RHODES UNIVERSITY
Where leaders learn

ECOLOGICAL REPORT

COMPARATIVE ASSESSMENTS FOR THE DEVELOPMENT OF THE PROPOSED SEA-BASED AQUACULTURE DEVELOPMENT ZONE LOCATED WITHIN ALGOA BAY IN THE EASTERN CAPE

PREPARED BY

PROFESSOR PETER BRITZ AND PROFESSOR WARWICK SAUER

FOR

Department of Agriculture, Forestry and Fisheries

31 August 2016

DAFF PURCHASE ORDER: 4013827

Front cover: Fish cages in Velfjorden, Brønnøy, Norway-Thomas Bjørkan

MARINE ECOLOGICAL IMPACT ASSESSMENT REPORT: MARINE AQUACULTURE DEVELOPMENT ZONES FOR FINFISH CAGE CULTURE

EXECUTIVE SUMMARY

In 2010 Department of Agriculture, Forestry and Fisheries (DAFF), Branch: Fisheries (then the Department of Environmental Affairs & Tourism) initiated an Environmental Impact Assessment (EIA) for the development of an Aquaculture Development Zone in the Eastern Cape for the farming of marine finfish. A Strategic Environmental Assessment (SEA) was undertaken in 2009 and updated in 2011 to identify potential aquaculture sites which were subject to a public participation and specialist review process. A number of sites were eliminated due to the identification of potential fatal flaws, with two possible Aquaculture Development Zones (ADZ) sites; i.e. Algoa 1 and Algoa 5 remaining. A detailed EIA needed to be undertaken for these sites, which was then completed in 2013. It is important to note that although Algoa 5 was considered as an alternative site during the EIA process, DAFF did not consider Algoa 5 as the preferred site and hence a detailed public participation process was not undertaken for this site. During the appeals process, which followed on the issuing of the decision; a total of twenty eight (28) substantive appeals were lodged against the decision, with a number questioning the conclusions of the EIA. Based on the grounds of appeal lodged, DAFF as the holder of the EA requested that the Minister grant them the opportunity to further explore the feasibility of Algoa 5 through a comparative assessment of the potential impacts associated with Algoa 1 and 5. This report, which builds on the findings of the Environmental Impact Report (EIR) Final Marine Specialist Report (hereafter referred to as the Final EIR) and responds to the ecological issues raised by Final EIR appeals, provides a comparative assessment of ecological impacts at Algoa 1 and Algoa 5. Based on the Review of the Final EIR and 28 Appeals, issues requiring further analysis were also diagnosed, and four additional potential impacts included in the current assessment, namely: algal blooms, sharks and potential threats to humans, and impacts to the pelagic purse-seine and the traditional line fisheries.

The Final EIR identified multiple potential impacts of aquaculture development on the marine fauna in Algoa Bay. These potential impacts include the attraction to, and interaction of piscivorous fish and sharks with fish cages, the entanglement of whales and dolphins, the spread of disease and parasites to wild fish populations, smothering of the benthic environment below the cages, waste discharge and genetic contamination of wild stocks by fish farm escapees. The appeals (and present socio-economic perception survey) raised the threat of sharks to humans as a major concern to stakeholders. Due to its proximity to bathing beaches, the current assessment rates both the significance and consequence of the impact of sharks as <u>Medium</u> at Algoa 1. As Algoa 5 is situated further offshore, the shark threat to humans from an ADZ at this site is rated as of <u>Low</u> significance and consequence. The interaction of piscivores with fish cages was not raised as a major issue of concern during the appeals process. The ratings have not been changed in the current assessment and reflect those given in the Final EIR, and no additional mitigation measures suggested. Due to its proximity to the seal and bird Islands the potential impacts regarding interactions with piscivores will be <u>Medium</u> (with mitigation) at Algoa 5. It was also noted that due to its distance from prey colonies, the risk relating to interactions with piscivores at Algoa 1 are considered <u>Low</u> (without and with mitigation). Similarly, the impact on, and risk to cetaceans from fish cage nets was not raised as a serious issue of concern during the appeals process. The ratings have not been changed in the current assessment, and reflect those given in the Final EIR. The impact on, and risk to cetaceans from fish cage nets is considered the same at both sites (<u>Medium</u>-risk of entanglement; <u>Low</u>-impact on habitat use). Despite being confined to sea cages, the risk of transfer of diseases and parasites to wild stock coming into contact with farmed animals was a concern highlighted during the appeals process. The significance of this impact and consequence were rated in the Final EIR as <u>High</u> to <u>Very High</u>. However, provided that only indigenous fish species are farmed (dusky kob, silver kob, yellowtail), the disease causing organisms and parasites will originate from the wild fish populations and pose a lower risk. The impact at both sites is estimated in the current assessment to be <u>Low</u> to <u>Very Low</u>. A number of appeals noted the <u>Very High</u> risk of genetic contamination to local wild populations. As documented in the Final EIR, the escape of fish from sea cages is

