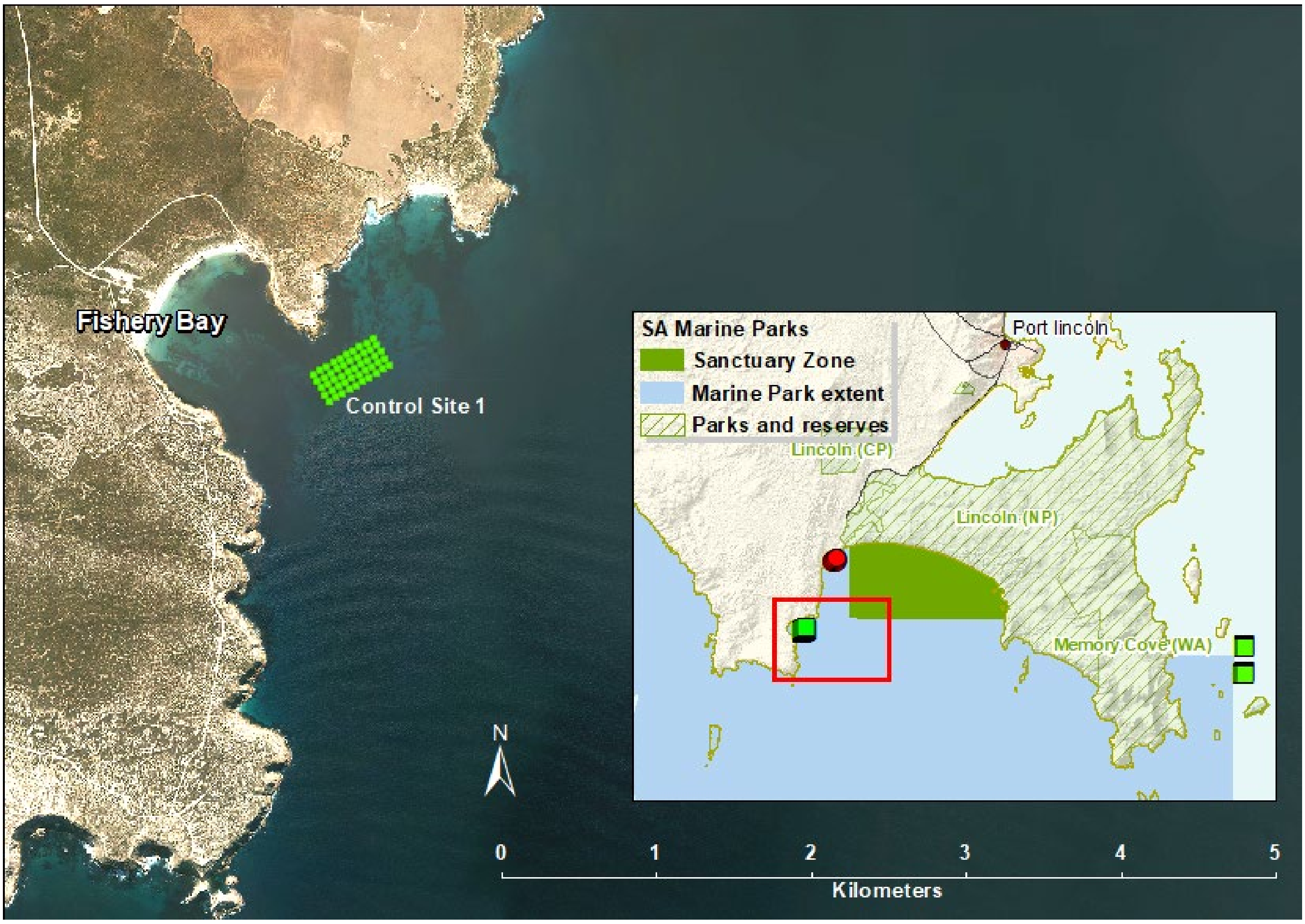


Figure 3. Satellite image showing the location and orientation of towed camera samples at Control site 1 outside of Fishery Bay.

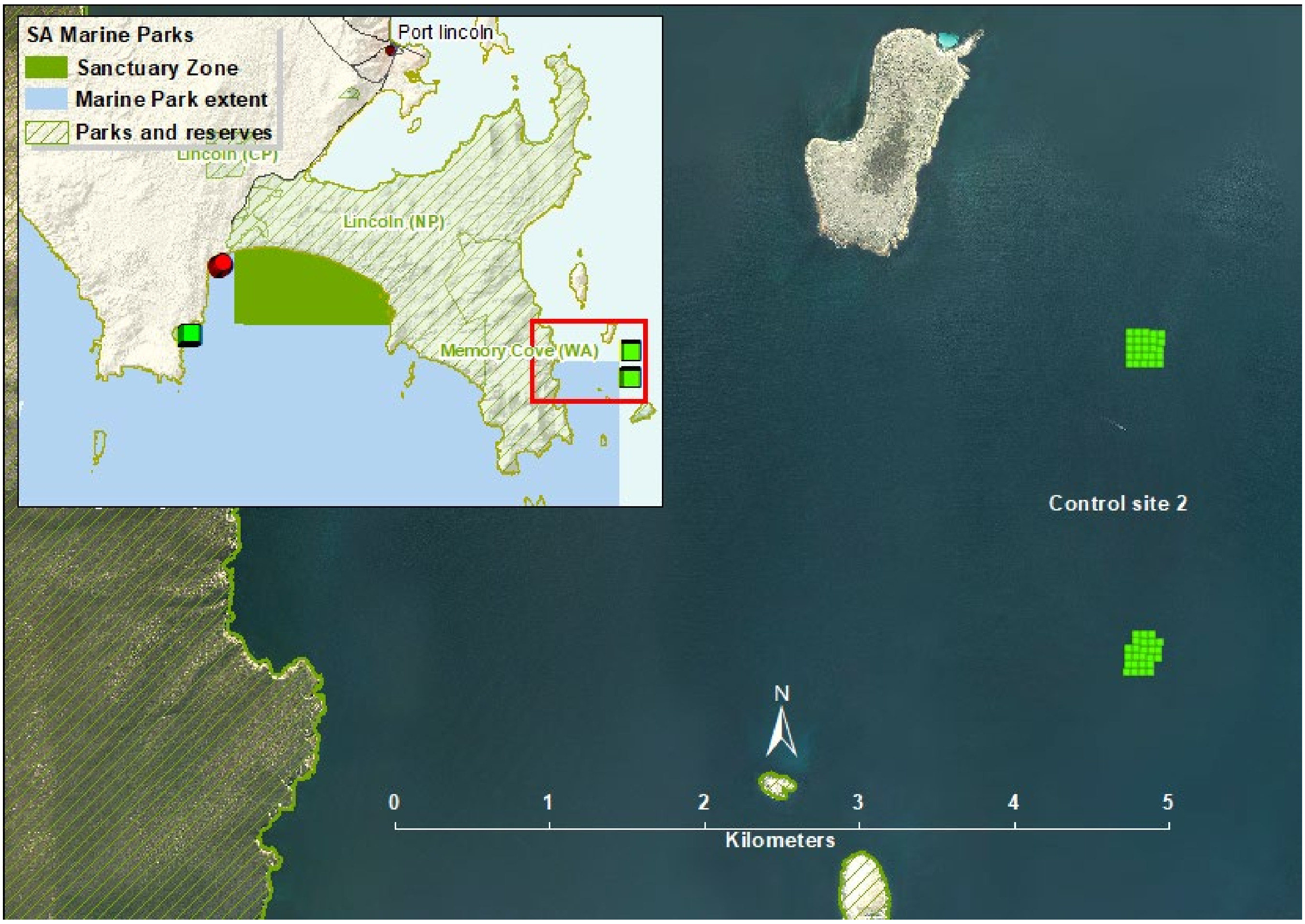


Figure 4. Satellite image showing the location and orientation of towed camera samples at Control site 2 which was split between Doolan and Harrison shoals.

Table 1. Habitat type classifications assigned to functional groups.

Functional group	**Habitat**
Canopy	Canopy forming brown algae including erect coarse branching and large canopy forming species
Brown understory	Brown understory macroalgae including laminate, sheetlike, filamentous, fine branching, and saccate species
Green Understory	Green understory macroalgae including laminate, sheetlike, filamentous, branching, and saccate species
Red understory	Red understory macroalgae including laminate, sheetlike, filamentous, branching, saccate and articulated calcareous species
Seagrass	*Halophila*, *Zostera tasmanica*, *Amphibolis* & *Posidonia* seagrasses
Turf	Turfing macroalgae
Animal	Sessile & mobile invertebrates
Bare	Sand

2.3 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 Park Network (DEWNR 2017).

Six replicate BRUVS drops were undertaken at each site with each BRUVS unit separated by 150-200m in autumn and spring 2019 (Figure 5). Depths ranged from 7-18m.

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. Six replicate sample videos were collected at each of the three sites (Figure 5). 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 refer to Miller et al. (2017).

