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Department:
Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

ALGOA BAY SEA-BASED AQUACULTURE DEVELOPMENT ZONE

BENTHIC MAPPING ASSESSMENT FOR ALGOA 1, 6 & 7



March 2019



ANCHOR
research & monitoring



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Report Prepared for:
Department of Agriculture, Forestry & Fisheries

Report Prepared by:
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PROJECT DETAILS

Objective	Conduct benthic mapping in support of an application for Environmental Authorisation in terms of the National Environmental Management Act, 1998 (Act No 107 of 1998) – Basic Assessment Process
Anchor Project Name	Algoa Bay ADZ Basic Assessment Process Benthic Mapping and Dispersion modelling
Anchor Project Number	1817
Deliverable	1

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DETAILS OF THE BASIC ASSESSMENT PROCESS

Applicant	Department of Agriculture, Forestry & Fisheries
Environmental Assessment Practitioner (EAP)	Vera Massie and Dr Barry Clark from Anchor Research & Monitoring (Pty) Ltd
Anchor Project Name	Algoa Bay Aquaculture Development Zone Basic Assessment Process
Anchor Project Number	1808
Status	Pre-application
Application submission date	Not submitted
Competent Authority Reference	Not currently assigned
Case Officer	Not currently assigned

OVERVIEW OF PROJECT OUTPUTS BASIC ASSESSMENT REPORT AND APPENDICES

Basic Assessment Report (BAR)	Pre-Application BAR, Draft BAR, Final BAR
Appendix A	Details of EAP, Expertise and Declaration
Appendix B	Details of Specialists, Expertise and Declaration
Appendix C	Background Information Document
Appendix D	<p>Specialist studies:</p> <ol style="list-style-type: none"> 1. Benthic Mapping Assessment for the Proposed Algoa Bay Sea-Based Aquaculture Development Zone (Dawson et al. 2019) 2. Dispersion Modelling Study for the Proposed Algoa Bay Sea-Based Aquaculture Development Zone (Wright et al. 2019) 3. Marine Specialist Study 2019 (Hutchings et al. 2019) 4. Maritime Underwater Heritage Specialist Study (Gribble 2019) 5. Comparative Assessments for the Development of the Proposed Sea Based Aquaculture Development Zone Located within Algoa Bay in the Eastern Cape in South Africa (Rhodes University August 2016) <ol style="list-style-type: none"> a. Socio-economic Report b. Ecological Report c. Feasibility study
Appendix E	Stakeholder Consultation Report
Appendix F	Environmental Management Programme (EMPr)
Appendix G	Additional Information

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GLOSSARY

Benthic	The benthic zone is the ecological region at the lowest level of a body of water such as an ocean or a lake, including the sediment surface and some sub-surface layers. Organisms living in this zone are collectively referred to as the “benthos”, i.e. the benthic invertebrate community, including crustaceans and polychaetes.
Granulometry	The measurement of the size distribution in a collection of sediment grains.
I&J	Irvin & Johnson
Isobath	A line of equal or constant depth below sea level.
Macrofauna	Also termed macrobenthos, are invertebrates that live on or in sediment, or attached to hard substrata – particularly those which are retained on a 1 mm sieve.
Physico-chemical	Relating to physiological chemistry
Shannon-Weiner Diversity	An index used to characterize species diversity within a community, which accounts for both abundance and evenness of the species present.
Taxon (plural – taxa)	Refers to any unit used in the science of biological classification, or taxonomy.
Thermocline	The abrupt transition layer in a body of water marking the rapid change of temperature between two layers of water.
Upwelling	An oceanographic process in which dense, cooler, often nutrient-rich water rises towards the surface.
Zoogeography	The geographic distribution of animal species.

ABBREVIATIONS

ABC	Abundance Biomass Comparison
ADZ	Aquaculture Development Zone
ANOSIM	Analysis of Similarity
ANOVA	Analysis of Variance
DAFF	Department of Agriculture, Forestry and Fisheries
BAP	Basic Assessment Process
BAP	Basic Assessment Report
EA	Environmental Authorisation
EIA	Environmental Impact Assessment
IDZ	Industrial Development Zone
IUCN	International Union for Conservation of Nature
PERMANOVA	Permutational Multivariate Analysis of Variance
PERMDISP	Permutational Multivariate Analysis of Dispersion
MDS	Multi-dimensional Scaling
MPA	Marine Protected Area
PRIMER	Plymouth Routines In Multivariate Ecological Research
SEA	Strategic Environmental Assessment
SIMPER	Similarity Percentage
TOC	Total Organic Carbon
ToR	Terms of Reference
WoRMS	World Register of Marine Species

1 INTRODUCTION

The Department of Agriculture, Forestry and Fisheries (DAFF), as the lead agent for aquaculture management and development in South Africa, intends to establish and manage a sea-based Aquaculture Development Zone (ADZ) in Algoa Bay in the Eastern Cape. A Sea-based ADZ typically consists of a selection of designated precincts that provide opportunities for existing aquaculture operations to expand and new ones to be established. ADZs are intended to boost investor confidence by providing ‘investment ready’ platforms with strategic environmental approvals and management policies already in place, allowing commercial aquaculture operations to be set up without the need for lengthy, complex and expensive approval processes. It is anticipated that an ADZ will create incentives for industry growth, provide marine aquaculture services and enhance consumer confidence. An ADZ provides economic benefits to the local community through job creation and regional economic diversification.

Aquaculture is one of the sectors that form part of Operation Phakisa under the Ocean’s Economy in South Africa. Operation Phakisa is an initiative of the South African government which aims to implement priority economic and social programmes better, faster and more effectively. Operation Phakisa was launched by the President of the Republic in October 2014. The sector offers significant potential for rural development, especially for marginalised coastal communities. The proposed development will provide employment opportunities for the local and regional communities.

In 2009 a Strategic Environmental Assessment (SEA) was undertaken for the entire South African coastline to identify suitable aquaculture precincts. In this assessment the Eastern Cape was highlighted as an area holding potential for the establishment of ADZs. As part of a finer-scale SEA undertaken by DAFF in 2011, two precincts, namely Algoa 1 and 5 were identified as the most promising options for establishment of an ADZ in this area. Environmental Authorisation (EA) was granted for Algoa 1 on 9 July 2014 following a lengthy Environmental Impact Assessment (EIA) process, which was initiated in 2010. During the appeals process that followed the positive decision, a total of twenty eight (28) substantive appeals were lodged against the decision. In response, the Minister of Environmental Affairs issued a decision on the Appeal suspending the EA to allow for further studies to be undertaken.

In mid-2016, DAFF commissioned three comparative assessments, including a detailed feasibility study (Britz & Sauer 2016b), a socio-economic assessment (Britz et al. 2016) and a marine ecological assessment (Britz & Sauer 2016a) for Algoa 1 and 5 (these three studies have been included as stand-alone documents in Appendix D of this Basic Assessment Report). The economic feasibility study (Britz and Sauer 2016b) found that conditions at Algoa 5 were sub-optimal for economic aquaculture and mitigation measures would be impractical or uneconomic to implement, which renders the proposed site not economically competitive. Furthermore, Algoa 5 is located in the middle of the Addo Marine Protected Area (MPA), which was recently approved by cabinet. For the reasons described above, Algoa 5 was screened out and has not taken forward as a potential precinct in the current Basic Assessment process.

DAFF has since withdrawn the original application for environmental authorisation and intends to submit a new application for the development of the ADZ for which a Basic Assessment process is required in terms of the 2014 EIA Regulations (as amended in 2017) of the National Environmental Management Act (Act 107 of 1998) (this application). DAFF intends for the ADZ to accommodate

finfish as well as bivalve culture (oysters/mussels) within a combination of precincts. Anchor Research and Monitoring Pty. Ltd are the Environmental Assessment Practitioners for this application for environmental authorisation.

The precincts considered in this application include one precinct from the previous process (Algoa 1), and two new precincts, designated as Algoa 6 and 7 (Figure 1). Algoa 6, situated near the Port Elizabeth Harbour, was identified but screened out in the scoping phase of the original EIA (2010-2014) which focussed only on finfish culture, and is now being put forward as a suitable site for bivalve production in this new (2019) application process. Algoa 7 is a new precinct located directly in front of the Ngqura harbour that has been identified as a potential site for finfish culture. This site has undergone an internal feasibility assessment in which it was found to be suitable in terms water depth, shipping traffic, and accessibility (i.e. financial considerations). This site overlaps with the recently approved Addo Marine Protected Area (MPA) but the Department of Environmental Affairs Branch Oceans and Coasts has indicated that the affected portion of this site could potentially be excised should Environmental Authorisation be granted for this precinct. Thus, in this application process, two sites, Algoa 1 and 7, are being put forward for finfish culture, while one of these, Algoa 1, along with a third site, Algoa 6, is being put forward for bivalve culture (Figure 1).

DAFF appointed Anchor Research and Monitoring Pty. Ltd. (Anchor) to undertake benthic mapping and habitat analysis for Algoa 7, and to conduct dispersion modelling of water quality and organic waste from the mariculture operations. This is to determine potential risks posed by the use of this site on the planned land-based COEGA Aquaculture Development Zone and adjacent conservation areas, and to better understand risks that future maintenance and expansion activities within the harbour may pose for the proposed aquaculture site.

The benthic mapping and habitat analysis and modelling study informs the marine specialist study and the Basic Assessment Report that will be submitted to National Department of Environmental Affairs (competent authority for this project). This report provides the outcome of the comparative benthic mapping conducted on the three proposed precincts (Algoa 1, 6 and 7) for this Basic Assessment (BA) process.

1.1 Terms of Reference

The benthic mapping and habitat analyses will provide baseline information and habitat conditions for the precincts taken forward into the Basic Assessment process for the proposed Aquaculture Development Zone in Algoa Bay.

As such, specific ToR for the benthic mapping phase of the project includes:

1. Conduct benthic mapping and habitat analysis of the Algoa 7 (new site) to determine species suitability and sensitivity of the sites.
2. Compare the results with benthic mapping and habitat analysis of previously collected data for the Algoa 1 and 6 sites so that the relative environmental sensitivity of all four sites can be adequately assessed.
3. Provide baseline benthic community and habitat data against which future (post development) monitoring results can be benchmarked.

Located between Cape Recife and Cape Padrone on the south-east coast of South Africa, Algoa Bay is one of the best-monitored coastal areas in Africa (Dorrington *et al.* 2018). The bay is home to the Port Elizabeth Harbour and Coega deep water port facility. The regional oceanography, biogeography and ecology of Algoa Bay is summarised in the marine specialist report, whilst comparative baseline water quality, sediment and macrobenthic ecology data is presented below for the three proposed precincts in the proposed Algoa Bay Aquaculture Development Zone (ADZ) (Figure 1).

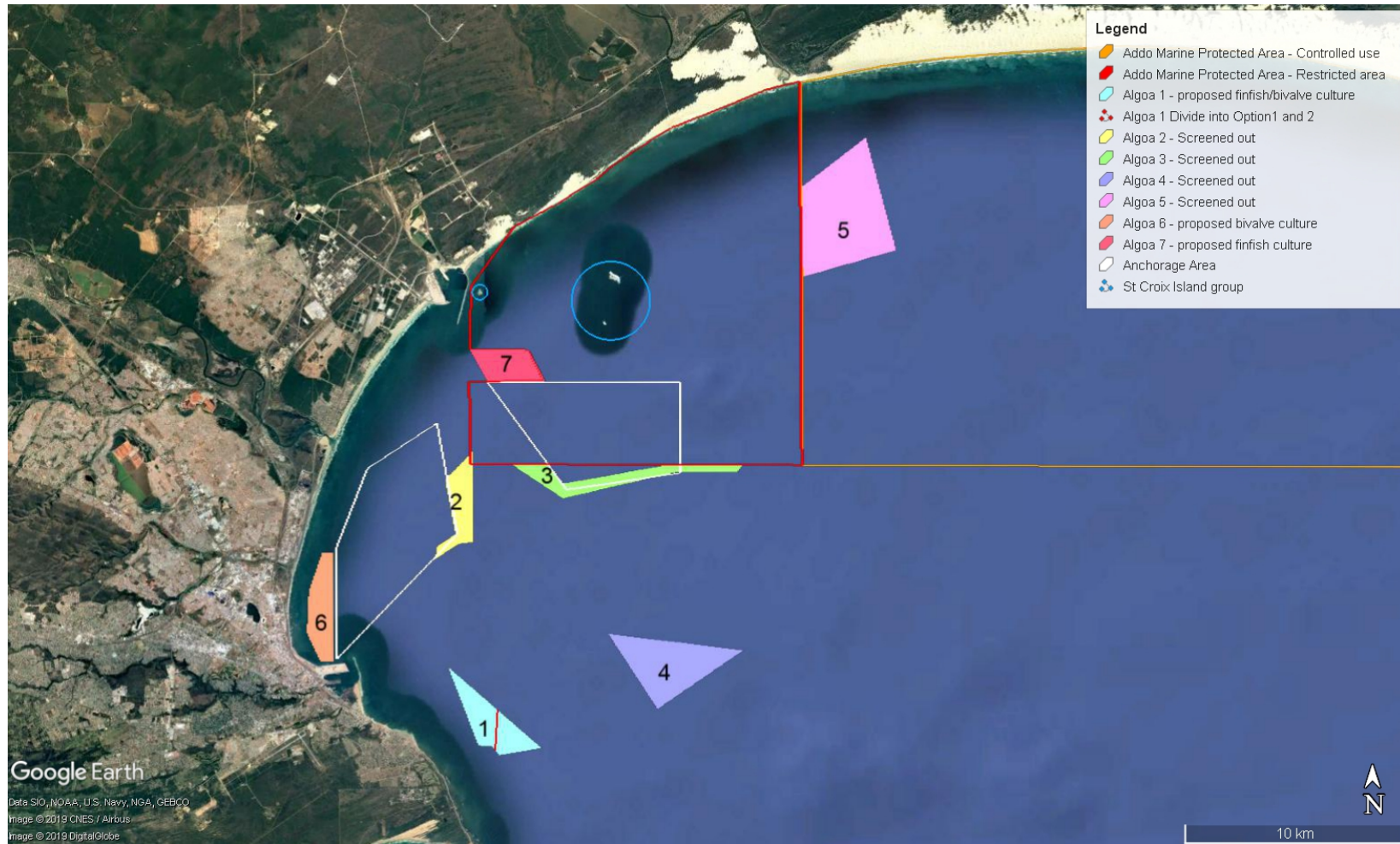


Figure 1 Sites considered during the previous and current application for environmental authorisation for a sea-based Aquaculture Development Zone in Algoa Bay, Eastern Cape. Precincts 2, 3, 4 and 5 were found to be unfeasible and were screened out. Precincts 1, 6 and 7 constitute feasible sites and have been considered during the present Basic Assessment process. Department of Environmental Affairs Branch Oceans and Coasts has indicated that Algoa 7 could potentially be excised from the Addo Marine Protected Area should Environmental Authorisation be granted for this precinct.