inevitable given that escape from fish farms is a common event globally. The suggested downscaled farm production, from the order of 50,000t to an initial phase ca 1000-3000t, would go a long way towards reducing the number of escapees, and hence the potential further loss of genetic diversity. The impact rating for Algoa 1, after mitigation, for mass farmed fish escapes is considered Low due to the more sheltered nature of this site. For Algoa 5, the impact is considered Medium (after mitigation) as this site is significantly more exposed to winter storms.

Deteriorating water quality, due to dissolved organic, chemical and particulate waste; and the potential impacts on benthic habitats (i.e. reefs), popular dive sites, benthic fauna and flora, biodiversity and algal blooms where all highlighted as major concerns in the 28 appeals. A lack of sufficient data to determine the severity of these impacts was also remarked upon. During the time the Final EIR was being compiled, oceanographic data was not yet available for both sites with which to model organic waste dispersal from the fish farm sites. The incorporation of Acoustic Doppler Current Profiler (ADCP) data into the current report allowed the assessment of water quality in the vicinity of the fish cages (*Modelling–Ongrowing fish farm–Monitoring System* - MOM outputs) and hence a better estimation of the impacts. The Final EIR assessed the impacts to water quality and the benthic environment from organic waste to be High at both sites. The "Marine Specialist Report: Description of the affected environment and existing marine users" reported no reefs were found to occur at Algoa 1. However, we note that some reef area may be present in the reconfigured area delineated in the proposed Addo Marine Protected area. It is suggested by this study that reef areas identified within this zone at Algoa 5 be excluded from the potential ADZ. In addition, the MOM Model outputs indicate a fish farm with a production of 3000 tons will have no significant impact on the benthic environment in terms of bottom dissolved oxygen concentration and deposition of particulates and impacts to benthic fauna and flora are therefore considered Low at both sites. This adequate dispersal and limited build-up below cages also indicates a somewhat lower risk from organic waste and pollutants. The original organic waste impact rating of Medium (with mitigation) at both sites, is therefore reduced to Low (with mitigation) in the current assessment. Organic waste from fish cages and the perceived increased risk of algal blooms was raised as a major concern by a number of appellants, particularly following the large-scale 2014 bloom. However, the main driver of algal blooms in Algoa Bay is considered to be the prevailing coastal scale environmental condition processes. In addition, the nutrient input from fish farms is so minuscule compared to the processed sewage nutrient input into the bay, and dispersion so rapid, that the fish farm impact would be negligible and is considered Very Low at both sites. Appellants also expressed concern regarding the high impact of chemical pollutants at Algoa 5. The Final EIR noted disinfectants, antifoulants and therapeutic chemicals (medicines) are typically used in sea cage fish culture; and that these chemicals are often directly toxic to non-target organisms and may remain active in the environment for extended periods. The current assessment (MOM model outputs) has shown high dispersal rates by strong intermittent currents, which would rapidly dilute and disperse any chemical pollutants. The quantity of chemicals used is also potentially very small and occasional. In the absence of mitigation, the intensity and overall significance of the impacts is currently assessed as Medium at both sites.