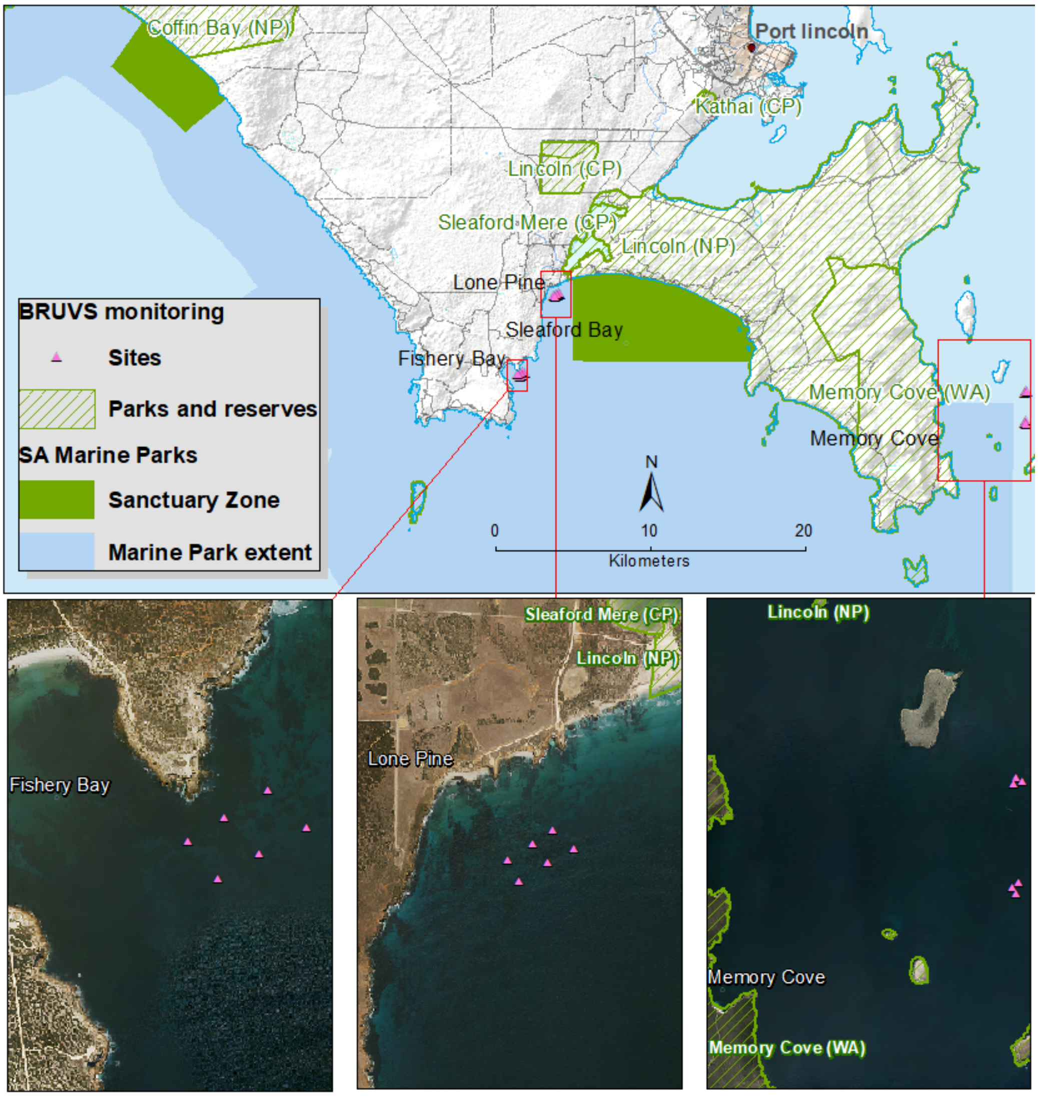


Figure 5. Clustered pink triangles indicating the 6 BRUVS drops at each of the three sampling sites.

2.4 Analysis and Change Detection

It was anticipated that these sites would be monitored over time to assess any potential impacts of hypersaline discharge. 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/biomass of fish) while change in community structure over time can be assessed using multivariate techniques.

In this “baseline” survey, diversity and abundance metrics were calculated and the community structure of fish and habitats were assessed using multivariate statistical techniques to display species and habitat type 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 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 scale (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 Benthic Habitats

3.1.1 Community structure

At the Impact site, bare sand was the dominant habitat type across both monitoring seasons accounting for more than half the cover (Figure 6). At this site, just over 40% of cover was algae (on reef, turf, red, green and brown understory) for both seasons with about 15% of that being made up of canopy forming species. The remainder (<10% total) was a mix of seagrasses (*Posidonia*, *Amphibolis, Zostera tasmanica* and *Halophila*) and sessile invertebrates (animal).

Control site 1 also had more than 50% bare substrate compared to Control site 2 where bare substrate was <15%. The proportion of functional groups across the 3 sites suggests that while Control site 2 was dominated by canopy forming brown algae, the Impact and Control site 1 more closely resembled one another having more diverse biotic cover (Figure 6). Brown algae (canopy and brown understory) was the dominant cover at all sites accounting for between 37 and 88%. Canopy forming macroalgae was significantly higher at Control site 2 where it accounted for over 87% cover at this site (Figure 6). Control site 2 also contained less green, brown and red understory and no seagrass was present. The Impact site contained slightly more brown and red understory than Control site 1 and slightly less brown understory. *Amphibolis* was the most common seagrass cover averaging 2% of the habitats in the Impact site and 3.6% of the habitats in Control site 1. Turfing algae and invertebrates made up only a minor part of all three habitat sites (Figure 6, Appendix A, B).

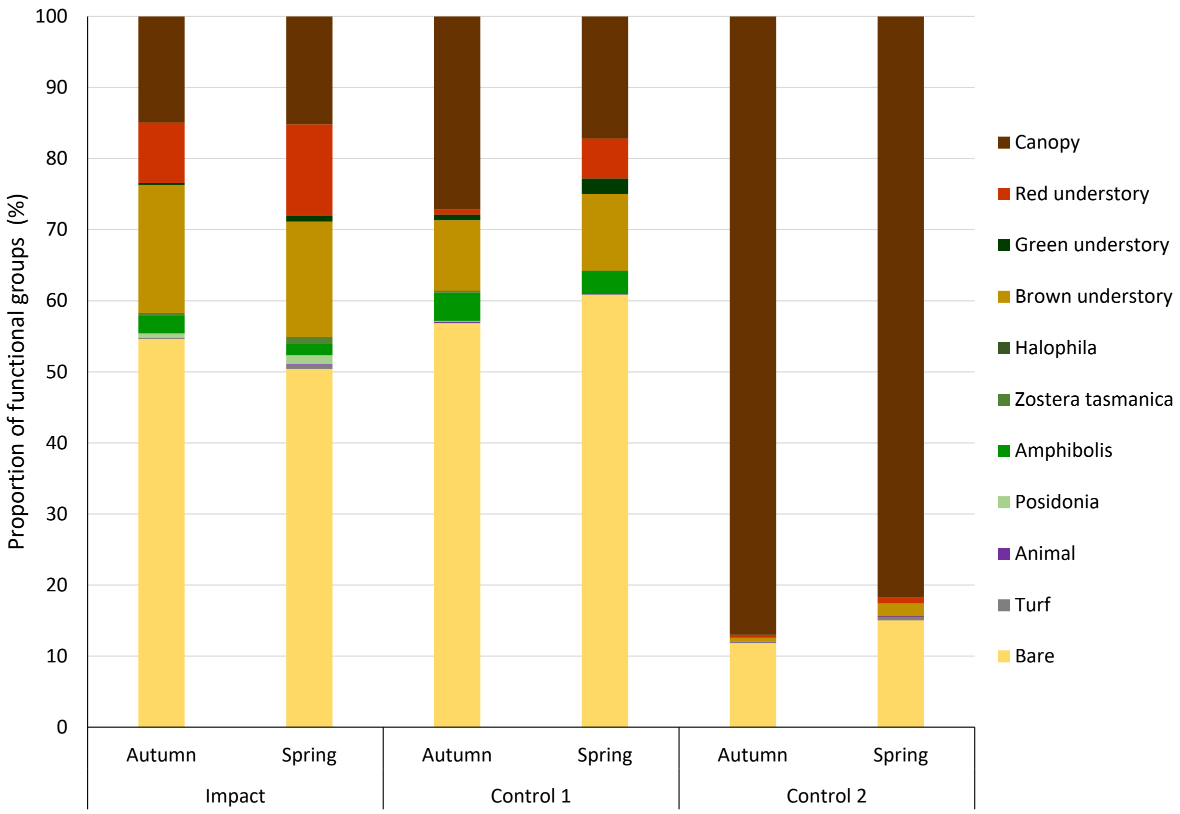


Figure 6. Percent benthic habitat cover at the Impact site and the two control sites in autumn and spring 2019.

Multivariate ordination of the habitat data broadly indicates that habitats at the Impact site and Control site 1 are more similar to each other in habitat structure than Control site 2 located in Thorny Passage (Figure 7). Points from the Impact site are broadly distributed across the ordination space suggesting heterogeneity among habitats at this site. Control site 1 also appears similarly heterogeneous, while Control site 2 displays tighter clustering of points in the ordination plot suggesting this site is more homogenous and likely has different habitat characteristics to the Impact site.

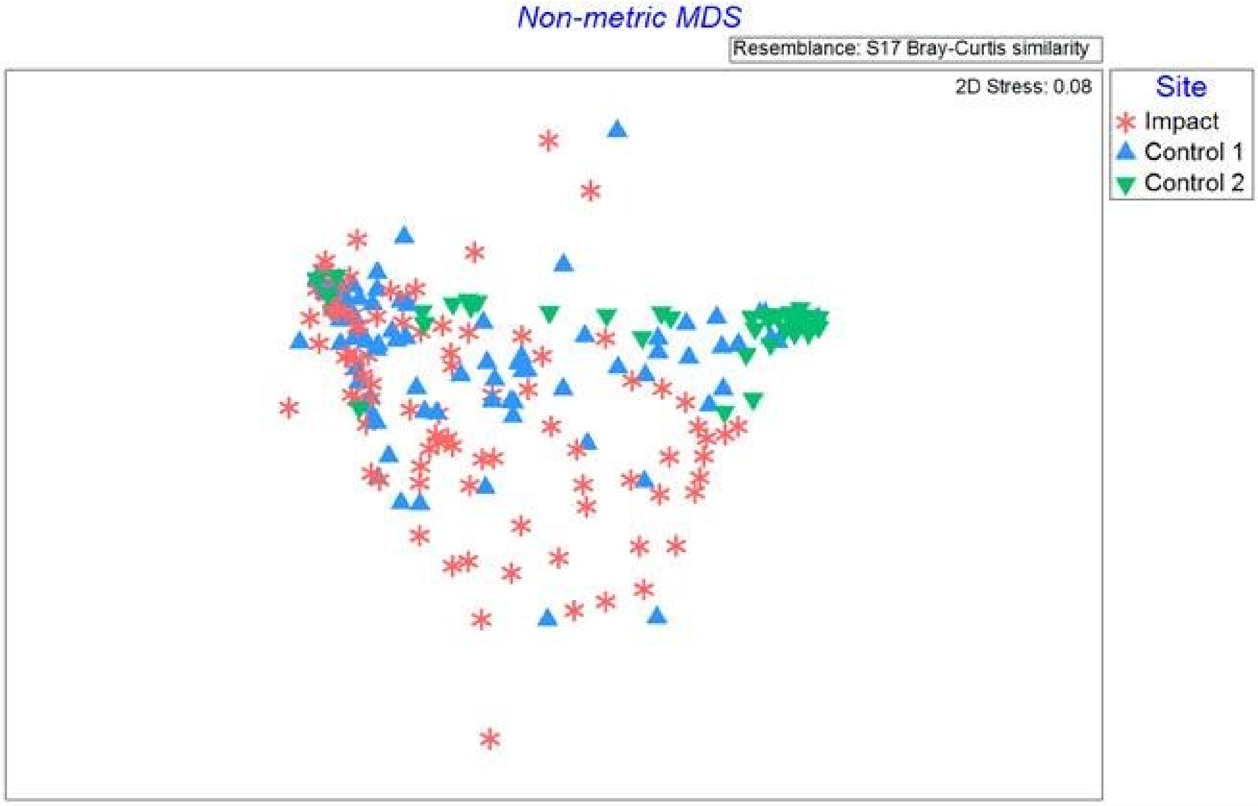


Figure 7. Non-metric multidimensional scaling (nMDS) ordination based on Bray-Curtis dissimilarities of habitats captured on towed video at Sleaford Bay (Impact) and control sites. * Note that the Impact site and Control site 1 occupy similar ordination space while Control site 2 is more tightly clustered.