2 *IN SITU* CHARACTERISTICS OF PROPOSED SITES

2.1.1 Methods

2.1.1.1 *Oceanographic data collection*

In situ baseline surveys of the ecology and oceanography of Algoa Bay commenced in February 2012 in the footprints of Algoa 2 and Algoa 3. However, concerns about Algoa 2 and 3 were raised during the Scoping Phase regarding shipping and safety after deployment of monitoring equipment (Clark 2012). Algoa 2 and 3 were considered unsuitable, and monitoring at these sites was ceased (Figure 1). Nevertheless, data from these previous surveys remains valid and provide information on local physical oceanographic conditions. The data presented here were collected over an 11 month period from Algoa 2, which lies approximately 4 km to the north of Algoa 7 (Figure 1). Therefore, these data provide a reasonable proxy of the oceanographic conditions that are likely to be experienced at Algoa 7. Monitoring equipment was deployed within precincts Algoa 1 and 5 in early 2013 (see Figure 1) as these appeared to be the next-most suitable areas that violated the fewest conditions outlined in the Strategic Environmental Assessment (Hutchings et al. 2012; Clark 2012). Only data collected for Algoa 1 and Algoa 2 (as a proxy for Algoa 7) are presented here, as the Algoa 5 site is no longer being considered (Figure 1).

2.1.1.2 *Benthic sample collection and laboratory analyses*

Benthic macrofauna samples were collected from 12 stations within Algoa 1 and Algoa 7 using a Van Veen grab, which sampled an area of 0.14 m² and to a depth of ±30 cm (Figure 2). All benthic macrofauna (>1 mm in size) in the samples was retained in a 1 mm mesh bag. Once collected, all samples were stored in plastic bottles, preserved with 5% formalin and transported to the laboratory for further analysis. In the laboratory, samples were rinsed in a 1 mm sieve to remove formalin and the macrofauna separated from the remaining sediment. The macrofauna were identified to the highest possible taxonomic resolution using available keys, dissecting and compound microscopes. The validity of each species was then checked on The World Register of Marine Species (WoRMS, www.marinespecies.org). The biomass (blotted wet mass to two decimal places) and the abundance of species was recorded for each sample.

Sediment samples were collected at all Algoa 1 and Algoa 7 sampling stations. Analysis of the grain size composition of the sediment samples was undertaken by Scientific Services, Cape Town. Sediment particle size was analysed by dry sieving each sample through graded sieves (2000 µm, 1000 µm, 850 µm, 710 µm, 500 µm, 425 µm, 300 µm, 212 µm, 150 µm and 62 µm) on a mechanical shaker for ten minutes. The weight of each fraction on each sieve was recorded to the nearest 0.1 g. Thereafter, data were analyzed using the program GRADISTAT V 8.0 (Blott 2008) to obtain both qualitative and quantitative results. For estimation of total organic content, sediment samples were oven dried at 40°C for 48 hrs. The dry soil samples were placed on crucibles, weighed to the nearest 0.01 g and placed in a muffle furnace at 600°C for 6 h. Thereafter, they were allowed to cool to room temperature in a desiccator, then weighed again. The difference in weight for the latter and former is assumed to be equal to the organic content of the sample. Sediment and macrofauna data for Algoa 6 was taken from a previous study conducted at this site by Nel & Winter (2009).



Figure 2 Map showing the benthic sampling stations for Algoa 1 and Algoa 7.

2.1.1.3 Statistical analyses

Sediment granulometry: Univariate data were analysed using the statistical programming language, R. Multivariate data were analysed using the Plymouth Routines in Multivariate Ecological Research (PRIMER) software package (version 6) with PERMANOVA+ add-on package (Anderson et al. 2008).

Grain size fraction data were analysed using GRADISTAT v8.0 (Blott, 2010) and divided into ten size classes as follows: gravel (>2000 µm), sand (subdivided into very coarse 1000-2000 µm, coarse 500-710, 710-850 and 850-1000 µm, medium 300-425, 425-500 µm, fine 212-300 µm, very fine 63-212 µm), and mud (< 63 µm).

Percentage grain size fractions were arcsine transformed and then normalised prior to multivariate analysis. Patterns of sediment composition were investigated with Multi-Dimensional Scaling (MDS) based on Euclidean distances i.e. the data points (samples) are plotted onto Euclidean axes where an “eigenvalue” associated with each successive axis indicates how much of the total variation in the data is explained by that axis (expressed as a percentage of the total). Multivariate dispersion of samples within sites was calculated using the PERMDISP function. ANOVA (analysis of variance) was employed to determine the influence of site on the total organic content and mean particle size of bottom sediment.

Benthic Macrofauna: Abundance and biomass data was converted from values within a single grab sample to values of per m². Spatial variability in macrofaunal community structure (based on abundance and biomass data where present) was visually assessed using MDS, in order to find ‘natural groupings’ between the precincts, with PERMANOVA (permutational analysis of variance) used to assess the statistical significance of a priori groups. All data were unstandardized and converted to a similarity matrix using the Bray-Curtis similarity coefficient. To measure how well the two-dimensional plot may represent the sample relationship, a stress value for MDS plots is given, whereby a value > 0.25 indicates that a higher dimensional projection may be more appropriate. For within site variation, multivariate dispersion of samples was calculated using the PERMDISP function. The contributions of each species to the average dissimilarity between two sites, and to the average similarity within a site, were assessed using a SIMPER (Similarity Percentages) analysis. This technique seeks to identify taxa that are principally responsible for differences detected in community structure between and within sites.

Macrofaunal community descriptors were calculated using the DIVERSE function in PRIMER V6 (Clark and Warwick, 2001).

The Shannon-Weiner diversity index (H') and Pielou's evenness (J') were calculated for each sampling station using:

$$H' = - \sum_i p_i (\log p_i) \quad \text{and} \quad J' = H' / \log(S)$$

(Where p_i is the proportion of the total count arising from the i th species and S is the total number of species. This is the most commonly used diversity measure and it incorporates both species richness and equability).

Taxonomic richness (alpha diversity or the total number of species), total abundance and biomass were also calculated. ANOVA was employed to determine the influence of site on these community descriptors, along with Post-hoc Tukey tests to identify these differences between sites. To meet the assumptions required for parametric testing, tests for homogeneity of variances (Bartlett Tests) and normality (Q-Q plots) were conducted. Where necessary, data were transformed (Log(x + 1) or 4th root) preceding any parametric testing. The statistical programming language R, was used to conduct all univariate statistical tests.

Taxonomic composition of the macrofaunal community was assessed per site, with the most abundant taxonomic groups identified. Each taxonomic group per site represents the sum of the average abundances (n = 9, 12 and 8 for Algoa 1, 6 and 7 respectively) of species making up that group.

For sites where both abundance and biomass data were available (Algoa 1 and Algoa 7) the DOMINANCE function was used to construct ABC (abundance biomass comparison) curves and to calculate W statistics in order to determine if any of the proposed precincts are currently experiencing disturbance effects.

2.1.2 Results

2.1.2.1 Water quality

Water quality data from both historical water samples collected at Algoa 6 in September 2009 during the I&J Pilot study (Nel & Winter 2009) and from water samples collected at Algoa 6 and Algoa 7 in October 2018 are presented in Table 1. The average values of data from the rings of sampling points located 30 and 60 m away from the pilot study cages are presented below. Using the water quality index of the Department of Environment, Washington State (<http://www.ecy.wa.gov>) the dissolved oxygen levels within Algoa 6 in 2009 can be classed as 'extraordinary' (>7 mg/l). Nutrient concentrations were generally low at both sites and both time periods. Schumann (1998) reported that salinity values within Algoa Bay are generally equivalent to the oceanic average of 35.2 PSU with limited variability in the bay.

Table 1 Water quality data for Algoa 6 and Algoa 7. P = phosphorus; NH4-N = Ammonium/ammonia - Nitrogen content; NO3-N = Nitrate total nitrogen content; PO4 = Phosphate; DO = Dissolved oxygen.

Origin	Sample date	P (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4 (mg/l)	DO (mg/l)
Algoa 6	Sept '09	-	0.21	<0.10	0.15	7.06
Algoa 6	Oct '18	0.12	0.63	<0.36	0.37	-
Algoa 7	Oct '18	0.05	<0.28	<0.36	0.15	-

2.1.2.2 Currents and waves

2.1.2.3 Algoa 1

During the four month monitoring period at Algoa 1, predominately southerly (SE-SW) currents were strongest throughout the water column (Figure 3). This indicates that most of the time, during this seasonal period (February-June) the currents should convey waste from the ADZ out of the bay and away from the popular bathing and surfing beaches. Currents were, however, recorded as flowing in all directions at times, and relatively strong flows ($>15 \text{ cm.s}^{-1}$) were recorded occasionally flowing towards the North and North West (i.e. into the Bay and towards bathing beaches) at mid-water and surface depths (12.9 – 2.9 m).

Surface and midwater current velocities occasionally exceeded 30 cm.s^{-1} , while bottom currents never exceeded 25 cm.s^{-1} . Highest velocities were generally associated with currents flowing in the most common i.e. southerly direction. Throughout the water column, most velocities ($\approx 75\%$ of the time) ranged between $0 - 15 \text{ cm.s}^{-1}$, and for approximately 85% of the time never exceeded 20 cm.s^{-1} (Figure 4).

Current velocities in the lower water column (deeper than 15m) at Algoa 1 exceeded 10 cm.s^{-1} for 34 - 43% of the time. Currents shallower than 10 m exceeded 10 cm.s^{-1} for more than 50% of the time and reached a maximum velocity of 62 cm.s^{-1} . This suggests that currents at Algoa 1 (during the February – June period) are suitable for the adequate dispersion of wastes and therefore should not lead to excessive organic build-up under the cages.

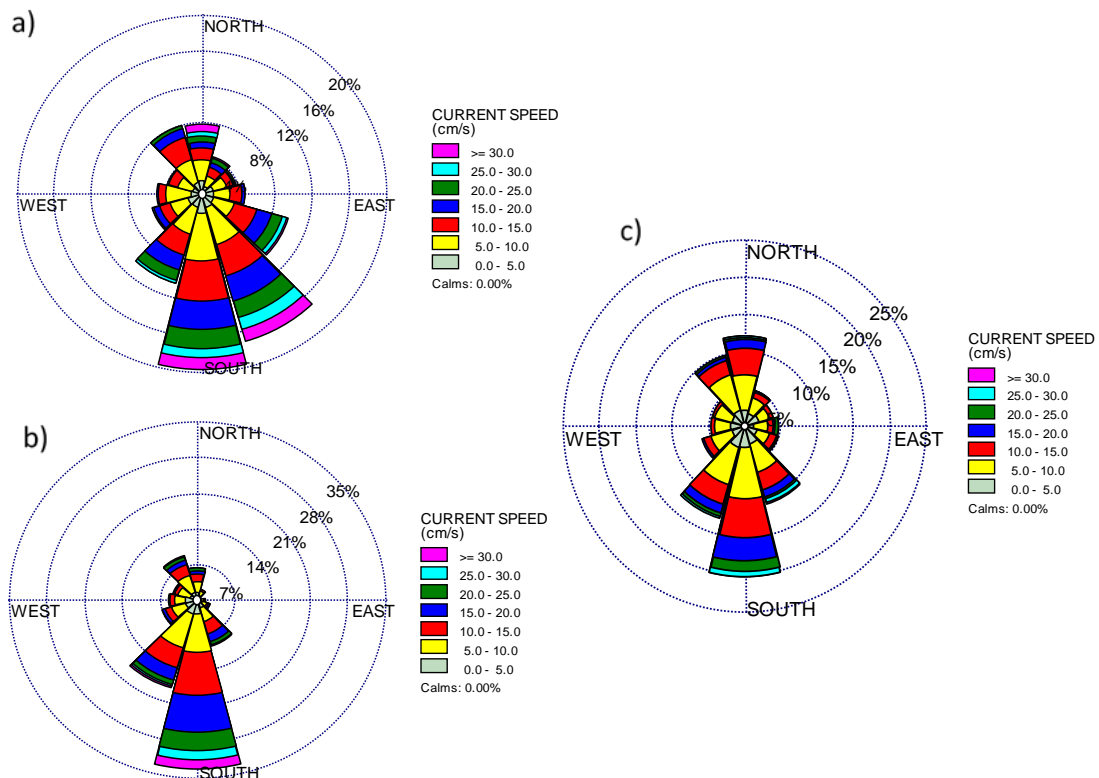


Figure 3 Current rose showing current direction and strength data measured during 2 February – 11 June 2013 at Algoa 1 for a) surface (2.9 – 5.4 m depth); b) mid-water column (10.4 – 12.9 m depth) and c) bottom (20.4 – 22.9 m depth). Note that the direction shows magnetic north.