Due to security and public safety concerns, any proposed fish farm in Algoa bay will need to exclude other users from what was previously public sea space. As a result of the lack of sheltered sea space off South Africa's coast, most of the areas suitable for cage culture are already heavily utilised for recreational activities. Exclusion from the ADZs will have implications for scuba-diving, yachting, water-sports and ski-boat angling. One hundred percent of the Algoa 1 site and 50% of the Algoa 5 size is used for yachting; however, the relatively large area utilized by yachts within Algoa Bay and relatively small proposed ADZ areas, means that these activities should not be mutually exclusive. The impact on and risk to yachting remains as in the Final EIR, and is assessed as Low at both Algoa 1 and 5. The impacts on ski-boat angling and water-sport also remains as in the Final EIR and is also assessed as Low at Algoa 1; and Low and Very Low, respectively, at Algoa 5. Scuba-diving is a well-established recreational activity in Algoa Bay, particularly off Port Elizabeth. Although none of the 18 popular Algoa Bay dive sites overlap with a proposed ADZ, appellants have expressed concern regarding risks from settleable waste and elevated nutrient levels at those sites close to the ADZ. With five popular dive sites situated 500-1000m from the border of Algoa 1, the Final EIR rated the significance of the risk to these areas as High (without mitigation). With Algoa 5 being more remote and further offshore, the impact on scuba-diving from this site was rated as Very Low. MOM Model results indicate intermittent currents at Algoa 1 are strong enough to flush possible deposits on the bottom. In the current assessment, the significance of the impact is therefore considered as Medium at the Algoa 1 site. With Algoa 5 being more remote and further offshore, the impact here remains as originally assessed - Very Low.

A number of commercial fisheries operate in Algoa Bay, and the potential economic impacts to these fisheries through loss of catch was one of the main appeal issues. The Final EIR assessed the impact resulting from user conflict on two of these fisheries, namely the squid and the shark longline fisheries. The Final EIR showed that the Algoa 1 site clearly overlaps with an important squid fishing ground, with nearly 8 % of the entire South African average annual effort and just over 1 % of the average annual catch reported from the grid block that overlaps the proposed ADZ. Also described in the Final EIR, was the shark longline fishery, with approximately 8% of the average annual reported catch and effort taking place within grid blocks that overlap with the proposed ADZs. As noted in the text of the Final EIR and remaining the same in the current assessment, the impact on the squid and shark longline fisheries is assessed as Medium, with one potential solution being reducing the size of the ADZs. Two other potentially impacted fisheries operating in the bay, identified in the "Marine Specialist Report: Description of the affected environment and existing marine users", are the small pelagic purse-seine and traditional line fisheries. It was found that the proposed ADZ areas only cover a small portion of the pelagic purse-seine fishery reporting grids. Proclamation of either or both the proposed ADZs within Algoa Bay would appear to have a minor effect on the Algoa Bay small pelagic fishery in terms of loss of fishing grounds, and the significance of the impact is considered Low in the current assessment. As noted in the "Marine Specialist Report: Description of the affected environment and existing marine users", only 2-3% of the traditional line fisheries average annual reported catch is for grid blocks that include the proposed ADZs. The significance of this impact is assessed as Very Low, in the current assessment.

The Final EIR concluded that, given the predicted medium and high significance impacts on marine vertebrates, particularly on sea birds, seals, sharks and cetaceans associated with the St Croix and Bird islands, as well as the position within a proposed Marine Protected Area (MPA) (thus contrary to conservation objectives) the development of Algoa 5 as an ADZ was not recommended. The Final EIR rated the possible negative impacts on the conservation objectives as High, with specific concerns raised such as attraction of sharks and other predators to the area, cetacean and bird entanglement in nets around cages, nutrient input from cages (smothering benthic invertebrates and algal growth), general water quality deterioration, disease transfer, genetic pollution and organic and chemical pollutants and their impact on the MPA and associated fauna. The original assessment concluded that threats from disease and parasite transfer, genetic impacts on wild stocks, organic and chemical pollutants emanating from the farm and interactions with piscivores to be particularly concerning. These impacts were all rated as High to Very High. The current report has modified some of these ratings. The impact rating for threats from disease and parasite transfer have been revised to Medium. Considering genetic impacts on wild stocks, the impact is now assessed as Low to Very Low. Impacts of organic and chemical pollutants are both considered Medium. The High impact of the Algoa 5 ADZ on piscivores remains as assessed in the original report. The close proximity of Algoa 5 ADZ to Seal and bird Islands, and its position within known feeding areas for some piscivores, suggests the impact will be High. However, the suggested reduction of the footprint of Algoa 5 ADZ would reduce the proximity. Impacts on cetaceans from threats of entanglement (Medium) and changes in habitat use (Low); and the potential threat to humans from sharks (Low) also remain unchanged. The threat of smothering of benthic invertebrates, algal growth and water quality (dissolved O_2, nitrogen and phosphorous concentrations) are considered Low. The present Socioeconomic Report (Britz et al, 2016) recommends a reduction the footprint of the Algoa 5 site to a maximum of two farm sites of 210ha each (total of 410ha) based on biosecurity and economic feasibility considerations. The results from this report, and the suggestion to reduce the footprint of the proposed ADZ alleviate many of the initial concerns, and the significance of the impact on the proposed MPA is reduced to Medium.