The benthic habitats differed significantly between sites but no influence of season or interaction between sites and season were detected (PERMANOVA, P=.0001 & P = 0.3282 respectively, (Appendix C)). Pairwise comparisons showed significant differences in habitat composition between all sites (Table 2).

Table 2. Pairwise comparison of sites (PERMANOVA). * Note that both control sites have significantly different habitat compared to the Impact site and each other. See appendix C for full PERMANOVA results.

Sites	P(perm)
Control 1, Impact	0.0067
Impact, Control 2	0.0001
Control 1, Control 2	0.0001

The observations seen in Figure 7 are borne out by SIMPER analysis which showed the Control site 2 had the most uniform habitat (i.e. the highest within site similarity score), due primarily to the high cover of canopy forming macroalgae (Table 3 A). The Impact site and Control site 1 appeared more heterogeneous with lower (but similar) similarity scores driven primarily by the presence of more brown understory algae and bare substrate. Similarly there was a lower dissimilarity value apparent between the Impact site and Control 1 than with those sites compared to Control site 2 (Table 3 B).

Table 3. Analysis of Similarity Percentages (SIMPER) results for Sleaford Bay (Impact) and control sites across all sampling periods. A) Average similarity within sites and B) Averaged dissimilarity between sites.

A)

Control 1 Average similarity: 53.26					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Bare	58.84	39.83	1.31	74.78	74.78
Impact Average similarity: 51.64					
Bare	52.52	33.99	1.23	65.81	65.81
Brown understory	17.13	8.64	0.99	16.74	82.55
Control 2 Average similarity: 75.07					
Canopy	84.34	72.30	2.06	96.31	96.31

B)

Control 1 & Impact Average dissimilarity = 49.03						
Species	**Av Abundance**	**Av Abundance**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Bare	58.84	52.52	18.83	**1.38**	38.41	38.41
Canopy	22.14	15.04	12.70	0.98	25.90	64.31
Brown understory	10.34	17.13	7.37	**1.01**	15.04	79.35
Control 1 & Control 2 Average dissimilarity = 69.72						
Canopy	22.14	84.34	33.38	**1.99**	47.88	47.88
Bare	58.84	13.44	26.56	**1.61**	38.10	85.99
Impact & Control 2 Average dissimilarity = 76.12						
Canopy	15.04	84.34	35.87	**2.47**	47.13	47.13
Bare	52.52	13.44	24.06	**1.54**	31.61	78.74

3.1.2 Habitat diversity and cover

The community structure described above is further illustrated by raw diversity and cover data. Diversity (i.e. no. of functional groups) data showed similar results for the Control 1 and Impact sites averaging 9.5 across the two seasons (Figure 8). Control site 1 contained the highest diversity of habitat functional groups (11) in autumn followed by the spring and autumn samples at the proposed Impact site (10 and 9 respectively; Figure 8). Control site 2 had the lowest number of habitat functional groups (7 and 6 in autumn and spring respectively).

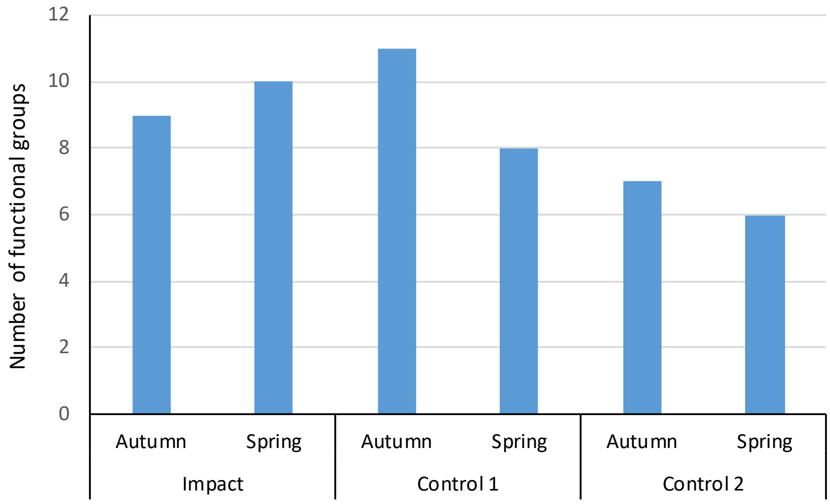


Figure 8. Total number of habitat functional groups recorded at sampling sites in autumn and spring 2019.

3.2 Fish communities

3.2.1 Community structure

At the Impact site, a total of 31 species were observed. The most abundant being trevally and Southern school whiting. The site was dominated by benthic invertivores (trevally and Southern school whiting for example) with higher carnivores making up the second most abundant functional group (Australian herring) and small proportions of browsing herbivores, omnivores and planktivores were also present (Figure 9). The site contained species common to patchy reef/sand habitats including recreationally and commercially targeted species such as sweep, leatherjackets, Australian herring, Australian salmon, calamari, King George whiting and Bight redfish. Many common non targeted species such as silverbelly, Barber perch, moonlighter, Old wife and Herring cale were also present. Large species such as Western blue groper and Samson fish were also observed (see Appendix D for more detail). Some seasonal difference in species present was also observed (Figure 9). Like the Impact site, Control site 1 was dominated by benthic invertivores followed by higher carnivores. Small proportions of browsing herbivores and planktivores were observed at these sites. Control site 2 differed with a greater proportion of browsing herbivores than the other two sites. It also recorded more planktivores than the other sites but recorded less benthic invertivores (Figure 9).

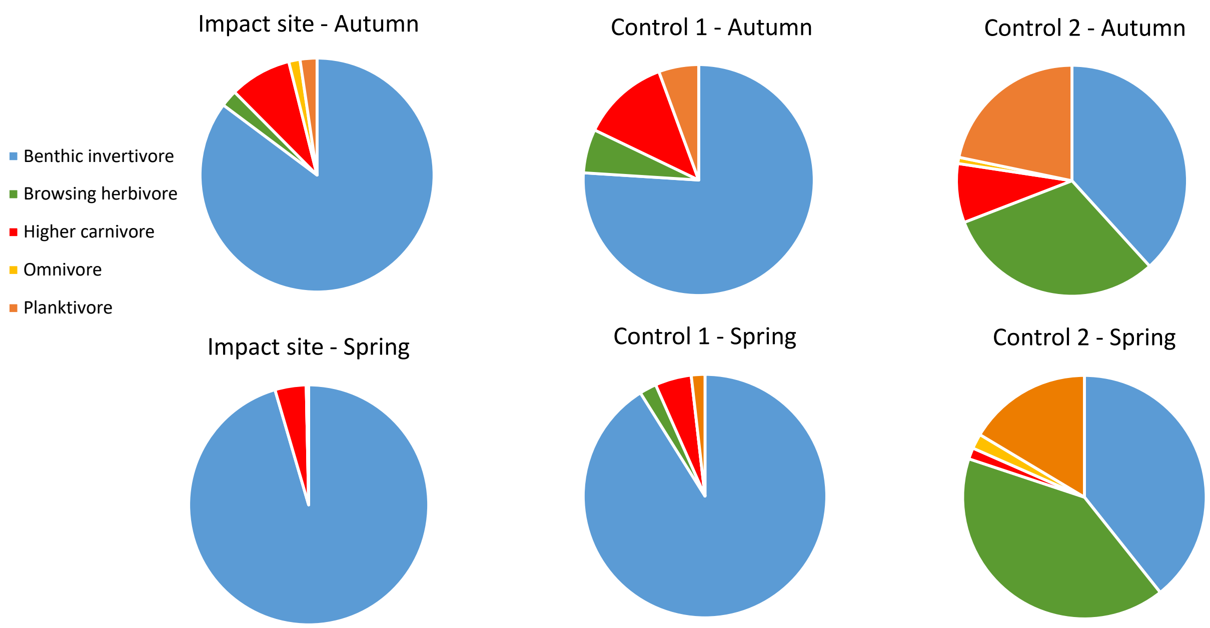


Figure 9. Fish functional groups observed at the Impact site and control sites in autumn and spring 2019.

Fish communities broadly reflected the patterns in habitats described above with the Impact site and Control site 1 showing some overlap of sample points in the ordination space (Figure 10) suggesting some degree of similarity in the nature of the fish communities at the two sites. The broad spread of points associated with these sites in the ordination space (Figure 10) compared to Control site 2 suggest that they share similar variability which is likely due to the more variable nature of the habitats. Sample points for Control site 2 ordinate more tightly and with no overlap with the other two sites suggesting fish communities at that site are more homogenous.