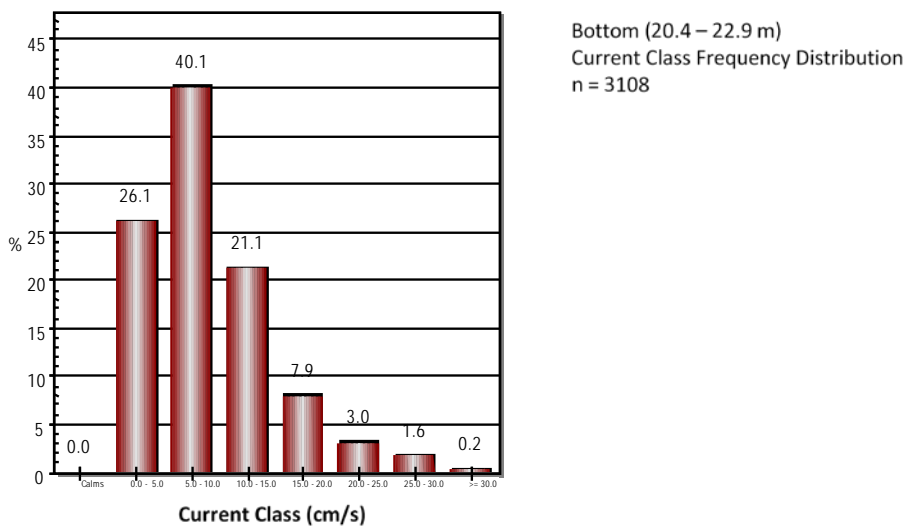
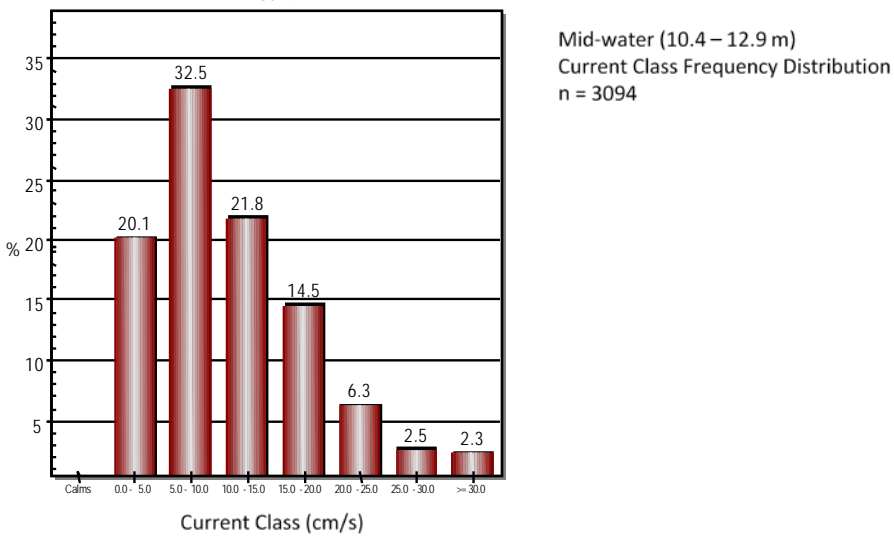
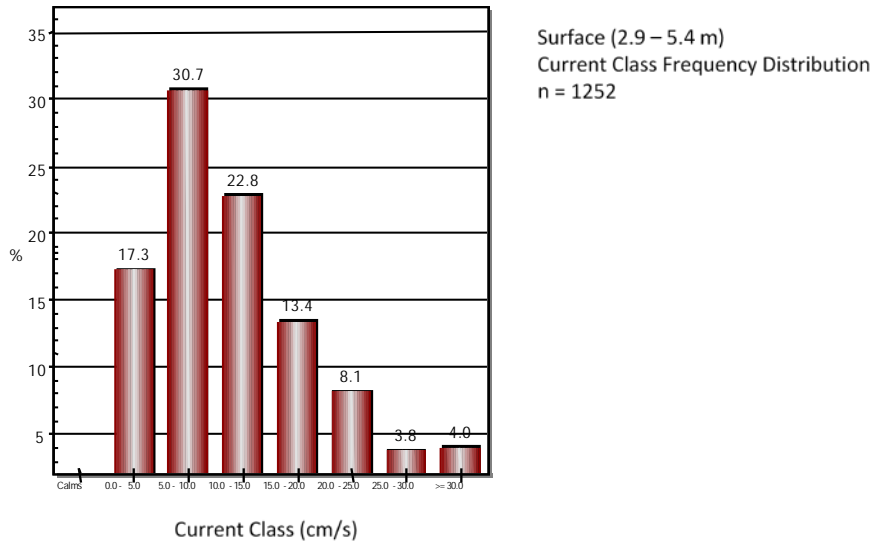


Figure 4 Frequency distribution showing current data measured during 2 February – 11 June 2013 at Algoa 1 for a) surface (2.9 – 5.4 m depth); b) mid-water column (10.4 – 12.9 m depth) and c) bottom (20.4 – 22.9 m depth).

2.1.2.4 Algoa 6

Research conducted by Schumann *et al.* (2005) highlighted the presence of two currents acting within the Algoa 6 site. Flow in the southern region is dominated by an offshore, east and east-north eastward flow of average speeds less than 4 cm.s^{-1} , with calm conditions ($<1 \text{ cm/s}$) occurring 41.5 % of the time. Conditions in the northern region of Algoa 6 are dominated by alongshore flow (south-north), predominantly in a northerly direction, with average current speeds of about 4 cm.s^{-1} and calm conditions occurring less frequently than in the south (only 9.5% of the time, Schumann *et al.* 2005).

2.1.2.5 Algoa 7

Currents measured at Algoa 2 (located 4km south of Algoa 7 and used as a proxy for this site) over an 11-month period flowed in south-westerly directions for approximately 30 % of the time at depths from the bottom (24 m) to the surface. When not flowing in a south-westerly direction, bottom and mid-water currents moved with similar frequency in ubiquitous directions. Contrastingly, dominant flow of surface currents from depths of 6.5 m upwards, moved in south-westerly and north-easterly directions (slightly less frequently towards the latter). These surface currents are likely to be wind driven. Current velocities rarely exceeded 30 cm.s^{-1} at all levels in the water column. Highest velocities were generally associated with currents flowing in the two most common directions (i.e. south-west and north-easterly flowing currents), and there was a general trend of decreasing current velocity with depth. Throughout the water column, most velocities (≈ 70 % of the time) ranged between $0 - 10 \text{ cm.s}^{-1}$, and for approximately 90 % of the time never exceeded 15 cm.s^{-1} (Figure 5),

Current velocities recorded at Algoa 2 over the sampling period indicated that calm conditions (current speed $<0.5 \text{ cm/s}$) were measured 0.4%, 0.6% and 0.1% of the time for the surface, mid-water and bottom respectively (Figure 6). Current velocities of $5 - 10 \text{ cm.s}^{-1}$ were measured 36.1% of the time at the surface, and 40.7% of the time mid-water and 44.4% of the time at the bottom (Figure 6). The maximum current speed recorded at the surface, mid-water and bottom were 40.7 cm.s^{-1} , 53.2 cm.s^{-1} and 40.6 cm.s^{-1} respectively (Figure 6). The minimum current speed recorded at the bottom was 0.1 cm.s^{-1} (Figure 6).

Significant wave height, defined as the average of the highest 1/3 of waves for a given period (in this case 8 min per every hour), approximated 1 m for 60 % of the time monitored, and was less than 2 m for 95 % of the time (Figure 7). Significant wave heights of 3.5 m or higher were experienced 1 % of the time. This equates to approximately 3 days (72.6 hr). The maximum significant wave height recorded was 5 m with a wave period of 13 seconds. Wave period approximated one wave every 12 seconds 41 % of the time, and generally ranged from 9 to 15 seconds (90 % of the time) (Figure 7).

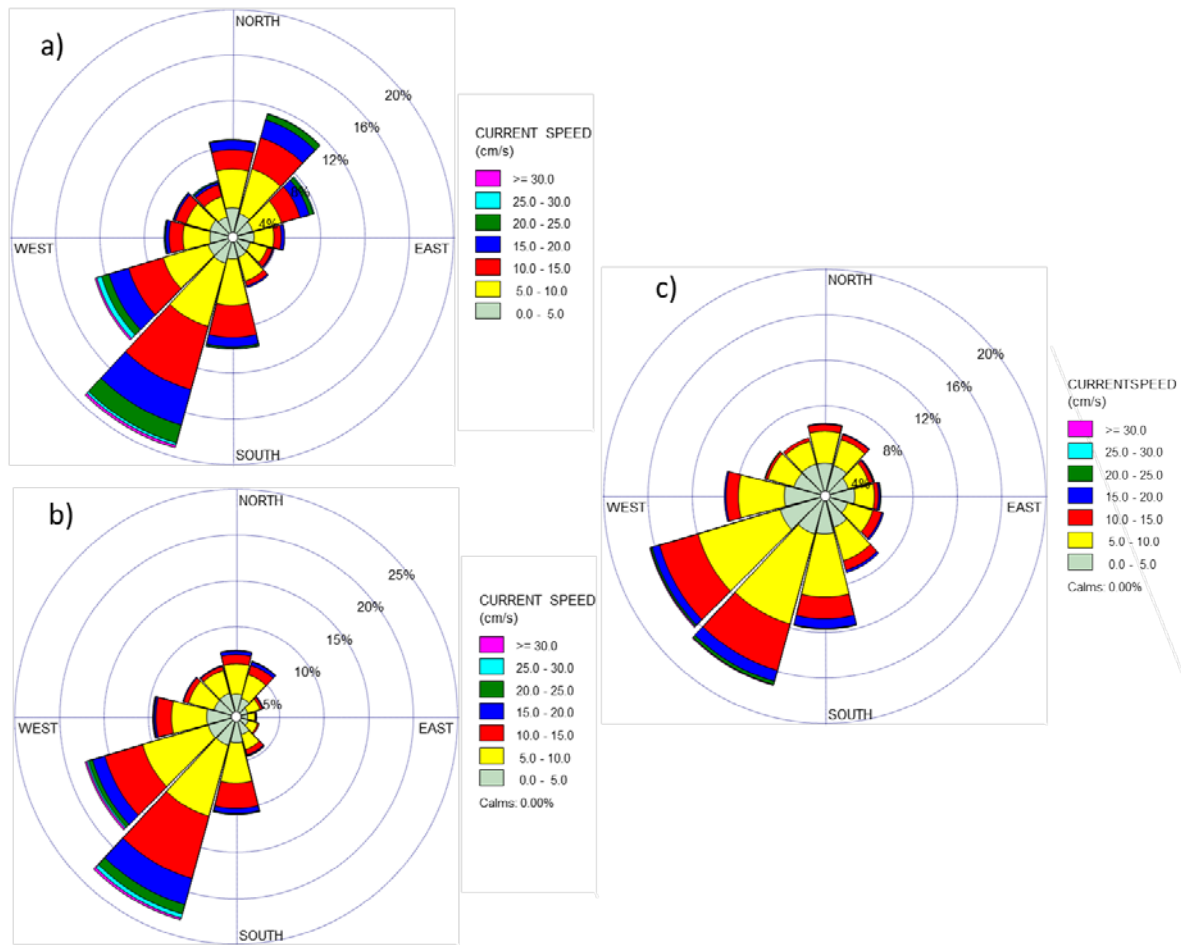


Figure 5 Current rose showing current direction and strength data for Algoa 7 for collected during February-November 2012 for a) surface (0-6 m depth); b) mid-water column (11.5 – 14 m depth) and c) bottom (21.5 – 24 m depth). Note that the direction shows magnetic north.