Acronyms

ADCP	Acoustic Doppler Current Profiler
ADZ	Aquaculture Development Zone
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
EA	Environmental Authorisation
EIA	Environmental Impact Assessment
EIR	Environmental Impact Report
EMPr	Environmental Management Programme
MOM	Modeling-Ongrowing-Monitoring
MPA	Marine Protected Area
MSR	Marine Specialist Report
SEA	Strategic Impact Assessment
VACM	Vector-Averaging Current Meter

TABLE OF CONTENTS

1. INTRODUCTION

The present "**Ecological Report**" forms part of a comparative assessment of ecological, social and economic feasibility of two proposed Aquaculture Development Zones in Algoa Bay ("Algoa 1" and "Algoa 5" respectively). The social and economic aspects were assessed in the "**Socio-Economic Report**" and the outputs of both reports used to compile the overall "**Detailed Feasibility Study**" report.

In 2010 Department of Agriculture, Forestry and Fisheries (DAFF), Branch: Fisheries (then the Department of Environmental Affairs & Tourism) initiated an Environmental Impact Assessment (EIA) for the development of an Aquaculture Development Zone in the Eastern Cape for the farming of marine finfish (CapeEAPrac, 2012). A Strategic Environmental Assessment (SEA) was undertaken in 2009 and updated in 2011 to identify potential aquaculture sites which were subject to a public participation and specialist review (CapeEAPrac, 2012). In the process a number of sites were eliminated due to the identification of potential fatal flaws (CapeEAPrac, 2013).

Two possible Aquaculture Development Zones (ADZ) sites; i.e. Algoa 1 and Algoa 5 remained and a detailed EIA was undertaken for these sites (CapeEAPrac, 2013). Findings were documented in the Environmental Impact Report (EIR) Final Marine Specialist Report (hereafter referred to as the Final EIR). This culminated in an Environmental Authorisation (EA) being granted for Algoa 1 dated 9 July 2014. It is important to note that although Algoa 5 was considered as an alternative site during the EIA process, DAFF did not consider Algoa 5 as the preferred site and hence a detailed public participation process was not undertaken for this site.

The EA attracted a total of twenty eight (28) appeals. Based on the grounds of appeal lodged, the DAFF as the holder of the EA requested that the Minister grant them the opportunity to further explore the feasibility of Algoa 5 through a comparative assessment of the potential impacts associated with Algoa 1 and 5. The DAFF thus commissioned the present comparative assessment of the environmental and socio-economic impacts (positive and negative) at both the Algoa 1 and Algoa 5 sites; with specific reference to the proposed sea-based ADZ in Algoa Bay

The present Ecological Report, builds on the findings of the Final EIR Marine Specialist Report, responds to the ecological issues raised by Final EIR appeals and provides a comparative assessment of ecological impacts at Algoa 1 and Algoa 5. Based on the "Review of the Final EIR and 28 Appeals, issues requiring further analysis were also diagnosed, and four additional potential impacts included in the current assessment. These included algal blooms, sharks and potential threats to humans, and impacts on the pelagic purse-seine and the traditional line fisheries.

This includes an assessment of the potential ecological interactions between the proposed expansion of the Addo Marine Protected Area (MPA) and the proposed ADZ (specifically at Algoa 5) relative to its location within the proposed expansion area of the MPA. Impacts associated with the establishment of the ADZ within the proposed MPA are identified and where relevant, mitigation measures suggested. Specific recommendations are made with regards to reducing the footprint of the site and creating a buffer zone between St Croix and Bird Island and the proposed Algoa 5 site.

Acoustic Doppler Current Profiler (ADCP) data not incorporated into the previous initial EIR Final Marine Specialist Report was analysed (Appendix 1) and the results modeled using the *Modelling–Ongrowing fish farm–Monitoring System* (MOM) system for determining the environmental carrying capacity for cage aquaculture (Stigebrandt et al. 2004; Appendix 2). The predicted waste discharge was calculated and the potential impact on the environment modeled.