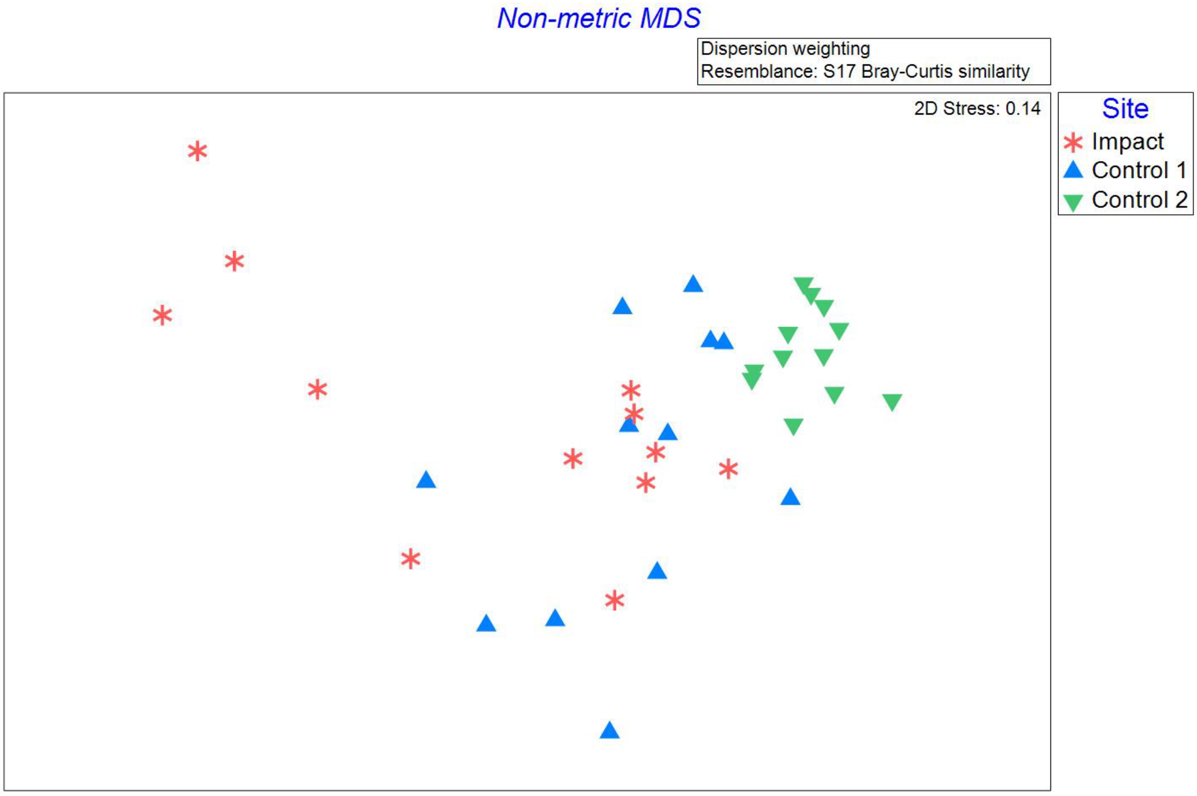


Figure 10. Non-metric multidimesional scaling (nMDS) ordination based on Bray-Curtis dissimilarities of fish assemblages captured on BRUVS at Sleaford Bay (Impact) and control sites.

Statistically there were no seasonal differences in fish communities, however, there were differences between sites (PERMANOVA, P=0.3103 and P=0.001 respectively). Pairwise comparisons suggested these differences reflect the pattern evident in the ordination above with no significant difference between the Impact site and Control site 1 while Control site 2 differed from both sites (Table 4). All sites when compared to one another had dissimilarity close to or greater than 70% with the largest difference seen between Control 2 and the Impact site at ~80% (Appendix H, I and J). It is likely Control site 2 stands out as different due to its more homogenous nature relative to the other two sites.

The patterns observed above are further evident in the SIMPER analysis which showed low within site similarity values for both the Impact site and Control site 1 compared to the more homogenous fish community observed at Control site 2 (Table 5). The different community structure at Control site 2 was driven mostly by high abundances of Horseshoe leatherjacket and Bluethroat wrasse, relative to the other sites (Appendix H). It is likely that the more homogenous cover of algae dominating the reef at Control site 2 provided a favourable habitat to support higher abundances of these species.

Table 4. Pairwise comparison of sites (PERMANOVA). Control site 2 is significantly different to both Control site 1 and the Impact site. See Appendix F for full PERMANOVA results.

Sites	**P(perm)**
Control 1, Impact	0.0757
Impact, Control 2	**0.0001**
Control 1, Control 2	**0.0001**

Table 5. Analysis of Similarity Percentages (SIMPER) results for Sleaford Bay (Impact) and control sites across all sampling periods. A) Average similarity within sites and B) Average dissimilarity between sites (top 5 species, See Appendix G and H for full SIMPER results). Low similarity scores for both the Impact site and Control site 1 relative to the higher value for Control site 2 suggest fish communities are more heterogeneous at those sites.

A)

Control 1 Average similarity: 32.85					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Notolabrus tetricus	2.41	12.29	**1.54**	37.42	37.42
Pseudocaranx sp	1.2	6.41	**1.04**	19.51	56.93
Pictilabrus laticlavius	1.5	6.31	0.92	19.2	76.13
Control 2 Average similarity: 55.58					
Meuschenia hippocrepis	4.69	14.89	**2.69**	26.79	26.79
Notolabrus tetricus	4.24	14.81	**2.62**	26.65	53.44
Pictilabrus laticlavius	1.58	5.21	**2.07**	9.37	62.81
Caesioperca rasor	1.86	4.34	**1.65**	7.81	70.62
Impact Average similarity: 25.52					
Pictilabrus laticlavius	1.83	8.64	0.92	33.86	33.86
Notolabrus tetricus	1.33	5.2	0.63	20.39	54.25
Pseudocaranx sp	0.63	2.14	0.73	8.39	62.64
Notolabrus parilus	0.5	1.95	0.53	7.62	70.26

B)

Control 1 & Control 2 Average dissimilarity = 69.66						
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Meuschenia hippocrepis	0.52	4.69	12.87	1.67	18.48	18.48
Notolabrus tetricus	2.41	4.24	7.55	1.31	10.84	29.32
Caesioperca rasor	0.2	1.86	4.98	1.01	7.15	36.48
Pseudocaranx sp	1.2	0	3.82	0.86	5.48	41.96
Pictilabrus laticlavius	1.5	1.58	3.55	1.16	5.1	47.06
Control 1 & Impact Average dissimilarity = 72.64						
Notolabrus tetricus	2.41	1.33	9.38	1.4	12.92	12.92
Pictilabrus laticlavius	1.5	1.83	8.38	1.16	11.53	24.45
Pseudocaranx sp	1.2	0.63	6.52	0.81	8.98	33.42
Parequula melbournensis	0.11	0.63	3.5	0.71	4.82	38.24
Sillago bassensis	0.06	0.41	2.84	0.55	3.91	42.15
Control 2 & Impact Average dissimilarity = 79.10						
Meuschenia hippocrepis	4.69	0.05	14.45	2.11	18.27	18.27
Notolabrus tetricus	4.24	1.33	9.67	1.66	12.22	30.49
Caesioperca rasor	1.86	0.2	5.17	1.05	6.53	37.02
Pictilabrus laticlavius	1.58	1.83	4.34	1.27	5.49	42.52
Achoerodus gouldii	1.08	0.08	3.03	1.64	3.83	46.34

3.2.2 Fish diversity

Five broad taxonomic groups were identified; bony fish species, shark (school shark), crustaceans (common sand crab), cephalopods (southern calamari) and mammals (Australian fur seal, Table 6).

Table 6. Taxonomic groups identified across all sites.

Broad taxonomic group	Impact	Control 1	Control 2
Sharks	0	1	1
Rays	0	0	0
Bony fishes	28	25	25
Crustaceans	1	0	0
Cephalopods	1	1	0
Mammal	1	1	0

In total, there were 52 individual species identified. Fourteen species were common to all three sites (barber perch, Bight redfish, bluethroat and brownspotted wrasse, herring cale, horseshoe leatherjacket, magpie perch, red mullet, sea sweep, senator wrasse, six spine leatherjacket, trevally and western blue groper), whereas five species were observed at both Control site 1 and the Impact site (King George whiting, southern calamari, southern school whiting, silverbelly, Australian herring). The Impact site and Control site 2 shared four common species (Large tooth beardie, moonlighter, Old wife and yellow fin pike). Fourteen species were unique to Control site 2, whereas Control site 1 and the Impact site both had six species unique to the site (Figure 11). See Appendix D and E for full species list.

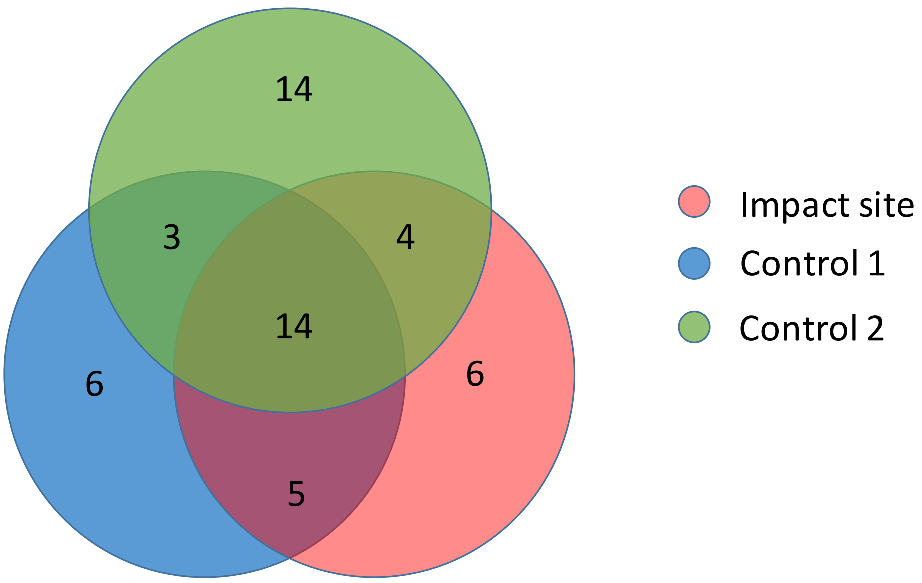


Figure 11. Venn diagram showing species overlap between Impact and control sites.

As with the multivariate analysis, assessment of functional groups suggested some difference between Control site 2 and the other sites. Control site 2 had the highest number of functional groups (5) for both seasons while the other sites were more variable. At the Impact site, 5 functional groups were recorded in autumn and 3 in spring, while Control site 1 recorded 4 in autumn and 3 in spring (Figure 12).

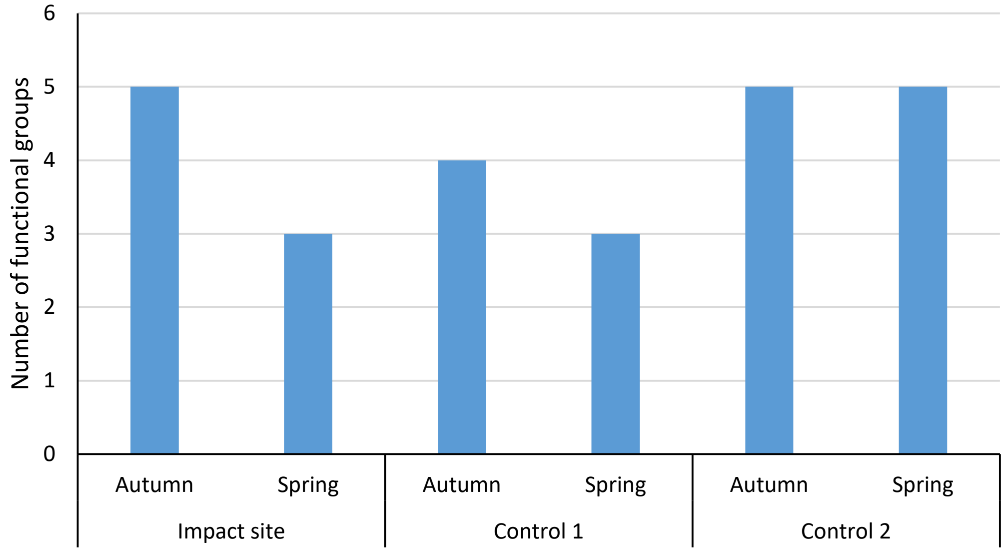


Figure 12 Total number of functional groups recorded at sampling sites in autumn and spring 2019.