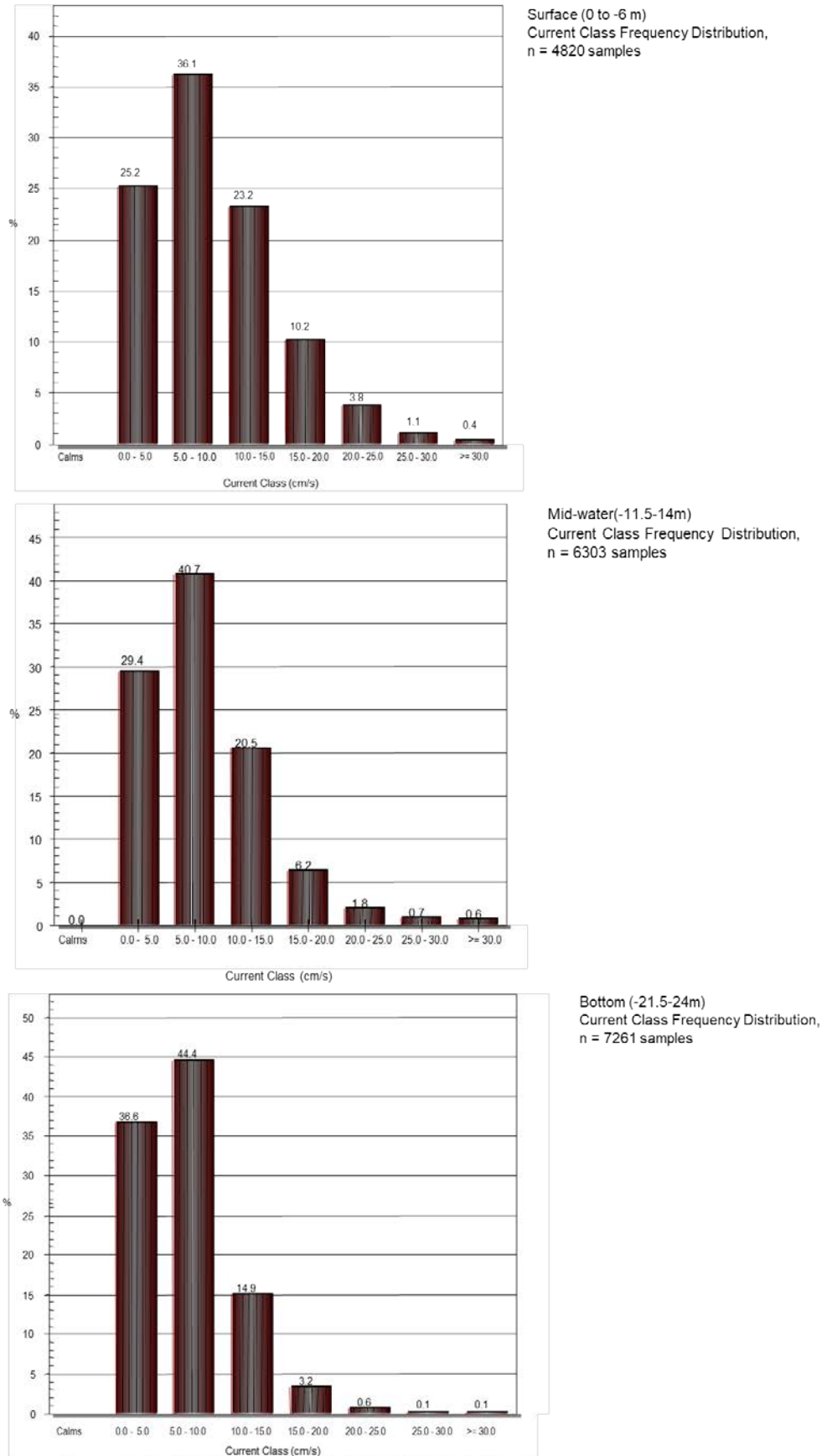


Figure 6 Frequency distribution showing current data for Algoa 7 for a) surface (0-6 m depth); b) mid-water column (11.5 – 14 m depth) and c) bottom (1.5 – 4 m depth).

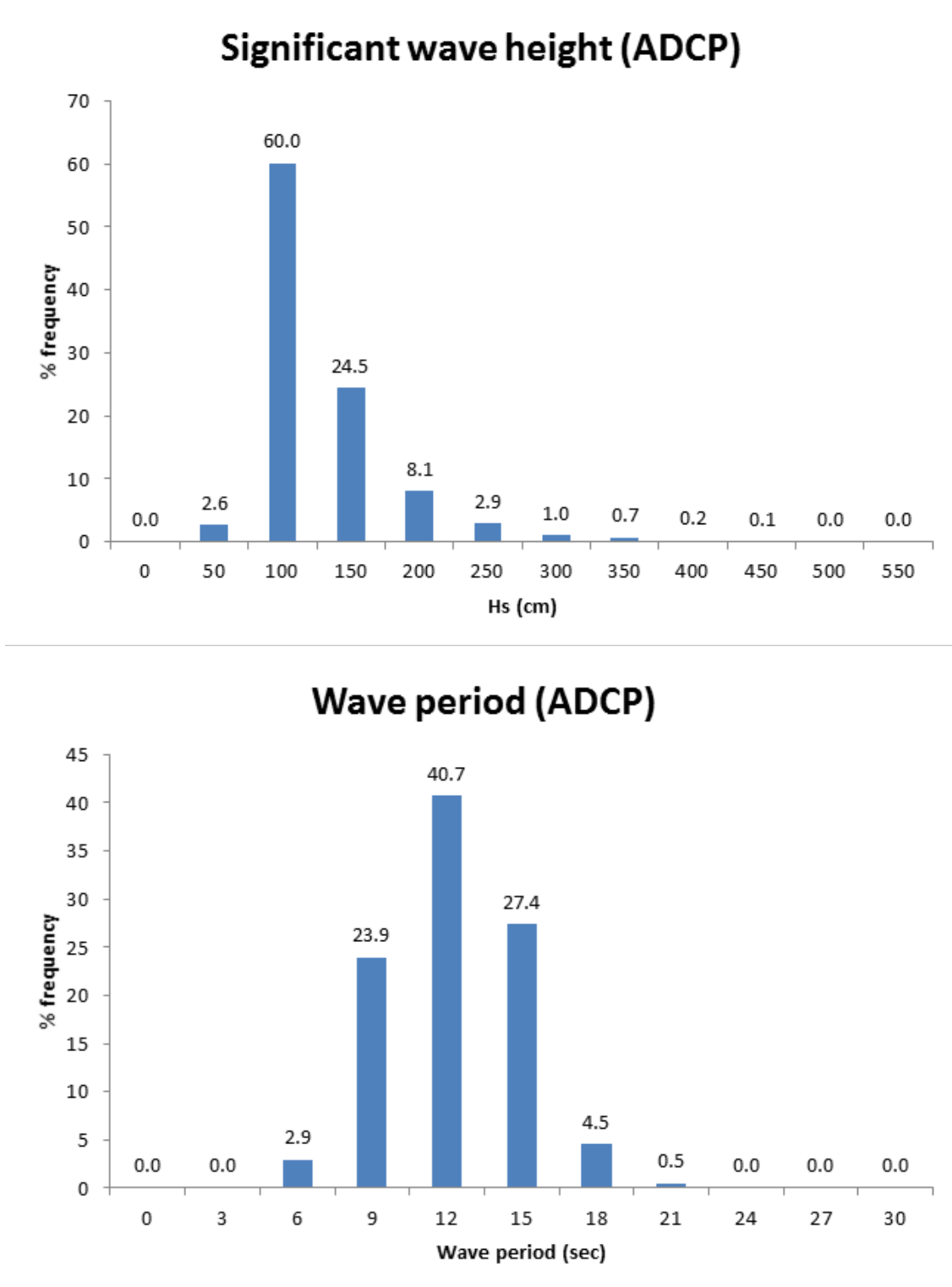


Figure 7 Significant wave height (top) and wave period (bottom) frequency distributions as recorded by ADCP moored in Algoa 2 for the period 20 February 2012 – 19 December 2012. The average significant wave height from an 8 minute sampling period every hour was recorded (n = 7 261 records). During this period, maximum significant wave height was 5 m (13 sec period).

2.1.2.6 Bathymetry and bottom type

Data on bathymetry and bottom type for Algoa 1 and Algoa 7 are presented below.

2.1.2.7 Algoa 1

Depth at Algoa 1 was found to range from 21.3 m at the inshore areas to 39.7 m further offshore (Figure 8), although this depth is deeper than the optimum depth for mussel and oyster production this can be overcome by the use of long lines. Depth gradients over the entire ADZ appear consistent and uniform, indicative of an area lacking in any reef.

No reef was detected according to bottom type analysis of the sediment at Algoa 1 either (Table 2). Sediments at Algoa 1 ranged from mean particle sizes per sample of 385.0 to 1362.5 μm and can be described as consisting of medium and very coarse sands. The percentage of total organic content comprising the sediments ranged from 2.27 to 5.04 %.

Table 2 Sediment results of bottom type from locations at Algoa 1.

Sample	Mean particle size (μm)	Sorting	Description (Folk & Ward method)	% Total Organic Content	Presence of reef
G1_1	385.0	Moderately Well Sorted	Medium Sand	3.06	No
G1_2	464.4	Moderately Well Sorted	Medium Sand	2.79	No
G1_3	1362.5	Moderately Sorted	Very Coarse Sand	5.04	No
G1_4	462.7	Poorly Sorted	Medium Sand	4.08	No
G1_5	402.0	Moderately Well Sorted	Medium Sand	2.49	No
G1_6	1730.8	Moderately Sorted	Very Coarse Sand	4.73	No
G1_7	668.5	Moderately Sorted	Medium Sand	2.27	No
G1_8	444.5	Moderately Well Sorted	Medium Sand	2.72	No
G1_10	1132.1	Poorly Sorted	Coarse Sand	4.62	No
G1_11	606.8	Poorly Sorted	Medium Sand	4.59	No
G1_12	1232.9	Poorly Sorted	Coarse Sand	4.05	No

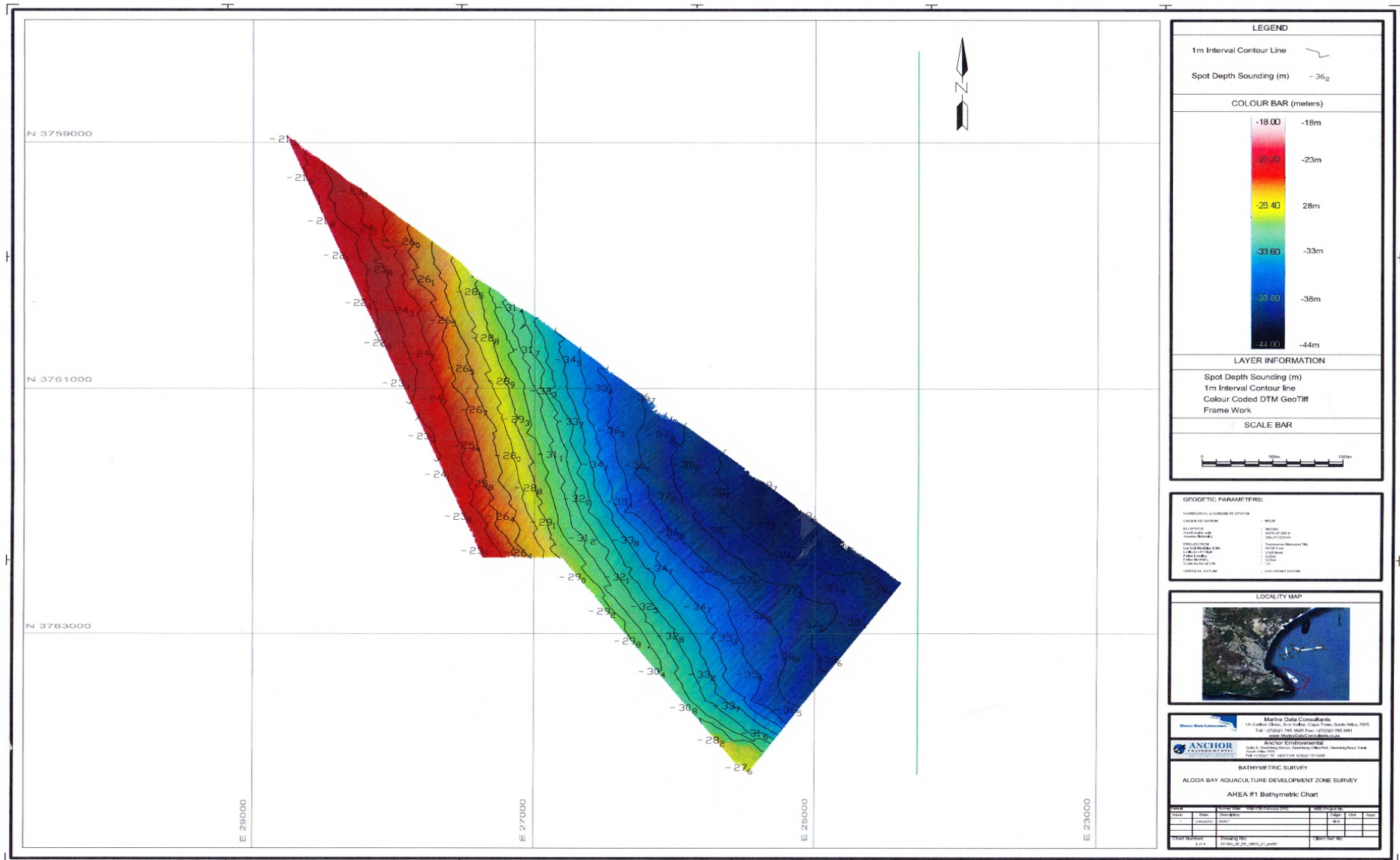


Figure 8 Bathymetry of Alga 1 (Source: Anchor Environmental Consultants 2013).

2.1.2.8 Algoa 6

Depth within Algoa 6 ranged from shallow (5.5 m) in the south-western corner to a maximum depth of only 13.2 m along the eastern boundary of the site. For the most part depth increased from the shoreline in the west to the eastern boundary of the site (Figure 9).