2. REVIEW OF THE FINAL EIR, 28 APPEALS AND DAFF RESPONSE DOCUMENT

2.1 GENERAL COMMENTS

The Algoa Bay Final Environment Impact Report, 28 EA appeals and the DAFF comments and response report was reviewed in respect of the socio-economic impact assessment, marine impact assessment and indicative feasibility information of the social, economic and environmental costs. The review was intended to produce a diagnostic analysis to inform the requirements for comparative impact assessment of the two proposed sites Algoa 1 and Algoa 5.

The EIA process followed was in many respects a model exercise which consisted of a SEA (Anchor Environmental, 2011), Scoping Study (Cape EAPrac, 2012), Final Environment Impact Assessment Report (CapeEAPrac 2013, EA, EA appeals and a DAFF comments and response report to the appeals lodged.

The Scoping Report adequately:

- Provided a description of the proposed project, including a sufficient level of detail to enable stakeholders to identify relevant issues and concerns;
- Described the local environmental and developmental context within which the project was proposed, to assist further identifying issues and concerns;
- Provided an overview of the process being followed in the Scoping Phase, in particular the public participation process, as well as the Plan of Study that would be followed in the subsequent EIA phase;
- Presented the issues and concerns identified to date from the baseline specialist studies and the initial stakeholder engagement process, as well as an explanation of how these issues will be addressed through the EIA process.

The Scoping Report eliminated all but two of six potential sites (Algoa 1-6) identified by the SEA, Algoa 1 the preferred site, and Algoa 5 within the proposed Greater Addo MPA for which a precautionary approach was recommended due to its proximity to conservation worthy habitats.

The Final EIR is a comprehensive and evidence-based document which followed proper procedures for public participation. The evidence presented in the Final EIR indicates that was process comprehensive providing most information required and enabling stakeholders to participate meaningfully. Interested and affected parties submitted 28 substantive appeals to the EA granted in favour of the Algoa 1 ADZ zone applied for by the DAFF. A comprehensive and evidence based comments and response report to the 28 appeals was provided by the DAFF which acknowledged areas requiring more information for the Minister to make an informed decision.

The ecological studies undertaken for Algoa 1 and Algoa 5 in the Scoping and Final EIR were comprehensive, providing most of the information required for the assessment of impacts. The general description of the regional biogeography, rocky intertidal areas, sandy shores, estuaries, sub-tidal habitats and the offshore pelagic region and islands adequately cover the required background data to assess the Algoa 1 and 5 sites. It is noted that the coordinates for Algoa 5 have changed slightly with the proposed MPA declaration that has been Gazetted for comment. Therefore the grab samples taken do not fully cover the boundaries of the revised area and the type of substrate in a small section of the revised area is unclear.

The DAFF comments and response report were science-based and comprehensively addressed the concerns raised in the 28 appeals on South African Hope spots, pharmaceutical benefits, biofouling, the use of therapeutants, the local fishing industry, climate change, impact on marine biodiversity, and no further elucidation is required. The DAFF is complemented on the comprehensiveness of the Appeals response document.

In assessing the EIA, EA appeals and the DAFF comments and response report, a number of gaps were identified where further information is required, concerning both Algoa 1 and Algoa 5. These are discussed under the headings below.

2.2 SHARKS

This issue of both the potential impact on piscivorous animals, such as sharks, by the cages and the impact of the cages on bather safety was assessed in the EIR report but remained an issue of great concern in several EA appeals. The impact on piscivore animals at Algoa 1 was rated as <u>Very Low</u> (with mitigation) and a <u>Medium</u> to <u>Low</u> confidence. Due to extensive foraging range of most large marine predators, interactions cannot be completely mitigated by site selection away from colonies but there are additional mitigation measures such as the use of predator nets, etc. that can be implemented. These issues were addressed in the DAFF response document but can be further elucidated, particularly the potentially negative effects of using nets. The impact of the cages on bather safety was assessed and the impact was rated as Low with a high degree of uncertainty. It is important to point out the fact that the current risk of shark attacks on bathers and other non-motorised users is considered high anywhere along the South African coast.

The DAFF comments and response report was detailed, science based, and objective in terms of the response to the appeal concerns in respect of sharks.

2.3 WASTE MATERIAL, SMOTHERING OF REEFS.

The impact of fish farm organic waste on reef habitats and beaches was identified as a key concern in the EA appeals.