Relative species numbers also reflected these patterns. Control site 2 had the highest number of species recorded across both seasons (36) and there was no difference (28 in both seasons) in the number of species between seasons (however some of these were not the same species). The number of species observed for both the Impact site and Control site 1 dropped markedly between autumn and spring (Figure 13). At the Impact site the number of species varied most (30 in autumn and 15 in spring).

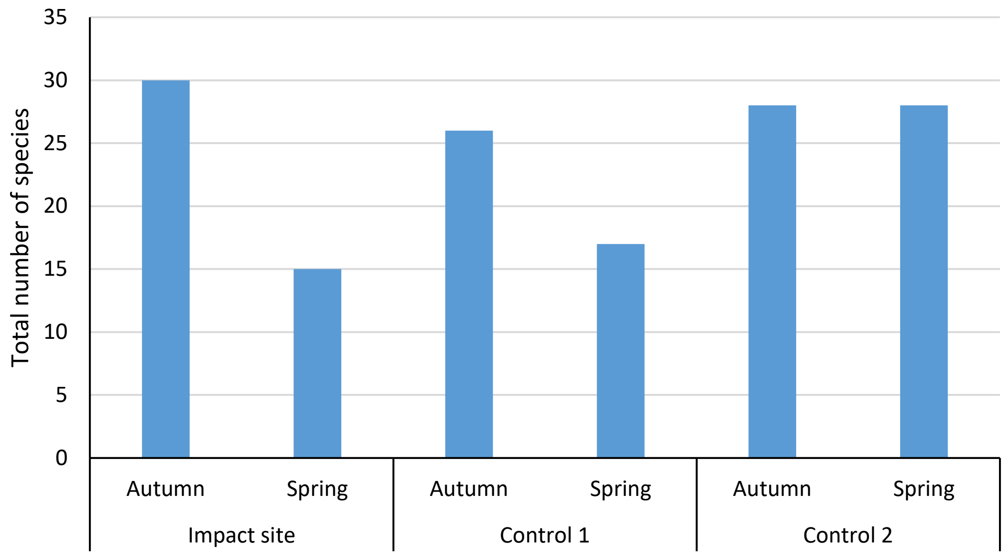


Figure 13. Species diversity observed at sampling sites in autumn and spring 2019.

3.2.3 Abundance

The combined abundance for all species was highest in Control site 1 and lowest at Control site 2 (Figure 14). Control site 1 also had the highest seasonal difference due to an increase in the amount of trevally recorded in spring. This is a schooling species which can impact on abundance if a large school detects and aggregates in the bait plume from the BRUVS. Seasonal differences at the Impact site and Control site 2 were much smaller with the difference at the Impact site also being attributed to the trevally species. The seasonal difference at Control site 2 was due to a small increase in the number of Sea sweep and Yellowfin pike.

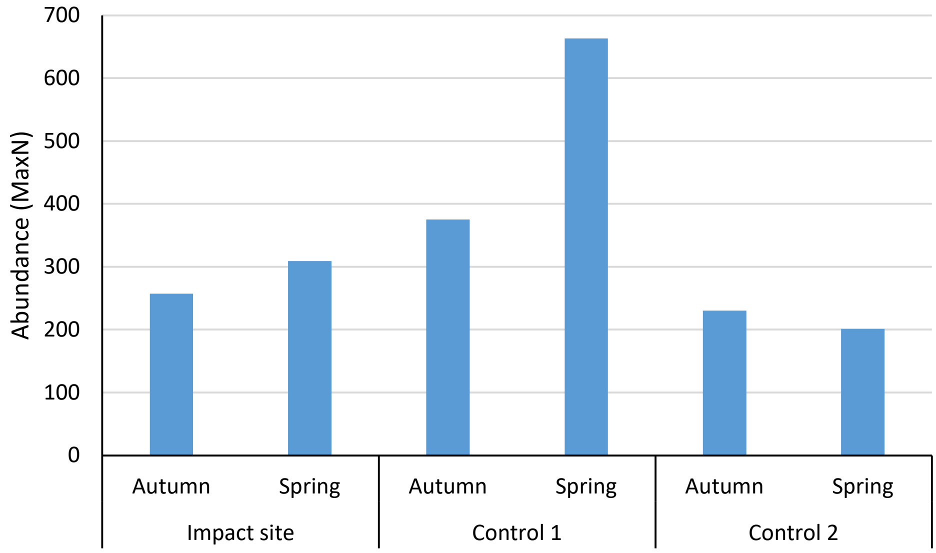


Figure 14. Total number of fish (MaxN) observed at each site in autumn and spring 2019.

3.2.4 Fish size

The highest number of large fish (>200mm) were observed at Control site 2 and the lowest at Control site 1. Seasonal differences in the number of large fish were observed at the Impact site and Control site 1 with both showing a decrease in spring relative to autumn. Control site 2 showed the opposite trend where there was an increase in spring relative to autumn (Figure 15). A selection of large fish over 200mm is presented in Figure 16. Average fish sizes appeared similar across the three sites for key species with the exception of the Western blue groper which were biggest at Control site 1 and smallest at Control site 2 (Figure 16). See Appendix E for full list of average fish size.

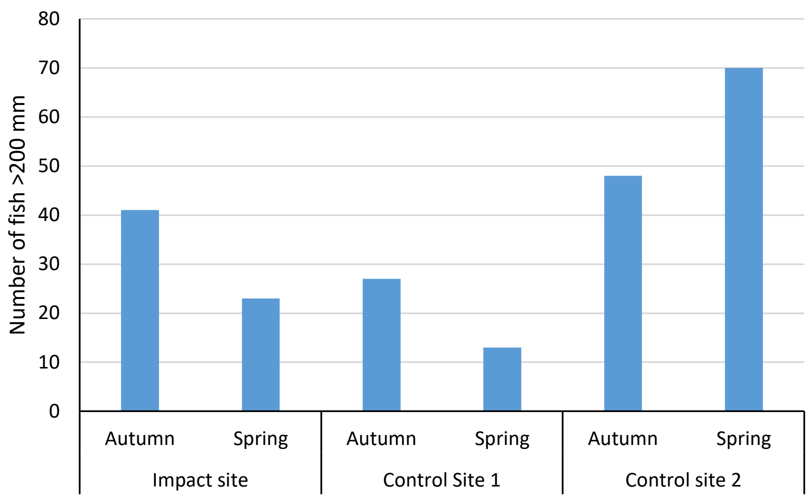


Figure 15. Number of species recorded at each site that were larger than 200 mm in autumn and spring 2019.

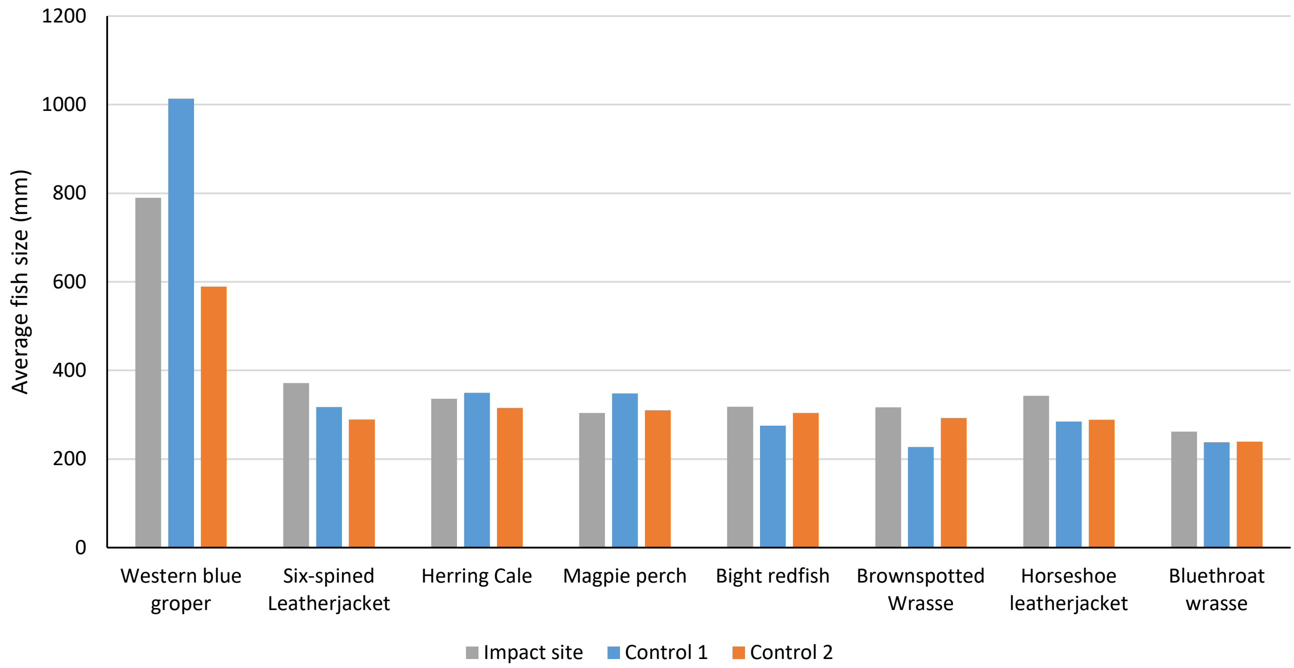


Figure 16. Average fish size over 200mm observed at all three sites (both seasons combined).

4 Discussion

4.1 Impact and control site biological characteristics

Sleaford Bay has a relatively high energy coastline and it was expected the hypersaline brine would be dispersed quickly. Modelling showed that an increase in salinity between 0.3-0.52 g/l from the discharge of hypersaline water was expected to be restricted to around 100m from the outfall site (Sadeghian 2019). This expectation guided the design of the present study, in particular, the size and location of the Impact and two control sites. The extent of the study sites (500m x 250m) should easily cover the area where elevated salinity is expected to occur while the control sites, located 5 (Control site 1) and 30km (Control site 2) away are more than adequate distances from the Impact site to be outside of this potential impact area.