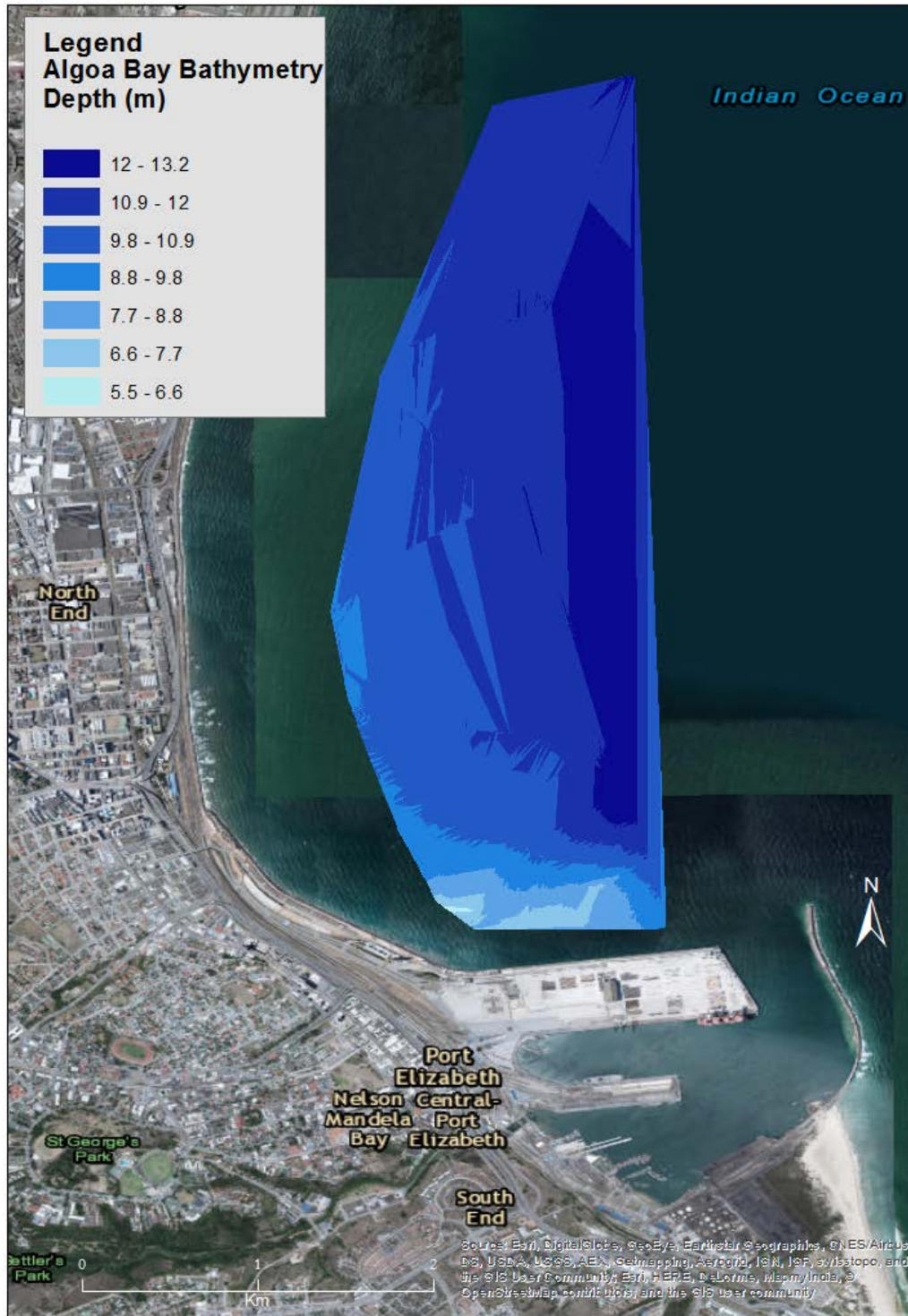


Figure 9 Bathymetry of precinct Algoa 6 of the proposed Algoa Bay Aquaculture Development Zone.

Sediment data for Algoa 6 comes from historical data collected for the I&J pilot fish-farming operation conducted in 2008/2009 (Table 3, only data from control sites F and S located 30 and 60 m from the cages was used (Nel & Winter 2009). Mean particle size (averaged from repeated samples collected during 2009) ranged from 203.2 - 220.4 μm across all sampling stations, therefore falling within the range of very fine sand (Folk & Ward 1957). Sediment samples were moderately to well-sorted and did exhibit a slight skewness to coarse sediments as a result of shell fragments. The average organic content ($n = 5$ for each site) of all sites ranged from 0.84 to 2.24 %, and were fairly stable over time. There was no reef recorded in the Algoa 6 substrate.

Table 3 Sediment results of bottom type from locations in Algoa 6, taken from control sites S and F in Nel and Winter 2009.

Sample	Mean particle size (μm)	Description (Folk & Ward method)	% Total Organic Content	Reef
F1	210.6	Fine Sand	1.85	No
F2	207.4	Fine Sand	1.82	No
F3	210.8	Fine Sand	1.74	No
F4	213.1	Fine Sand	1.63	No
F5	205.1	Fine Sand	1.52	No
F6	209.6	Fine Sand	1.82	No
F7	210.6	Fine Sand	1.55	No
F8	203.1	Fine Sand	1.58	No
S1	209.7	Fine Sand	1.56	No
S2	212.6	Fine Sand	1.52	No
S3	216.1	Fine Sand	1.36	No
S4	216.3	Fine Sand	1.20	No

2.1.2.9 Algoa 7

Depth at Algoa 7 was found to range from 18 m at the inshore, north-western corner of the area to 31 m further offshore, in the south-eastern corner of the area (Figure 10). Depth gradients over the entire ADZ appear consistent and uniform, indicative of an area lacking in any reef. This was supported by sediment data which showed an absence of any rock or reef within samples.

Indeed, sediment samples within Algoa 7 were more uniform than any other site. Sediments ranges from mean particle sizes per sample of 188.8 to 324.0 μm and can be described as consisting of fine sand throughout all sampled sites (reflecting the weaker currents found here compared to Algoa 1). The percentage of total organic content comprising the sediments ranged from 2.18 to 3.64 % (Table 4). For the purposes of future referral, the values of trace metals within the sediment can be found in Table 5 with locations of sampling stations seen in Figure 2.

Table 4 Sediment results of bottom type from locations at Algoa 7.

Sample	Mean particle size (μm)	Sorting	Description (Folk & Ward method)	% Total Organic Content	Reef
A7_1	226.7	Moderately Sorted	Fine Sand	2.43	No
A7_2	212.1	Moderately Sorted	Fine Sand	2.70	No
A7_3	201.2	Moderately Sorted	Fine Sand	2.74	No
A7_4	276.6	Poorly Sorted	Fine Sand	3.11	No
A7_5	324.0	Poorly Sorted	Fine Sand	3.64	No
A7_6	312.9	Moderately Sorted	Fine Sand	3.08	No
A7_7	266.1	Moderately Sorted	Fine Sand	2.98	No
A7_8	286.1	Moderately Sorted	Fine Sand	2.18	No
A7_9	236.7	Moderately Sorted	Fine Sand	2.40	No
A7_10	265.2	Moderately Sorted	Fine Sand	2.27	No
A7_11	188.8	Moderately Sorted	Fine Sand	2.26	No
A7_12	238.5	Moderately Sorted	Fine Sand	2.81	No

Table 5 Trace metals present in sediment samples collected during October 2018 from Algoa 7

Sample #	Al (ppm)	As (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Hg (ppb)
A7 - 1	2330	6.3	0.2	9.2	<0.5	3736	2.2	5.3	5.0	74.1
A7 - 2	3074	4.4	0.2	9.9	<0.6	4975	2.7	4.2	5.9	63.2
A7 - 3	2789	5.6	0.2	8.3	<0.7	4720	2.7	3.1	5.2	<20
A7 - 4	4724	7.7	0.3	13.2	<0.8	7032	3.4	4.3	9.4	43.4
A7 - 5	5497	7.2	0.4	15.0	0.7	7806	3.9	4.5	12.5	29.8
A7 - 6	2888	7.7	0.3	13.7	0.7	4665	2.6	5.1	10.3	33.5
A7 - 7	4797	5.5	0.3	11.7	0.9	5313	3.1	4.3	7.6	43.2
A7 - 8	2281	6.1	0.3	9.5	<0.5	4017	2.0	3.2	5.7	26.5
A7 - 9	2028	6.7	0.2	8.8	<0.5	3932	2.2	2.7	4.8	30.3
A7 - 10	4980	6.4	0.4	13.0	0.7	5944	3.4	3.0	9.6	33.8
A7 - 11	4266	6.0	0.3	13.5	<0.5	6371	3.1	4.9	9.7	60.8
A7 - 12	5085	7.1	0.4	12.3	<0.5	7405	3.7	4.2	10.6	63.1

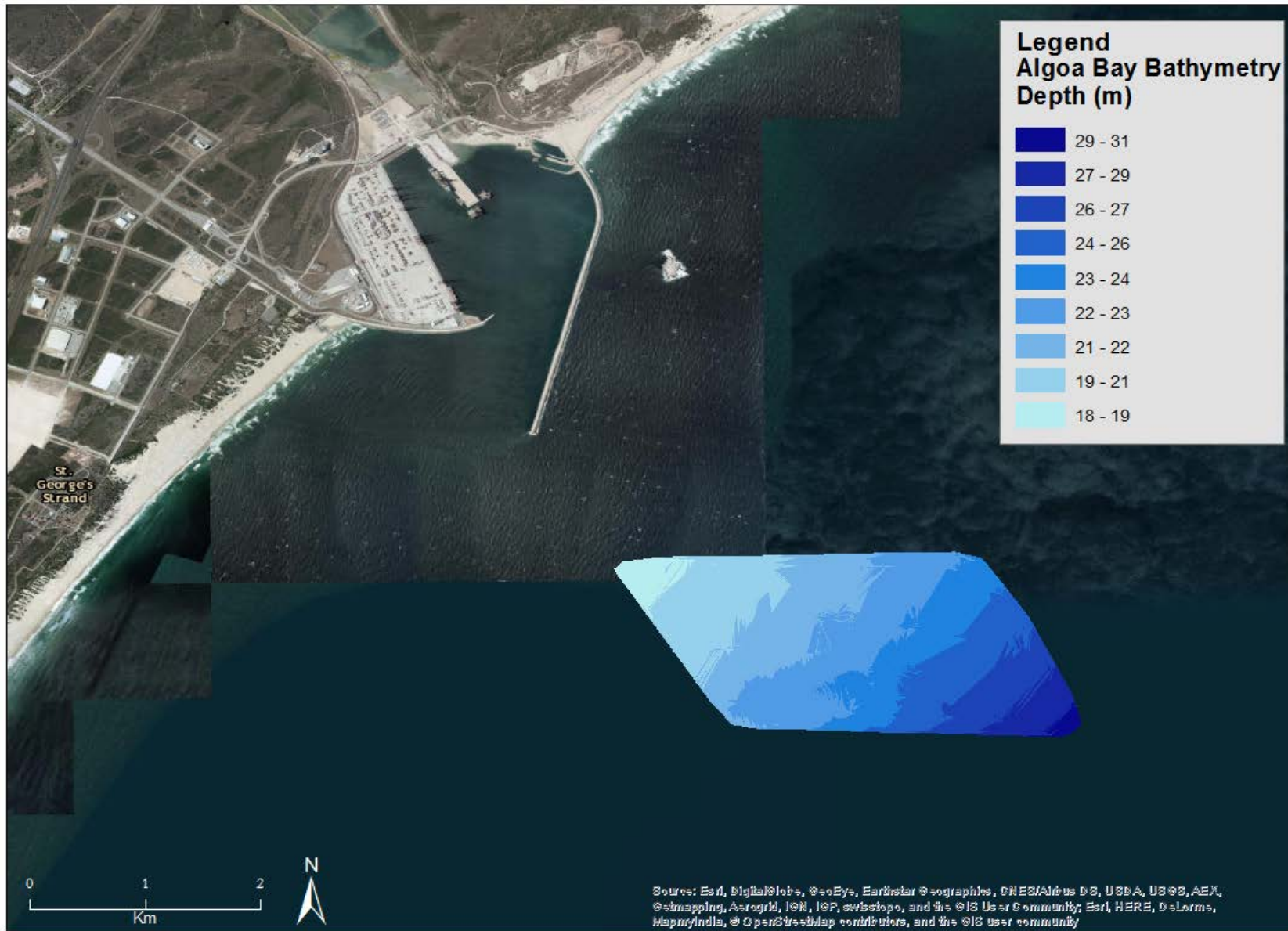


Figure 10 Bathymetry of precinct Algoa 7 of the proposed Algoa Bay Aquaculture Development Zone.

2.1.2.10 Sediment and Benthic macrofauna

Marine environments are known to include some of the most diverse ecosystems globally however, there is a gap in the knowledge available on coastal sedimentary habitats (Costello 2010). Recent research within Algoa Bay suggests the Bay is home to an extraordinary invertebrate diversity which may include several novel, previously undescribed taxa (Dorrington *et al.* 2018). In line with this, a study on nearshore macrobenthic fauna conducted in 2008 and 2009 reported a high overall species count of 187 species from 137 different genera (Masikane 2011). This study investigated natural variation in the community structure and spatial distribution of benthic macrofauna assemblages and sediment quality within Algoa Bay. For the purposes of the mariculture EIA's, two proposed precincts (Algoa 1 and Algoa 7) were sampled to determine and compare benthic sediment and macrobenthic community composition, the results are compared to historical data at a third site (Algoa 6). An overall count of 1454 individuals from grab samples of Algoa 1 and 7 were examined and identified. Included were 158 species, 85 genera, 63 families, 19 orders and 11 classes. The Algoa 6 site is proposed for bivalve production while Algoa 1 is proposed for finfish and/or bivalve culture and Algoa 7 is proposed for finfish only. These results provide information that can assist in the assessment of benthic impacts at the different sites, as well as providing baseline benthic community and habitat data against which future (post development) monitoring results can be benchmarked.

The composition of sediment percentage grain fractions of the two proposed finfish precincts (Algoa 1 and Algoa 7) differed significantly between sites (PERMANOVA pseudo $F_{1,214} = 11.18$; $p = 0.001$). Multivariate dispersion tests showed increased variability in percentage grain fractions at Algoa 1 (3.03 ± 0.24 SE) relative to the lower variability seen at Algoa 7 (1.68 ± 0.13 SE). The MDS ordination (Figure 11) visually supported these results, displaying a distinct clustering of samples from Algoa 7, with samples from Algoa 1 displaying greater dispersion.

The mean particle size among the sites (including Algoa 6) differed significantly (Figure 12; ANOVA, $F_{2,34} = 49.74$; $p < 0.001$) with post-hoc tests revealing that sediment mean particle size at Algoa 1 differed from Algoa 6 and 7, the latter two having similar particle size distributions. The total organic content was significantly different amongst sites (Figure 12; ANOVA, $F_{2,34} = 50.58$; $p < 0.001$), mean total organic contents differed between all three sites (Post-hoc Tukey $p < 0.05$).