The EIR report identified possible pollution impacts from fish fecal and feed waste affecting benthic habitats, water quality and bathing beaches. The EIA impact rankings were based on the modeling of waste (nutrient and chemical) dispersal from a proposed fish farm at Mossel Bay (an area with similar current speeds to Algoa Bay) was conducted in 2009 (CapeEAPrac, 2013). This Mossel Bay study concluded that settlable waste was expected to sink to the sea floor within 200 m of the cages and this conclusion was extrapolated to Algoa Bay without any modeling using local current data (speed, duration, depth). The lack of waste modeling using Algoa Bay oceanographic data identified as a weakness in the Final EIR and in the DAFF's ability to respond to appeal concerns.

The DAFF comments and response report to the Appeal concerns were rational and evidence based, acknowledging the oceanographic evidence uncertainties and the need for further waste dispersal modeling based on Algoa Bay current data.

The Ecological Report fish farm waste modeling report (Appendix 2 above) addressed the requirements for sustainable waste assimilation by the environment based on Algoa Bat oceanographic data (Appendix 1). The MOM model (Stigebrandt, 2004) was used to model the above for Algoa 1 and Algoa 5 using updated Algoa Bay current data. The model provides evidence that the following conditions can be met with a reasonable degree of confidence:

- The accumulation of organic material under and in the vicinity of the farms must not result in extinction of the benthic macro infauna. This condition is met if the flux of organic matter from the farm is adjusted to local dispersion and re-suspension conditions so that the decomposition capacity of the benthic system is not exceeded.
- The water quality in the net pens must meet the needs of the fish. This means that the concentration of oxygen is kept above the threshold level and that concentration of ammonium and other potentially harmful substances are kept below the threshold levels. These conditions can be met if the respiration of, and emissions from, the fish are adjusted to the rate of water renewal in the net pens.
- The water quality in the areas surrounding the farm must not deteriorate. This requirement is fulfilled if the outlets of nutrients and organic matter from the farm do not contribute to significantly higher algae production in the surrounding surface water or result in low oxygen concentrations in deep water. When the environmental impact is being assessed the contributions of all other sources must also be taken into account, thus considering the total impact.

2.4 ALGAL BLOOMS

The DAFF response to the appeal comments provided on possible threat of algal blooms was comprehensive and does not need any additional response. A report on the 2014 red tide event by the South African Environmental Observation Network (SAEON) Elwandle Node is provided in Appendix 3. The Detailed Feasibility Report assesses new information relating to impact of harmful algal blooms in Algoa Bay on aquaculture operations.

2.5 KOB POPULATION GENETIC STRUCTURE

An update and implications of escapees on Kob population genetic structure was required and is addressed in the Ecological Report.

2.6 CETACEANS

An appeal suggested that in impact of Algoa 1 on cetaceans was a 'fatal flaw' in the ADZ EA application. The DAFF response document (p109) appeared to misunderstand the appeal and the issue thus requires clarification. The appeal comment and response were as follows:

> Appeal Comment: *One of the grounds upon which Algoa 5 is rejected as a location for fish farm is the concern of the impact of the accidental entanglement of cetaceans in the nets and the moorings, and of alternation in cetacean habitat use or migration patterns. Why these considerations do not similarly, constitute grounds for the rejection of Algoa 1, is left unexplained in the EIA, and it is submitted that this is a fatal flaw in the document.*

> Response by DAFF: *Due to the high importance placed on the proposed Addo MPA, Algoa 5 was considered unfeasible for a finfish farm.*

The DAFF response thus did not address the question of why cetacean habitat use and migration patterns are not considered to be an issue or 'fatal flaw' at Algoa 1. This issue is addressed in the present Ecological Report's comparative assessment of Algoa 1 and Algoa 5.

3. ECOLOGICAL IMPACT COMPARISON OF ALGOA 1 AND ALGOA 5 SITES

The ecological impacts of the Algoa Bay ADZ are evaluated and compared under the headings below and summarised in Table 1.

3.1 IMPACT ON MARINE FAUNA AND FLORA

The Final EIR identified multiple potential impacts of aquaculture development on the marine fauna in Algoa Bay including:- the attraction to, and interaction of piscivorous fish and sharks with fish cages; the entanglement of whales and dolphins; the spread of disease and parasites to wild fish populations; smothering of the benthic environment below the cages; chemical waste discharge; and genetic contamination of wild stocks by fish farm escapees.