This project aimed to describe the habitats and associated fish communities present at the proposed Sleaford Bay desalination plant outfall site and at two control sites. The information collected over two seasons (spring and autumn 2019) is intended to provide a baseline against which any future changes resulting from the desalination outfall at the Impact site can be assessed. It also informs the design of ongoing monitoring of the site should the desalination plant commence operation.

Results from this study found the Impact site contained a high diversity of highly mobile fish species including both benthic and pelagic species characteristic of patchy temperate reef environments. Half the area of the Impact site contained sand while the other half comprised primarily of a range of canopy forming macroalgae and understory with smaller amounts of seagrass and other habitat types.

Control site 1 was more similar to the Impact site, both in terms of fish communities and habitat characteristics than Control site 2. Sand was the dominant habitat cover for both the Impact site and Control site 1 with canopy forming macroalgae being the next most significant habitat type. In terms of fish assemblages, the Impact site and Control site 1 had 19 overlapping fish species, a similar proportion of species belonging to the most common functional group (benthic invertivore), and similar seasonal trends (with the exception of overall fish abundance which was driven by schools of highly mobile fish species).

Control site 2 had a much higher cover of canopy forming macroalgae than the other two sites and also differed in terms of its dominant functional group of fish with a higher proportion of browsing herbivores, and different seasonal trends observed. Although this site differed to some degree from the Impact site and Control site 1, a similar suite of algal species were found and differences are related mostly due to the extent and consistency of canopy forming algae and a lack of seagrass species. There were also a high number of common fish species, and the site will provide a valuable indicator of background change in the region.

4.2 Ongoing Monitoring

The habitat and fish assessment methods used in this study (towed video with high definition stills and BRUVS) were 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 size and abundance
- Diversity indices
- Fish community structure
- Fish and habitat community structure

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.

Ideally the second Control site would have shared more similarity with the Impact site and Control site 1. Nonetheless, the slightly different physical characteristics of the site will provide valuable information for detecting change from baseline condition, in particular as a reference for broader changes that may occur in the region.

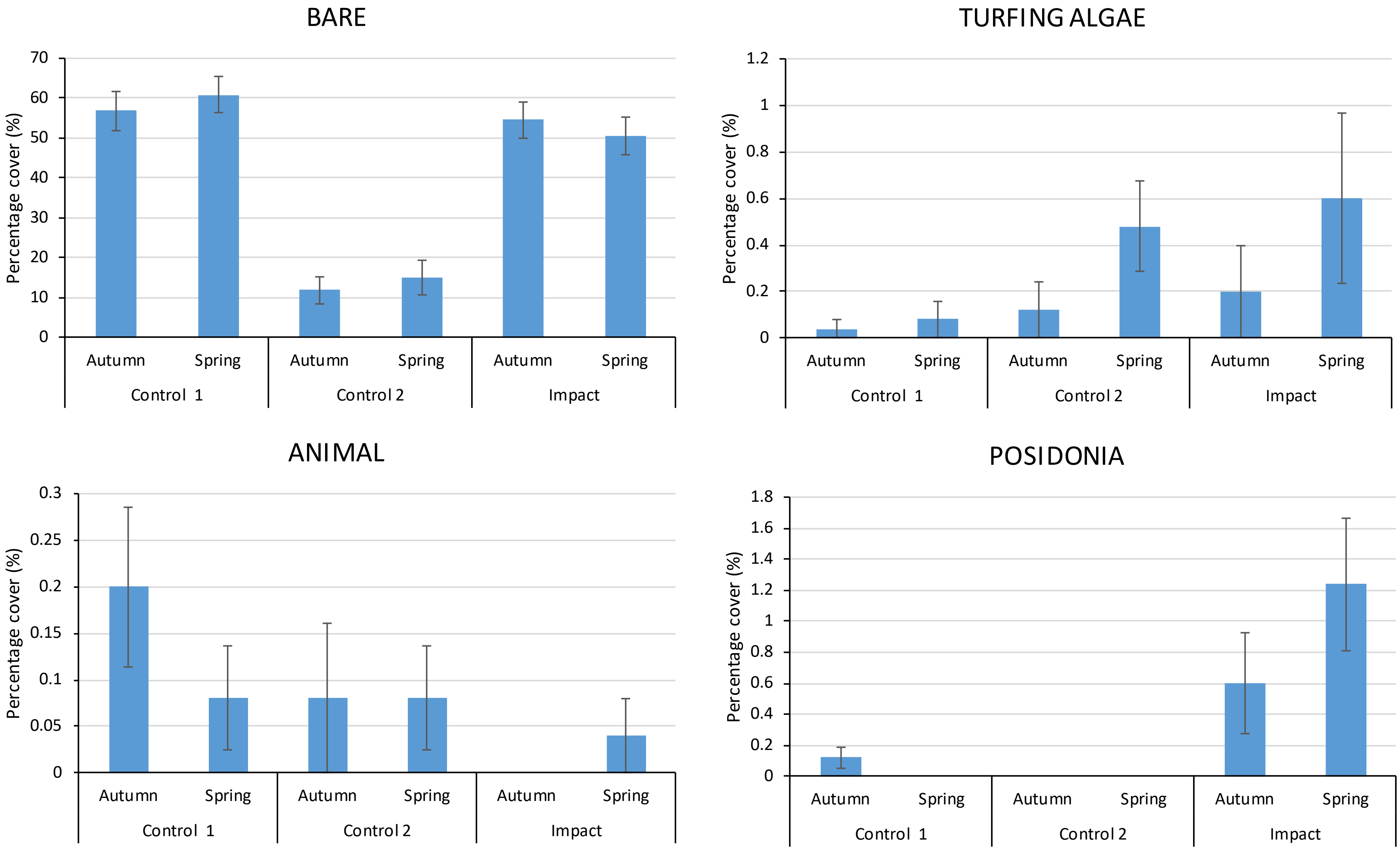
The way the baseline data collection has been designed and the type of data collected will enable a range of biological characteristics to be assessed at different temporal and spatial scales. It was recommended where practicable to repeat the surveys as soon as possible post construction and then annually for three years and at the five year post construction mark. Given the seasonal variation in fish communities it was recommended to include seasonal sampling as part of the ongoing monitoring program, however, the frequency and timing of repeat surveys would depend somewhat on the legislated requirements specified for the construction and post operation phase in the development application.

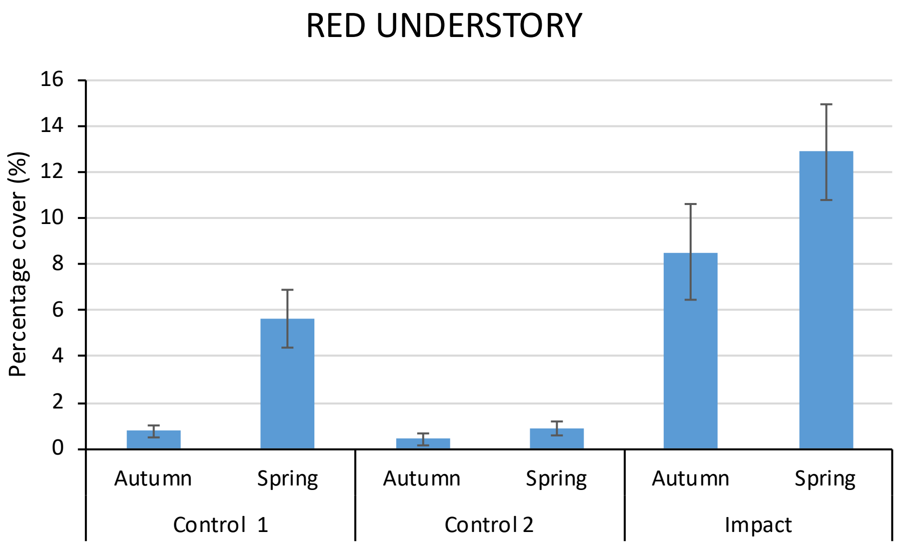
5 Appendices

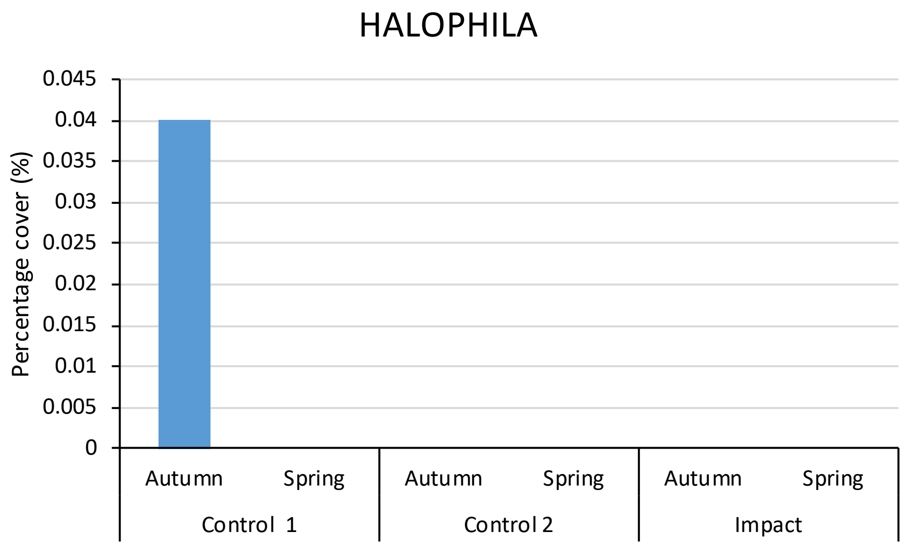
Appendix A. Percent cover of all benthic habitats in spring and autumn at control and Impact sites.