Total organic content is related to sediment grain size, with a higher content correlating with increased surface area of smaller particle sizes (Bergamaschi *et al.* 1997). In light of this, percentage composition of sediment fractions showing a slightly higher proportion of mud within Algoa 1 (Figure 13) provides a potential explanation for the increased total organic content values, relative to Algoa 7, despite Algoa 1 having higher mean particle sizes (coarser sediment in general) (Figure 12). The combination of low within site variation in sediment percentage grain fractions, finer sediment particle size and the reduced total organic content at Algoa 7; suggests that the habitat is more homogenous, exhibiting less natural sedimentary variation than the alternative sites.

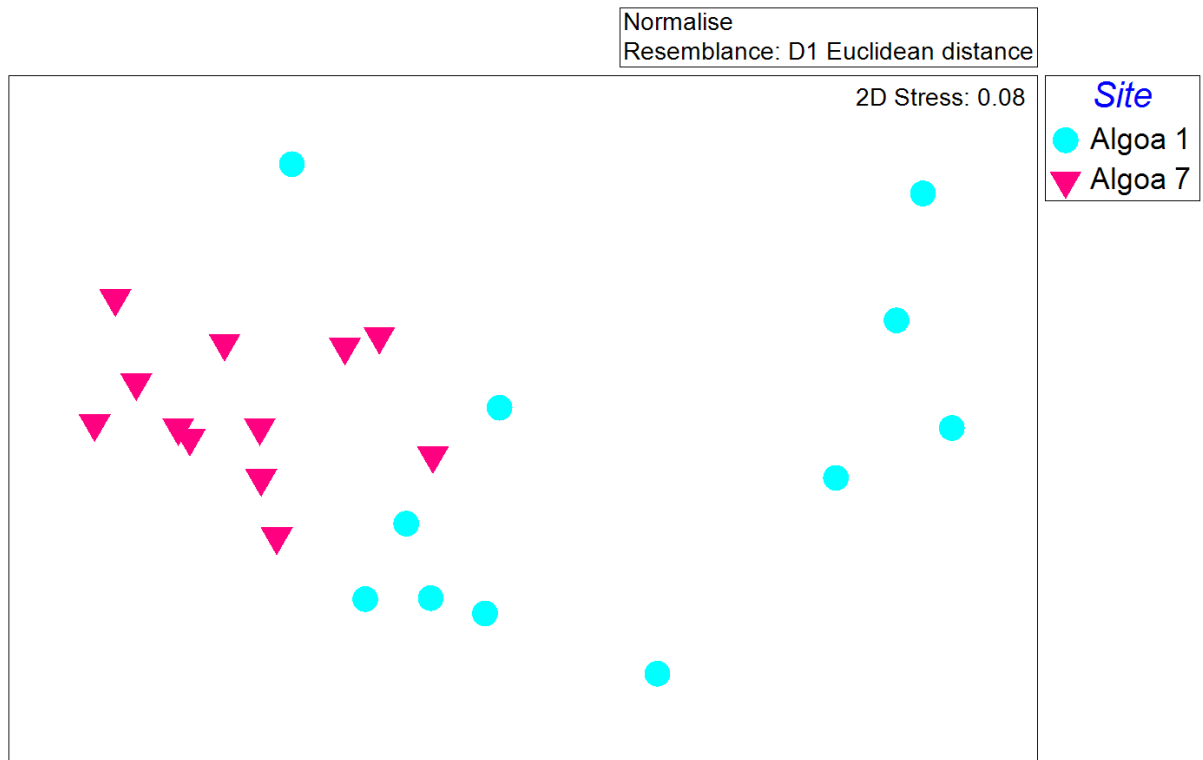


Figure 11 Multidimensional scaling ordination (MDS) showing spatial variation in sediment composition, between sites, based on data from GRADISTAT V8.0 (Blott 2008).

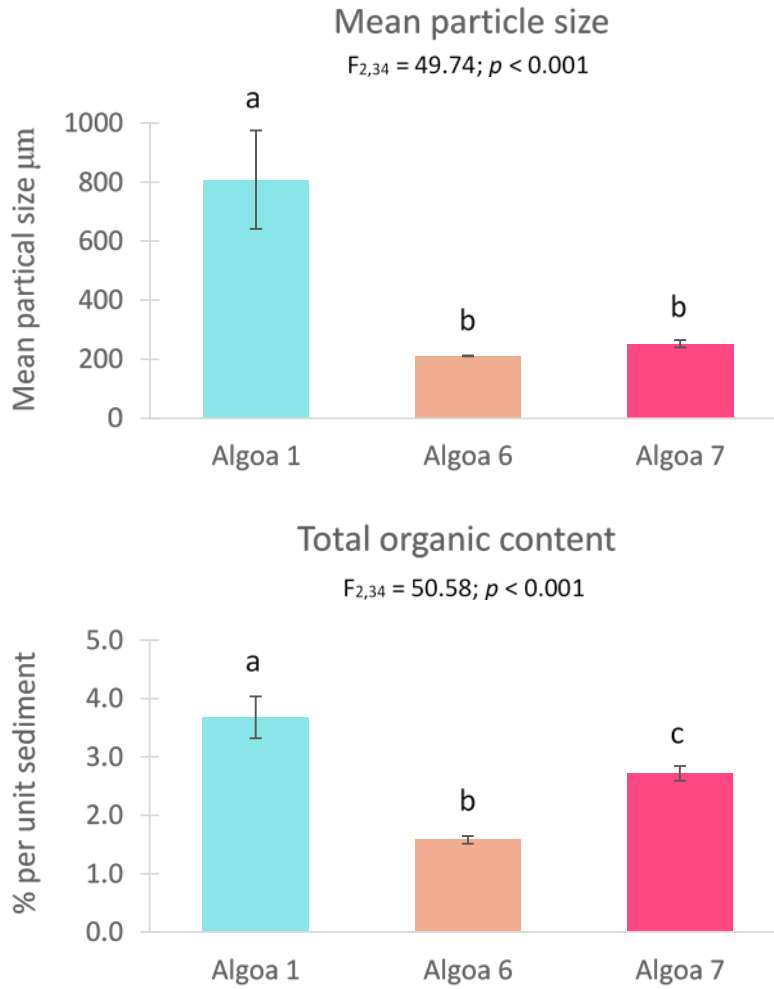


Figure 12 Comparisons of sediment mean particle size (top) and total organic content (bottom) for all precincts taken forward into the Basic Assessment process for the proposed Aquaculture Development Zone in Algoa Bay.

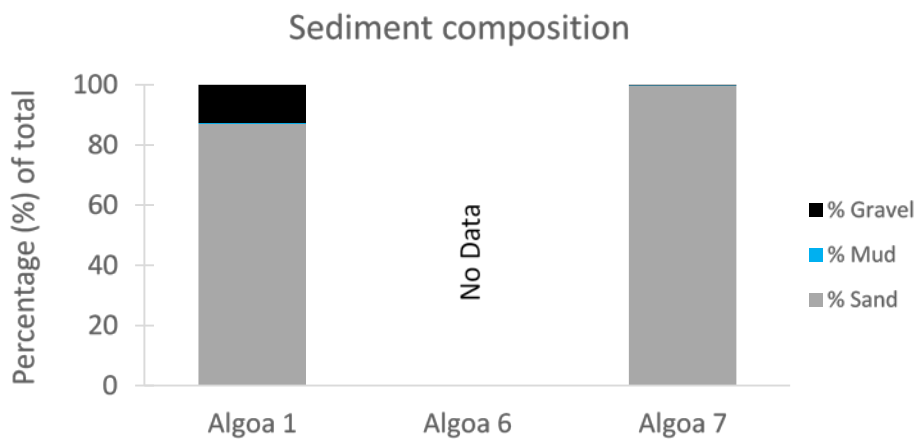


Figure 13 Percentage contributions of gravel (>2000 µm), sand (63 - 1000 µm), and mud (< 63 µm) in sediment samples for Algoa 1 and 7 of the proposed Aquaculture Development Zone in Algoa Bay.

Macrofaunal community descriptors showed little difference amongst the proposed finfish precincts (Figure 14). Patterns for diversity, evenness and taxonomic richness among the sites were similar, indicating that although values of these descriptors differed significantly among sites (ANOVA, Diversity: $F_{2,26} = 13.67$; $p < 0.001$, Evenness: $F_{2,26} = 17.49$; $p < 0.001$ and richness: $F_{2,26} = 26.92$; $p < 0.001$) the only significant comparisons responsible for the differences in all cases were between Algoa 6 and the remaining two sites (Post-hoc Tukey $p < 0.05$). Total abundance and biomass did not differ significantly among sites (ANOVA, Abundance: $F_{2,26} = 1.87$; $p = 0.174$, Biomass: $F_{2,26} = 1.451$; $p = 0.243$).

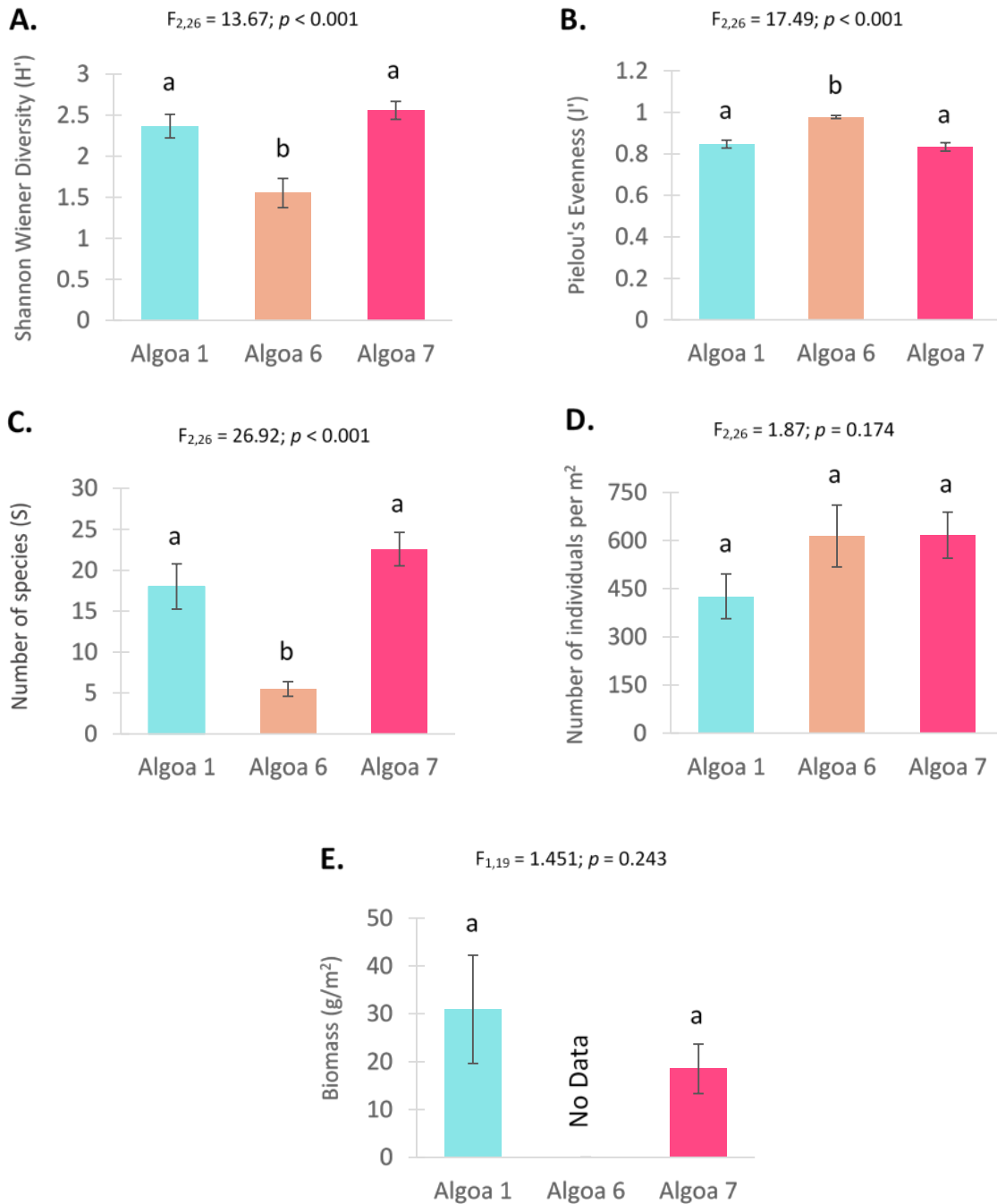


Figure 14 Variation in macrofaunal community descriptors A. Diversity, B. Evenness, C. taxonomic richness, D. Abundance (individuals/ m^2) and E. Biomass (g/m^2) for all proposed precincts. Values are means \pm 1 SE. Letters represent Post-hoc Tukey pairwise comparisons where similar letter indicate homogeneity or no significant differences between sites.

Multivariate analyses have been shown to be more powerful and successful than univariate analyses in identifying community changes or differences, specifically in response to disturbance (Gray et al. 1990, Warwick & Clarke 1993). In this regard, multivariate analyses of community structure of macrofaunal assemblages, based on species abundance data, showed statistically significant differences among sites (PERMANOVA pseudo $F_{2,26} = 6.19$; $p = 0.001$, with pairwise PERMANOVA showing significant differences between all sites). Results of PERMANOVA were visually supported by MDS ordinations (Figure 15), which show a spatial separation of the macrofaunal community structure of all sites. Multivariate dispersion tests showed that community abundance at Algoa 6 and Algoa 7 was less variable (PERMDIST, Algoa 6: 46.12 ± 3.21 SE; Algoa 7: 48.32 ± 1.69 SE), than the variability of abundance at Algoa 1 (PERMDIST, Algoa 1: 60.29 ± 1.57 SE). This was supported visually by the closer clustering of sample points for Algoa 6 and 7 relative to Algoa 1 (Figure 15).