3.1.1 INTERACTION WITH SHARKS

The EIR Final "Marine Specialist Report" highlighted that marine predatory fish and sharks are frequently attracted to fish farms due to not only the fish and food in the sea cages, but also the concentration of other fish attracted by the caged fish and food waste (Anchor Environmental, 2013). In the Final EIR, the threat of sharks to humans was assessed under possible impacts on recreational water sport participants. The significance and consequences of the impact was assessed as <u>Low</u> and <u>Medium</u>, respectively at Algoa 1; and <u>Very Low</u> and <u>Low</u>, respectively at Algoa 5. Despite the impact rating of shark risk in the EIR, the appeals (and present socio-economic perception survey) raised this as an issue of major concern to stakeholders. The primary concern is that the presence of fish farms within Algoa Bay could increase the prevalence of passing/migrating animals as well as the residency time of sharks in the vicinity of bathing beaches; particularly if they easily find prey (other fish also attracted to the fish farm) within the immediate area. It is agreed that a large degree of uncertainty exists relating to the potential impacts of fish farms on shark presence and residency times within Algoa Bay; and there is a severe lack of data and understanding of the site and species specifics, and indeed individual shark behavioural responses to such a development. Due to its proximity to bathing beaches, the current assessment rates both the significance and consequence of the impact as <u>Medium</u> at Algoa 1 (Table 1). As Algoa 5 is situated further offshore, the shark threat to humans from an ADZ at this site is rated as of <u>Low</u> significance and consequence. The importance of extensive monitoring of shark movement patterns was identified as an essential mitigation measure in the "Marine Specialist Report: Description of the affected environment and existing marine users" (Anchor Environmental, 2013), both at the ADZ sites, and at the popular bathing beaches inshore, before and after the stocking of cages. Baseline data would have to extend for at least 12 months to cover seasonal variation in shark movement patterns, and preferably longer to include inter-annual variation.

3.1.2 INTERACTION WITH LARGE PISCIVORES

The interaction of piscivores with fish cages was not raised as a major issue of concern in the EA appeals. The Final EIR noted the location of Algoa 5 as being within known feeding areas for some piscivores (penguins, gannets, dolphins) and its proximity to the seal and bird Islands suggests that potential impacts regarding interactions with piscivores will be <u>High</u> (without mitigation) at this site. It was also noted that due to its distance from prey colonies, the risk relating to interactions with piscivores at Algoa 1 are considered Low (without and with mitigation), but that the extensive foraging range of most large marine predators means interactions cannot be completely mitigated by site selection. The ratings have not been changed in the current assessment, and no additional mitigation measures suggested (Table 1).

3.1.3 CETACEANS

Similarly, the impact on, and risk to cetaceans from fish cage nets was not raised as a serious issue of concern during the appeals process. The ratings have not been changed in the current assessment, and reflect those given in the Final EIR. The impact on, and risk to cetaceans from fish cage nets is considered the same at both sites. The area inshore of the proposed Algoa 1 ADZ is a key habitat for southern right whales, humpback dolphins and bottlenose dolphins. A long coastal strip from just east of the Sundays River estuary mouth to Woody Cape was identified as a key habitat for southern right and humpback whales and bottlenose dolphins. This area lies inshore and to the east of the proposed Algoa 5 ADZ. However, it should be noted that humpback whales (along with Brydes whales and common dolphins) often inhabit deeper water and have distributions that may more frequently overlap with this proposed ADZ. The risk of entanglement is considered Medium at both proposed ADZs (Table 1). Cetaceans may be able to avoid entanglement in fish cage infrastructure, but the mere presence of sea cages, as well as work boats continually travelling between land and the farm, may adversely affect habitat use and may have chronic negative effects on populations (as well as ecotourism activities). The impact on habitat use is however considered Low at both sites (Table 1).

3.1.4 DISEASE SPREAD TO WILD FISH

Despite being confined to sea cages, the risk of transfer of diseases and parasites to wild stock coming into contact with farmed animals was a concern highlighted during the appeals process. The high stocking densities in fish aquaculture often lead to outbreaks of infectious diseases and parasites, requiring chemical treatment of the caged fish. The significance of this impact and consequence were rated in the Final EIR as High to Very High.