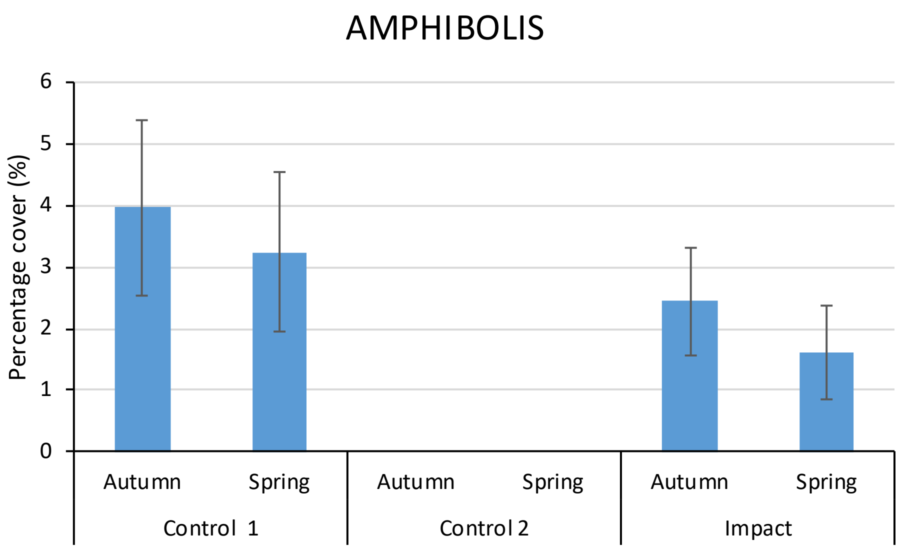
Row Labels	*Posidonia*	*Amphibolis*	*Zostera tasmanica*	*Halophila*	Canopy	Brown understory	Green understory	Red understory	Turf	Animal	Bare
Autumn											
Control 1	0.12	3.96	0.20	0.04	27.13	9.92	0.80	0.76	0.04	0.20	56.82
Control 2	0.00	0.00	0.00	0.00	87.03	0.52	0.04	0.40	0.12	0.08	11.81
Impact	0.60	2.44	0.44	0.00	14.90	18.03	0.28	8.45	0.20	0.00	54.65
Spring											
Control 1	0.00	3.24	0.00	0.00	17.16	10.76	2.20	5.64	0.08	0.08	60.84
Control 2	0.00	0.00	0.00	0.00	81.64	1.84	0.00	0.88	0.48	0.08	15.07
Impact	1.24	1.60	1.00	0.00	15.15	16.15	0.80	12.87	0.60	0.04	50.54

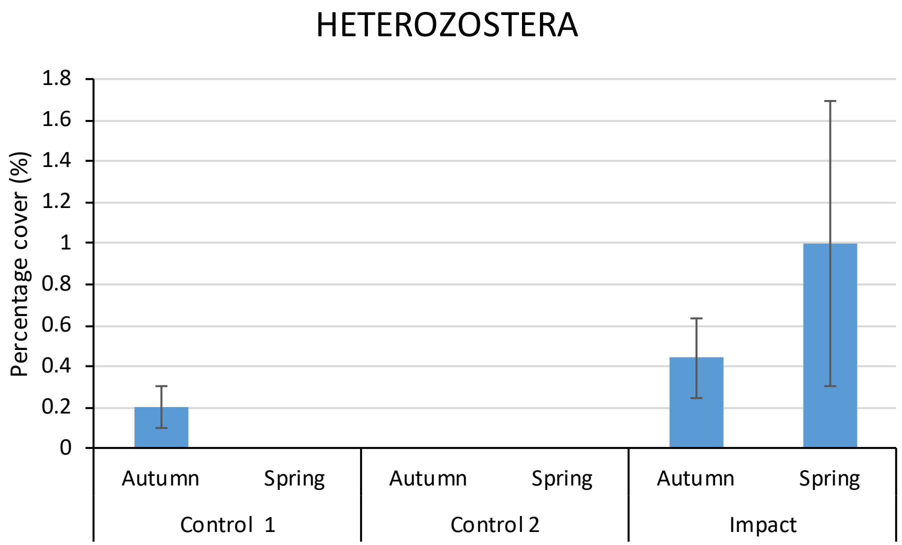
Appendix B. Mean percentage cover for all habitat functional groups for sites and seasons. Error bars represent standard error.

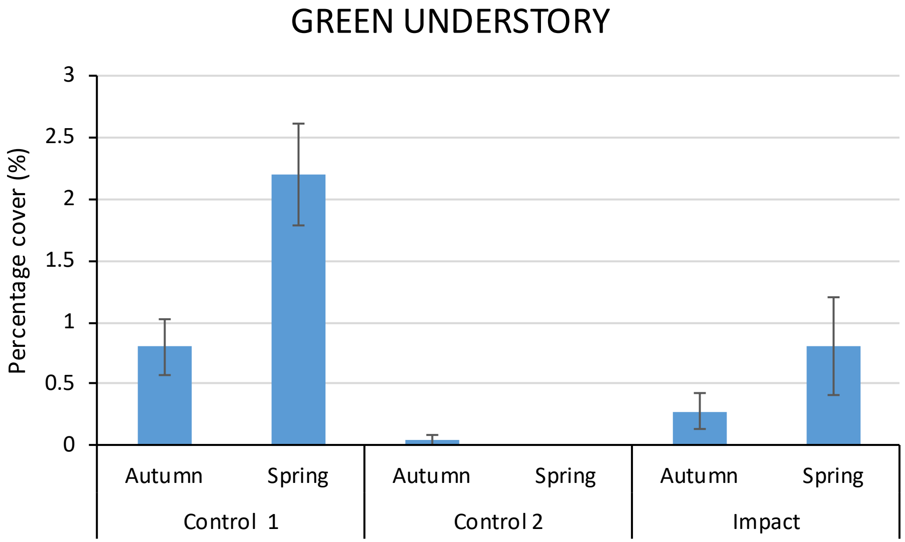


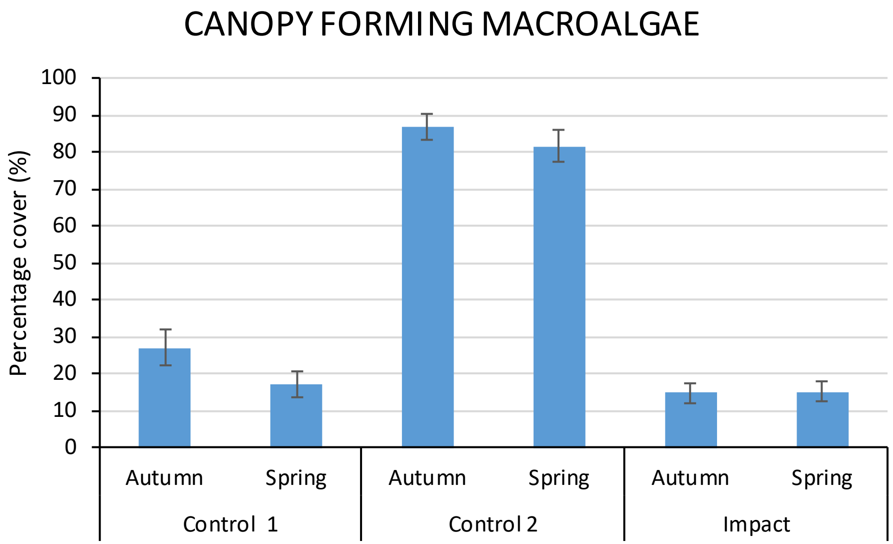

RED UNDERSTORY
Percentage cover (%)
16
14
12
10
8
6
4
2
0
Autumn
Spring
Autumn
Spring
Autumn
Spring
Control 1
Control 2
Impact

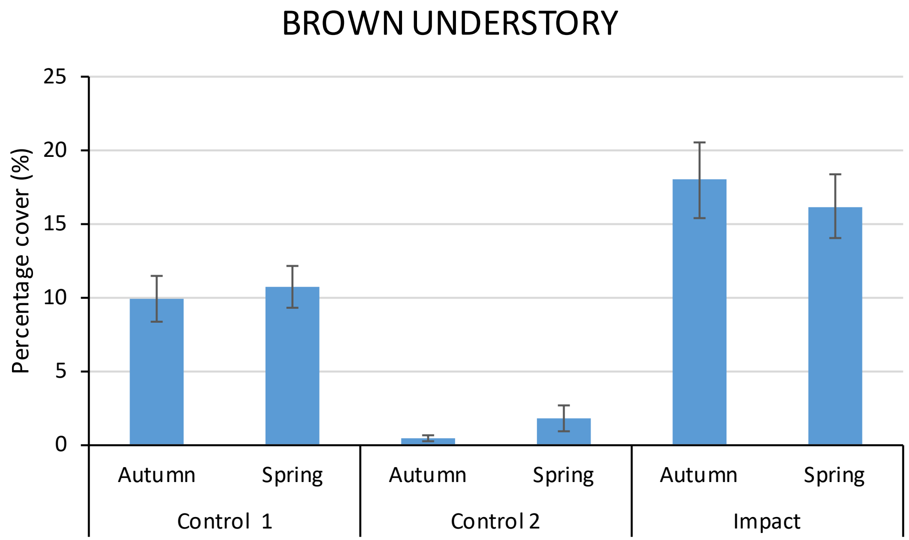

HALOPHILA
Percentage cover (%)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Autumn
Spring
Autumn
Spring
Autumn
Spring
Control 1
Control 2
Impact


AMPHIBOLIS
Percentage cover (%)
6
5
4
3
2
1
0
Autumn
Spring
Autumn
Spring
Autumn
Spring
Control 1
Control 2
Impact


HETEROZOSTERA
Percentage cover (%)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Autumn
Spring
Autumn
Spring
Autumn
Spring
Control 1
Control 2
Impact


GREEN UNDERSTORY
Percentage cover (%)
3
2.5
2
1.5
1
0.5
0
Autumn
Spring
Autumn
Spring
Autumn
Spring
Control 1
Control 2
Impact


CANOPY FORMING MACROALGAE
Percentage cover (%)
100
90
80
70
60
50
40
30
20
10
0
Autumn
Spring
Autumn
Spring
Autumn
Spring
Control 1
Control 2
Impact


BROWN UNDERSTORY
Percentage cover (%)
25
20
15
10
5
0
Autumn
Spring
Autumn
Spring
Autumn
Spring
Control 1
Control 2
Impact

Appendix. C) Two-way permutational multivariate analysis of variance (PERMANOVA) based on Bray-Curtis dissimilarities of habitats captured on towed video at Sleaford Bay (Impact) and control sites. B) Pairwise tests for each site by site.

A)

Source	df	ss	ms	Pseudo-F	P (perm)	Unique perms	(MC)
Site	2	2.5889E+05	1.2945E+05	101.72	0.0001	9946	0.0001
Season	1	3022.9	3022.9	3.3787	0.3282	60	0.1457
Site X Season	2	1789.4	894.71	0.70308	0.5568	9944	0.5535
Res	294	3.7413E+05	1272.6				
Total	299	6.3784E+05					

B)

Sites	t	P(perm)	Unique Perms
Control 1, Impact	2.3742	0.0067	9958
Control 1, Control 2	12.284	0.0001	9935
Impact, Control 2	13.184	0.0001	9946

Appendix D. Raw BRUVS data showing the sum of MaxN.