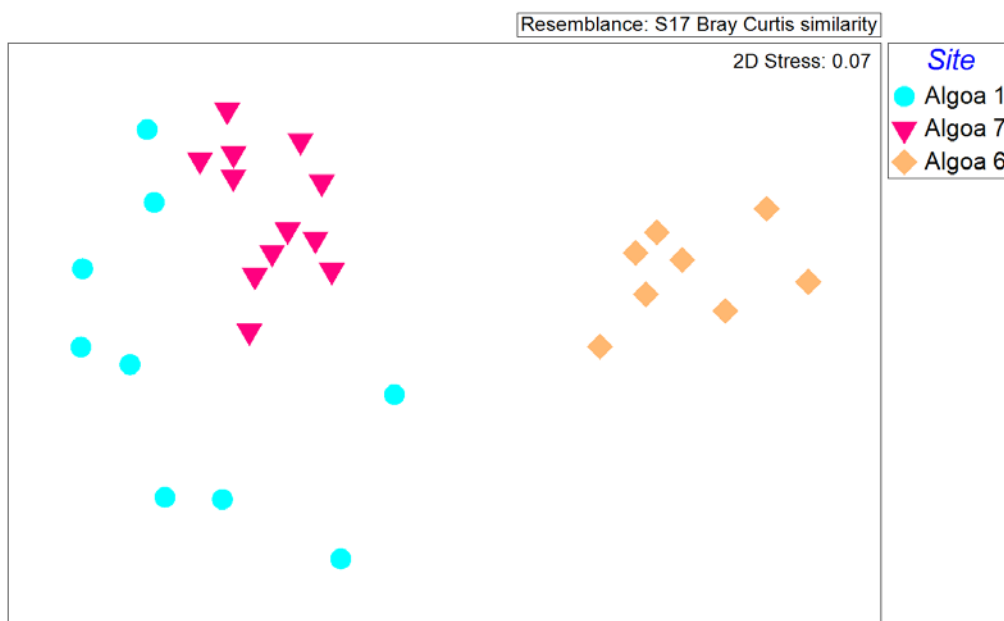


Figure 15 Multidimensional scaling ordination (MDS) showing spatial variation in macrofaunal community structure, between sites, (based on abundance data) including historical data from Algoa 6.

SIMPER was used to determine the level of similarity within samples from the same site and dissimilarity between sites. Average similarity at Algoa 1 was low (10.28 %), an expected outcome given the greater dispersion within this site. Species that cumulatively contributed to 50 % of the similarity within this group included, *Ampelisca brevicornis*, *Mandibulophoxus stimpsoni*, *Magelona cincta* and *Photis longidactyla*. Algoa 6 had the highest average similarity of 30.15 %, with a single group, the brittle stars, responsible for contributing 52 % of the overall similarity within this site. Four species cumulatively contributed to 50 % of the higher similarity value seen within Algoa 7 (29.31 %), these include: an unidentified Nemertea species, and polychaetes *Scolaricia dubia*, *Magelona cincta* and *Mediomastus capensis*. These results align with those of the dispersion tests showing that within site variability was greatest at Algoa 1, with Algoa 6 and 7 less variable and therefore more similar.

Despite the fact that univariate analyses indicated abundance not differing significantly between site, SIMPER analyses show very high average dissimilarities between sites, with 92.16 % between the two finfish sites (Algoa 1 and 7), while dissimilarity values between Algoa 6 and finfish sites were both greater than 99 %, supporting the suggestion that comparisons between these sites should be limited to higher taxonomic resolutions.

It is important to note that the historical data for Algoa 6 does not include biomass data and the sampling techniques employed at this site varied substantially from those employed at the other two sites. More specifically, the size of the core/grab used to collect the benthic macrofauna differed, 0.0038 m² for Algoa 6 as compared to 0.1428 m² for all other sites. In addition, Algoa 6 cores were collected by scuba divers who included *in situ* observational counts of epibenthos (such as Echinodermata, sea pens and anemones). Samples for the other two sites were collected using a Van Veen grab from aboard a boat. Also of importance, for the purposes of the I&J pilot study for which the data were collected, the Algoa 6 macrofauna was only identified into broad taxonomic groups (Polychaetes, echinoderms, Amphipods) while identification of macrofauna from Algoa 1 and 7 were identified to the highest possible taxonomic level possible. Therefore, comparisons at a higher taxonomic level, such as those below, may be more appropriate when comparing Algoa 6 with the remaining two finfish sites. In line with this, it is recommended that for improved comparative strength, future monitoring efforts should employ standardised field and laboratory methods.

At a higher taxonomic level (class and order) all three sites differed. At Algoa 1 taxonomic compositions highlighted both Amphipoda and Polychaeta as the most important groups in terms of abundance (see Figure 16). While the most abundant groups at Algoa 6 were the Echinodermata followed by Polychaeta and Decapods in almost equal proportions. Unique to Algoa 7 is the complete dominance of Polychaeta, contributing 69 % to the overall abundance.

Masikane (2011) conducted a study of nearshore (10 m depth contour) macrofaunal communities within Algoa Bay which also used Van Veen grab samples and identified macrofauna to the finest possible taxonomic resolution. The results of broad taxonomic composition for sites located inshore of the proposed precincts are shown in Figure 17 with their locations relative to the proposed ADZ zones shown in Figure 18. The variation of taxonomic composition seen within and between sites from 2008, 2009 and the results of the current study are in line with previous research reporting a measure of natural temporal and spatial variability in macrobenthos over relatively small scales (Morrisey et al. 1992a, 1992b).

The taxonomic composition of Algoa 1 is similar to that of the corresponding nearshore site (Site 6) in both 2008 and 2009 (i.e. Amphipoda and Polychaetes were dominant and contributed over 50 % to the total abundance). The present data for Algoa 6 and Algoa 7 do not, however, match that of the two nearshore sites with which they correspond. The variation in the taxonomic composition of Algoa 6 is possibly an artefact of the differing sampling methods, as diver observations of epibenthos may over-estimate the abundance of taxa, such as Echinoderms, relative to Van Veen grab samples. In contrast, relative depth (10 m at Site 2 compared to a range of 18 – 31 m at Algoa 7) or sediment composition (predominantly medium sand as compared to fine sand respectively) may explain the differences between Site 2 and Algoa 7.

Interestingly, community composition of Algoa 7 better matches that of Site 4 (a disturbed area), especially in 2008, where Polychaetes contributed significantly more to overall abundance than all other taxa (Figure 16 and Figure 17). In addition, the percentage contribution of Echinoderms, a taxa know to be sensitive to disturbance (Warwick and Clarke 1993, Swartz *et al.* 1986), dropped from 12 % in Algoa 1, to only 3 % in Algoa 7, suggesting that the macrofaunal community at Algoa 7 is experiencing some level of disturbance.

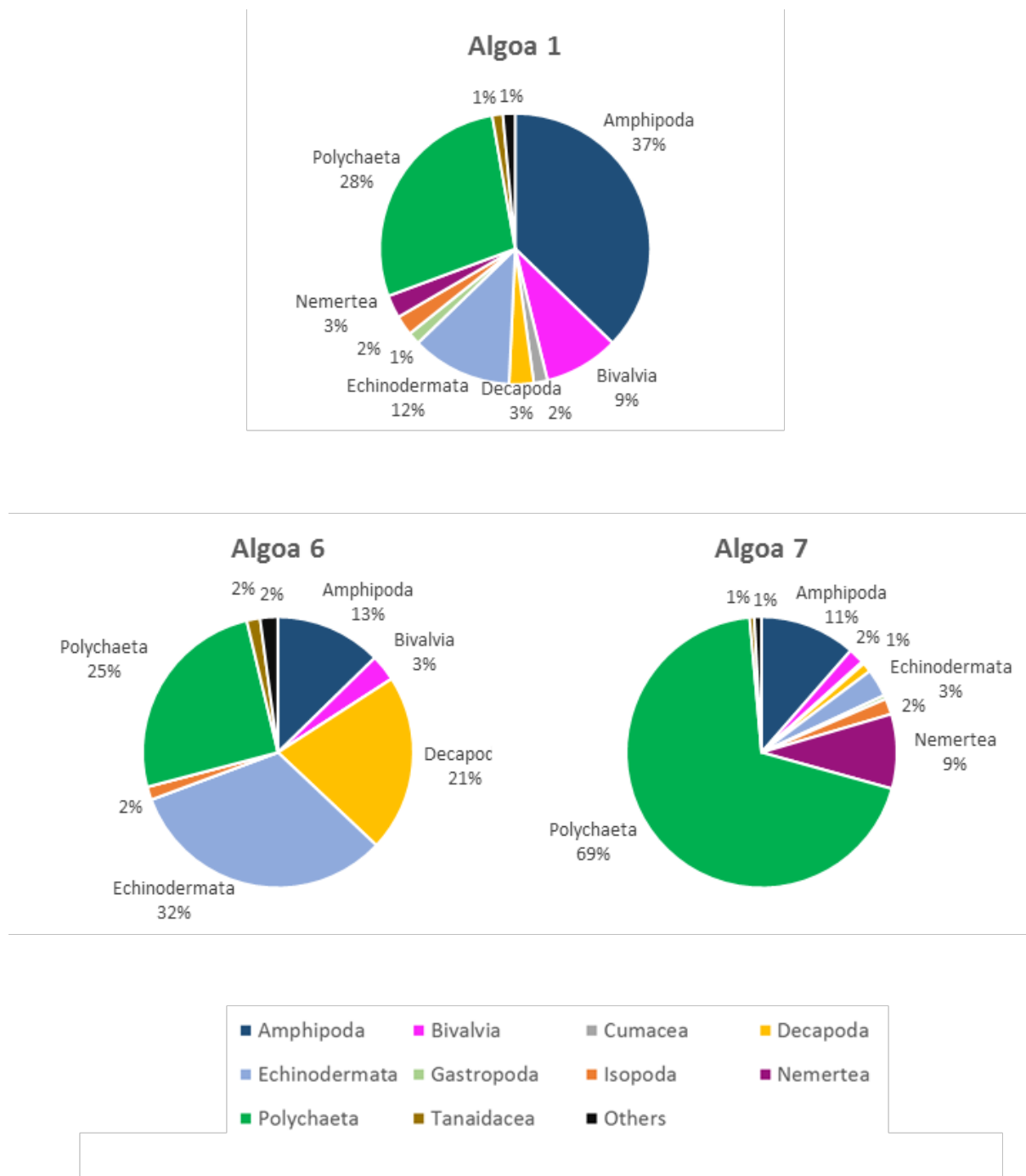


Figure 16 Taxonomic composition and most abundant groups for the community assemblages at all proposed Precincts. Other is a combination of smaller, least abundant or rare groups, including Anthozoa, Cephalochordata, Hydrozoa, Ostracoda, Pennatulacea, Polyplacophora, Scleractinia and Turbellaria. Decapoda were represented by brachyuran and anomuran crabs, shrimps and prawns.

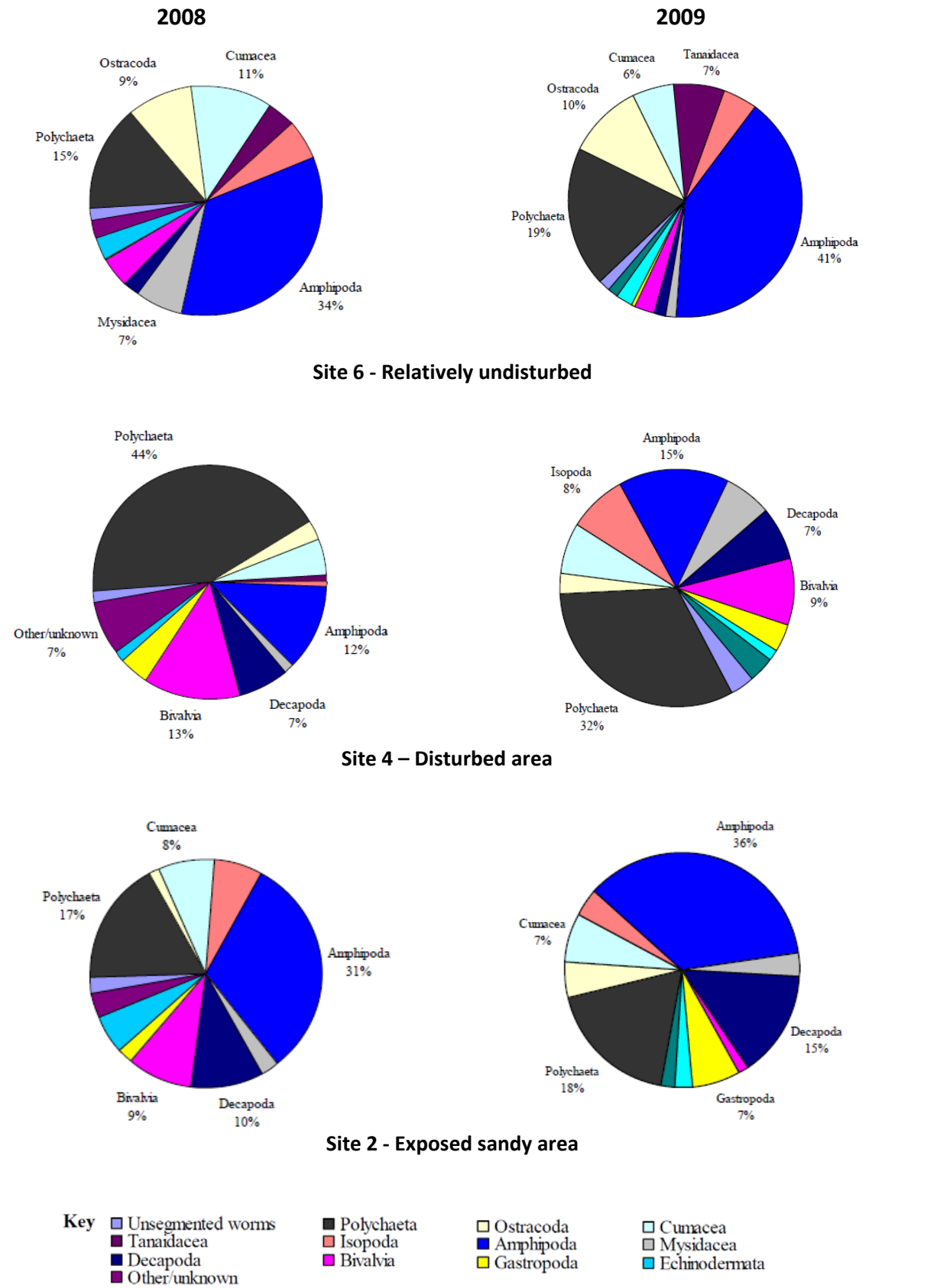


Figure 17 Taxonomic composition of sites located in shallow nearshore sites adjacent to proposed precincts: site 6 – located west of Algoa 1; Site 4 – a disturbed site located west of Algoa 6 and Site 2 located west of Algoa 7 (Modified from Masikane 2011 see Figure 18).

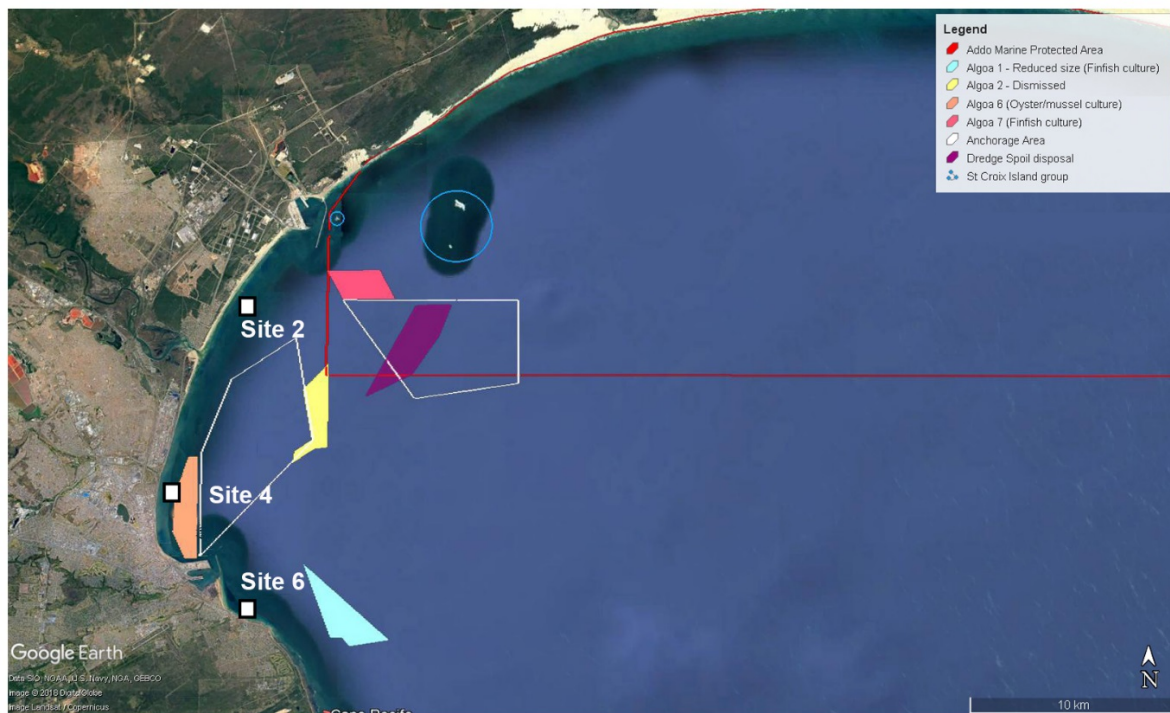


Figure 18 Map of Algoa bay showing the location of the dredge spoil disposal site and sample sites of macrobenthic collection from Masikane 2011 relative to the precincts of the proposed Aquaculture Development Zone in Algoa Bay.

Cumulative abundance-biomass plots of macrobenthic communities (Warwick 1993), also called k-dominance curves, were plotted to visually assess patterns of abundance and biomass in the proposed sites (Warwick 1993, see Figure 19). Algoa 1 exhibited responses indicative of stable conditions, where the frequency or intensity of disturbance is low. In this site k-selected (larger, long-lived species) make an important contribution to community structure (Warwick 1993) and while they seldom dominate numerically, these species usually provide the largest contribution to biomass. Smaller r-selected, opportunistic species with a shorter life-span are also represented, and usually dominate numerically but make a small (often insignificant) contribution to overall biomass (Warwick 1993). When cumulative contributions by species to overall abundance and biomass are plotted together on the same graph, in the case of undisturbed communities, the curve for biomass generally lies above the curve for abundance for its entire length, this is the case for samples within Algoa 1 ($W = 0.333$ - Figure 19). Under moderate or low levels of disturbance, the large competitive species are eliminated and the inequality between abundance and biomass dominants is reduced so that the curves coincide closely and may cross one another. The ABC curve produced for Algoa 7 appears to be approaching this state (Figure 19) and the lower W – statistic (0.147) suggests that abundance is becoming patchier, with many species contributing to overall biomass. This supports the previous assumption that the macrofaunal community at Algoa 7 may be experiencing some minor disturbance.

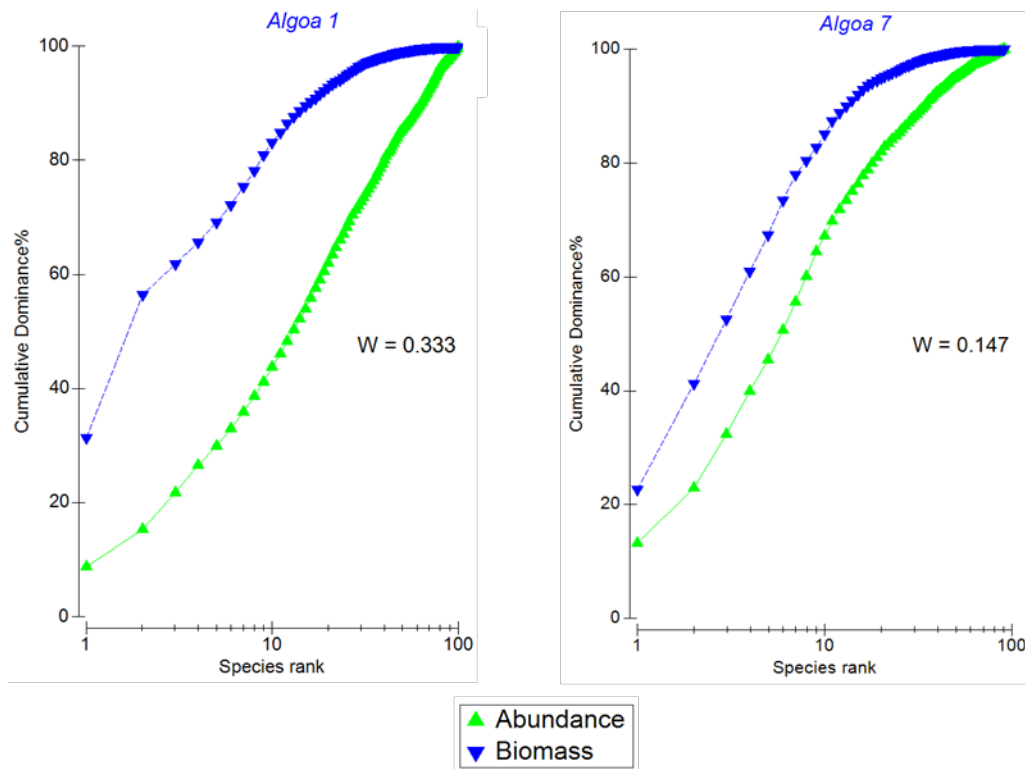


Figure 19 Abundance-Biomass Comparison (ABC) curves (Warwick 1993) for precincts Algoa 1 and 7 of the Algoa Bay Aquaculture Development Zone.

Benthic sediment parameters, grain size in particular, are recognised as principle factors influencing benthic macrofaunal community structure and distribution (Gray 1974; Snelgrove & Butman 1994). The sediment composition of Algoa 7 differed from that of Algoa 1, consisting mostly of fine sand and yet having a low mud content. This is potentially due to its proximity to the dredge spoil disposal site for the Port the Coega, which is located south east of Algoa 7 (Figure 18). The natural/undisturbed suspended sediment concentrations within the Bay generally average less than 5 mg/l, however values as high as 30 mg/l have been recorded in bottom waters (Schumann and Campbell 1999). Records show that dredging and the disposal of dredge spoil from the Port did not alter adjacent, surface water suspended sediment concentrations (turbidity) appreciably. However, the bottom water concentrations were generally between 2 to 7 times higher post dredging (Carter 2014). This increased turbidity can be attributed to the fact that finer sediment from the dredge spoil is easily re-suspended within the water column (Klages and Bornman 2005b). Modelling of the dredge disposal conducted to determine the possible impacts of dredging and spoil disposal reported that the suspended sediment threshold level of 20 mg/l occurred most often on the seabed and could persist for as long as 30 days after dumping occurred (Figure 20).

Algoa 7 is located outside the range of the modelled plume of influence, however, re-suspended fine sediment from this site may have had a limited impact on sediment composition and subsequently, macrobenthic community structure at this site. It is important to note however, that previous benthic monitoring reports could not unequivocally attribute localised macrofaunal community variability due to dredging and dredge spoil disposal activities (Carter 2014).

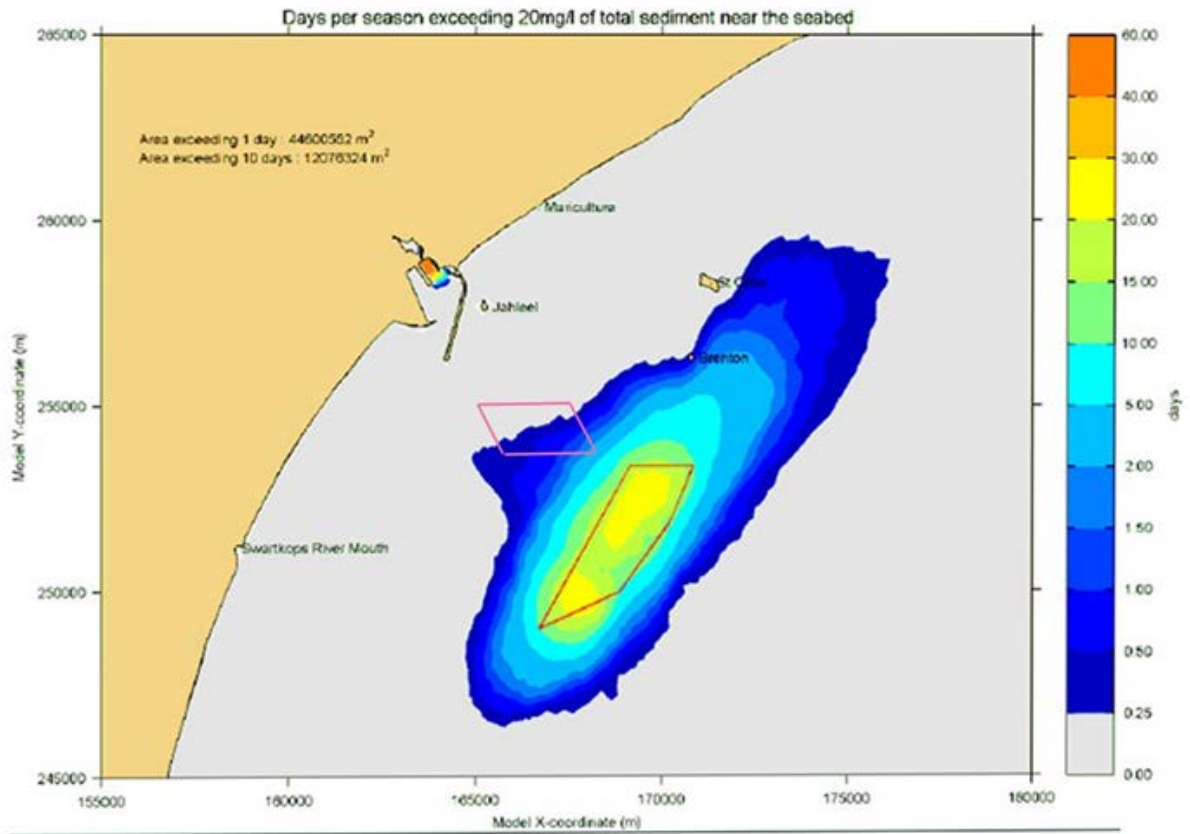


Figure 20 Modelled effects of dredge spoil dumping showing the number of days per season that suspended solids concentration threshold of 20 mg/l is exceeded in bottom water, near the seabed. Location of Algoa 7 included. (Source: Carter 2014).

3 CONCLUSION

In summary, univariate analyses indicate that there is little to no difference, beyond that of natural and physio-chemical induced variability, between the proposed ADZ precincts suggesting that in terms of macrofaunal community descriptors, no one site is more suitable than another. However, multivariate tests show that Algoa 1 displayed greater within site variability thereby suggesting this site may have greater overall diversity than Algoa 7 and be more representative of natural conditions within the Bay. In addition, Algoa 7 displayed significant differentiation of community structure and had reduced within site macrofaunal community and sediment variability relative to Algoa 1. Results also indicated that Algoa 7 may already be slightly disturbed from nearby dredge disposal activities. Therefore, based on the conclusions provided by benthic macrofauna and habitat analyses, Algoa 7 is recommended as the most suitable of the two precincts under consideration for finfish cage culture.

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