Sum of MaxN	Sleaford Control 1			Sleaford Control 2			Sleaford Impact			Grand Total
Species	***Autumn***	***Spring***	**Total**	***Autumn***	***Spring***	**Total**	***Autumn***	***Spring***	**Total**	
Australian herring	40	30	70				10	12	22	92
Australian sealion	3		3				1	1	2	5
Banded seaperch					1	1				1
Banded sweep	1		1							1
Barber perch	5	3	8	28	27	55	4		4	67
Barracouta							2		2	2
Bight redfish		1	1	3	2	5	2		2	8
Black-spotted wrasse				1		1				1
Blue morwong				4	2	6				6
Bluelined leatherjacket	1		1	4	2	6				7
Bluethroat wrasse	23	31	54	41	45	86	13	9	22	162
Brownspotted wrasse	2	3	5	6	4	10	4	1	5	20
Bullseye unidentified				1		1				1
Castelnau's wrasse							1	1	2	2
Common sand crab							1	3	4	4
Foxfish				1	1	2				2
Harlequin fish				1		1				1
Herring cale	3	3	6	5	5	10	1		1	17
Horseshoe leatherjacket	3	8	11	38	61	99	1		1	111
King George whiting	2	1	3				2	9	11	14
Largetooth beardie				1		1	1		1	2
Leatherjacket sp					2	2				2
Magpie perch	4	1	5	5	5	10	3	1	4	19
Moonlighter				5	2	7	2		2	9
Old Wife				4		4	1		1	5
Pencil weed-whiting				1		1				1
Port Jackson shark					1	1				1
Rainbow cale				1	2	3				3
Red banded wrass					1	1				1
Red mullet	4		4		1	1	3	5	8	13
Rough leatherjacket	1		1							1
Samsonfish							1		1	1
School shark	2		2							2
Sea sweep	15	9	24	22	6	28	2		2	54
Senator wrasse	10	12	22	11	8	19	12	6	18	59
Silver drummer					2	2				2
Six-spined leatherjacket	3	1	4	8		8	3		3	15
Snook		1	1							1
Southern calamary	1		1				1	1	2	3
Southern school whiting	14		14				33	68	101	115
Southern silverbelly	3		3				17	1	18	21
Spinytail leatherjacket					2	2				2
Swallowtail				1		1				1
Toothbrush leatherjacket							4		4	4
Trevally	220	554	774		1	1	125	190	315	1090
Victorian scalyfin	4	1	5	2	1	3				8
Weedy seadragon								1	1	1
Western Australian salmon	1		1				1		1	2
Western blue groper	2	2	4	7	6	13	1		1	18
Western talma				2	1	3				3
Yellowfin pike				13	1	14	4		4	18
Yellowstriped leatherjacket	2		2	5	2	7				9
Zebrafish	6	2	8	9	7	16	1		1	25
Grand Total	375	663	1038	230	201	431	257	309	566	2035

Appendix E. Raw BRUVS data showing average fish length.

Average of Length (mm)	Sleaford Control 1		Sleaford Control 2		Sleaford Impact	
Species	***Autumn***	***Spring***	***Autumn***	***Spring***	***Autumn***	***Spring***
Australian herring	128.17	149.19			176.22	128.69
Australian sealion	1556.50					
Barber perch	203.21		186.57	198.63	178.18	186.75
Barracouta					433.92	
Bight redfish		275.06	309.84	295.43	318.42	
Blue morwong			516.97	486.77		
Bluelined leatherjacket			309.89			
Bluethroat wrasse	235.94	251.86	204.25	264.58	283.71	240.16
Brownspotted wrasse	227.36		170.28	333.46	298.11	344.47
Foxfish			432.64			
Harlequin fish			524.12			
Herring cale	349.49		311.47	322.78	335.91	
Horseshoe leatherjacket	271.57	323.52	288.81	288.47	342.53	
King George whiting					381.44	372.23
Largetooth beardie					442.28	
Leatherjacket sp				271.33		
Magpie perch	348.04		288.58	324.35	308.42	294.64
Moonlighter			165.54	190.84	237.36	
Old wife					148.90	
Port Jackson shark				947.08		
Rainbow cale				169.27		
Red band wrasse				200.48		
Red mmullet	140.03					193.87
School shark	1377.64					
Sea sweep	258.53	293.22	279.65	249.32	293.54	
Senator wrasse	194.83			202.82	171.76	189.76
Silver drummer				622.62		
Six-spined leatherjacket	300.93	367.10	289.55		371.89	
Southern calamary					336.76	202.46
Southern school whiting	184.32				194.45	171.82
Southern silverbelly	89.08				105.31	83.33
Spinytail leatherjacket				345.39		
Swallowtail			204.23			
Toothbrush leatherjacket					144.77	
Trevally	138.95	208.69		228.55	167.11	158.22
Victorian scalyfin	148.55		204.33	216.17		
Weedy seadragon						279.20
Western blue groper	1148.27	879.07	660.01	546.55	790.13	
Western talma				167.72		
Yellowfin pike			331.94	431.29	281.94	
Yellowstriped leatherjacket	198.29		256.76	253.57		
Zebrafish	252.75		319.83	318.19		

Appendix F. A) Two-way permutational multivariate analysis of variance (PERMANOVA) based on Bray-Curtis dissimilarities of fish communities recorded on BRUVS at Sleaford Bay (Impact) and control sites. Factors are Site (df=2), Season (df=1) and Site X Season (df=2). B) Pairwise tests for each site by site.

A)

Source	**Df**	**SS**	**MS**	**Psuedo-F**	**P(perm)**	**Permutations**
Site	2	22449	11224	5.3416	**0.0001**	9904
Season	1	2364.9	2364.9	1.0479	0.4699	60
SitexSeason	2	4513.5	2256.8	1.074	0.3526	9904
Res	30	63040	2101.3			
Total	35	92253				

B)

Groups	**t**	**P(perm)**	**Unique perms**
Control 1*Control 2	2.6986	**0.0001**	9943
Control 1*Impact	1.33	0.0757	9930
Control 2*Impact	2.8986	**0.0001**	9930

Appendix G. Species contributing to the similarity within Control 2.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Meuschenia hippocrepis	4.69	14.89	2.69	26.79	26.79
Notolabrus tetricus	4.24	14.81	2.62	26.65	53.44
Pictilabrus laticlavius	1.58	5.21	2.07	9.37	62.81
Caesioperca rasor	1.86	4.34	1.65	7.81	70.62

Appendix H. SIMPER analysis showing dissimilarity between Control site 1 and Control site 2.

Control 1, Control 2						
Average dissimilarity = 69.66						
	Control 1	Control 2				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Meuschenia hippocrepsis	0.52	4.69	12.87	**1.67**	18.48	18.48
Notolabrus tetricus	2.41	4.24	7.55	**1.31**	10.84	29.32
Caesioperca rasor	0.2	1.86	4.98	**1.01**	7.15	36.48
Pseudocaranx sp.	1.20	0.00	3.82	0.86	5.48	41.96
Pictilabrus laticlavius	1.5	1.58	3.55	**1.16**	5.1	47.06
Girella zebra	0.47	0.94	2.63	**1.19**	3.77	50.83
Achoerodus gouldii	0.33	1.08	2.59	**1.26**	3.72	54.55
Scorpis aequipinnis	0.57	0.66	2.41	0.78	3.46	58
Olisthops cyanomelas	0.42	0.83	2.31	0.87	3.31	61.31
Cheilodactylus nigripes	0.42	0.83	2.23	**1.24**	3.2	64.51
Meuschenia freycineti	0.33	0.67	2.18	0.78	3.12	67.64
Notolabrus parilus	0.33	0.83	2.01	**1.1**	2.89	70.52

Appendix I. SIMPER analysis showing dissimilarity between Control site 1 and the Impact site.

Control 1, Impact						
Average dissimilarity = 72.64						
	Control 1	Treatment				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Notolabrus tetricus	2.41	1.33	9.38	**1.4**	12.92	12.92
Pictilabrus laticlavius	1.5	1.83	8.38	**1.16**	11.53	24.45
Pseudocaranx sp.	1.20	0.63	6.52	0.81	8.98	33.42
Parequula melbournensis	0.11	0.63	3.5	0.71	4.82	38.24
Sillago bassensis	0.06	0.41	2.84	0.55	3.91	42.15
Notolabrus parilus	0.33	0.50	2.67	0.88	3.67	45.82
Scorpis auquipinnis	0.57	0.05	2.49	0.97	3.43	49.25
Arripis georgianus	0.41	0.13	2.47	0.66	3.4	52.65
Upeneichthys vlamingii	0.19	0.37	2.39	0.72	3.29	55.94
Cheilodactylus nigripes	0.42	0.33	2.38	0.81	3.27	59.21
Sillaginodes punctatus	0.07	0.39	2.35	0.53	3.23	62.44
Ovalipes australiensis	0.00	0.33	2.25	0.45	3.1	65.54
Meuschenia hippocrepis	0.52	0.05	2.19	0.60	3.02	68.56
Olisthops cyanomelas	0.42	0.17	2.02	0.84	2.78	71.34

Appendix J. SIMPER analysis showing dissimilarity between Control site 2 and the Impact site.

Control 2, Impact						
Average dissimilarity = 79.10						
	Control 2	Treatment				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Meuschenia hippocrepis	4.69	0.05	14.45	**2.11**	18.27	18.27
Notolabrus tetricus	4.24	1.33	9.67	**1.66**	12.22	30.49
Caesioperca rasor	1.86	0.2	5.17	**1.05**	6.53	37.02
Pictilabrus laticlavius	1.58	1.83	4.34	**1.27**	5.49	42.52
Achoerodus gouldii	1.08	0.08	3.03	**1.64**	3.83	46.34
Girella zebra	0.94	0.06	2.58	**1.17**	3.26	49.6
Olisthops cyanomelas	0.83	0.17	2.45	0.89	3.1	52.7
Cheilodactylus nigripes	0.83	0.33	2.35	**1.36**	2.97	55.67
Meuschenia freycineti	0.67	0.25	2.15	0.8	2.72	58.38
Tilodon sexfasciatus	0.58	0.17	2.06	0.86	2.6	60.99
Pseudocaranx sp	0	0.63	2.03	0.65	2.57	63.55
Parequula melbournensis	0	0.63	1.98	0.71	2.5	66.05
Scorpis aequipinnis	0.66	0.05	1.97	0.57	2.49	68.54
Notolabrus parilus	0.83	0.5	1.87	1	2.37	70.91

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