The potential negative effects on wild stocks were noted, as all three potential aquaculture species (dusky kob, silver kob, yellowtail) are important in the commercial and recreational line fisheries and furthermore, both wild kob stocks are assessed as collapsed. It was noted that potential disease and parasite transmission to wild stocks could have negative impacts throughout the natural distributional range of the species, wider ecosystem impacts and fisheries impacts. The appeals questioned the merit of the development of ADZs to alleviate pressure on wild linefish stocks, when this method could likely threaten natural populations through disease and parasite transmission. If aquaculture species which are not part of the receiving ecosystem are used, there is indeed a high risk that wild fish will become infected with new disease causing organisms to which they have no natural resistance. However, provided that only indigenous fish species (dusky kob, silver kob, yellowtail) are farmed, the disease causing organisms and parasites will originate from the wild fish populations and pose a lower risk due to the natural resistance of the wild fish. Under natural conditions, these potential disease causing organisms are not normally pathogenic as they have coevolved with the host fish species. They may become pathogenic when the fish's immune systems are compromised by environmental stress. This is likely under aquaculture conditions. Farmed fish therefore are inherently more prone to these disease vectors inducing pathogenic symptoms. It is possible that wild fish in close proximity to farm cages may pick up higher parasite loads due to the shedding of parasite transmission stages by the farmed fish. This effect is likely to be highly localised to wild fish which come into the proximity of the farm and is therefore unlikely to compromise the ecology and productivity of wild fish populations and the associated fisheries. Therefore, provided only indigenous species are used, the impact at both sites is estimated in the current assessment to be Low to Very Low (Table 1).

3.1.5 GENETIC CONTAMINATION OF WILD FISH STOCKS

A number of appeals noted the EIR's Very High risk rating for genetic contamination to local wild populations. As documented in the Final EIR, the escape of fish from sea cages is inevitable given that escape from fish farms is a common event globally. Farmed fish that are typically spawned from a limited number of brood stock have reduced genetic diversity compared to wild stocks. The significance and impact were therefore originally assessed as Very High. However, the suggested downscaled farm production, from the order of 50,000t to an initial phase of 1000-3000t, would go a long way towards reducing the number of escapees, and hence the potential further loss of genetic diversity. The impact rating for Algoa 1, after mitigation, for mass farmed fish escapes is considered Low due to the more sheltered nature of this site (Table 1). For Algoa 5, the impact is considered Medium (with mitigation) as this site is significantly more exposed to winter storms and the probability of escapes due to cage system failure is considered higher (Table 1). Essentially the effectiveness of the two mitigation measures to reduce escapes and recover escapees is considered to be lower at this site.

3.1.6 IMPACT OF ORGANIC AND CHEMICAL WASTE

Deteriorating water quality, due to dissolved organic, chemical and particulate waste; and the potential impacts on benthic habitats (i.e. reefs), popular dive sites, benthic fauna and flora, biodiversity and algal blooms where all highlighted as major concerns in the 28 Appeals. A lack of sufficient data to determine the severity of these impacts was also remarked upon. During the time the Final EIR was being compiled, ADCP data was not yet available for both sites. The incorporation of ADCP data (Appendix 1) into the current report allowed the assessment of water quality in the vicinity of the fish cages (see MOM model outputs, Appendix 2) and hence a better estimation of the impacts.

The Final EIR assessed the impacts to water quality and the benthic environment from organic waste to be High at both sites. The "Marine Specialist Report: Description of the affected environment and existing marine users" reported no reefs were found to occur at Algoa 1 and 5 (Anchor Environmental, 2013). However some reef area may be present in the reconfigured Algoa 5 area delineated in the proposed Addo MPA (Department of Environmental Affairs, 2016). This reconfiguration, if accepted, would result in a small portion of the benthic environment that has not yet been assessed. It is suggested that reef areas identified within this zone at Algoa 5 be excluded from the potential ADZ. The MOM model outputs however indicate that a fish farm with a production of ~3000 tons will have no significant impact on the benthic environment in terms of bottom dissolved oxygen concentration and deposition of particulates (Appendix 2). This is largely due to the high intermittent current speeds at both sites. This suggests the dispersal of large amounts of particulate waste capable of smothering surrounding reefs will not occur. For these reasons, the original organic waste impact rating of Medium (with mitigation) at both sites, is reduced to Low (with mitigation) in the current assessment (Table 1).

The role of nutrient loading of the water column, along with the reduction of dissolved O_2 concentrations, in stimulating harmful algal blooms was discussed in the Final EIR (CapeEAPrac, 2013). Organic waste from fish cages and the perceived increased risk of Algal Blooms was raised as a major concern by a number of appellants, particularly following the large-scale 2014 bloom. However, the main driver of algal blooms in Algoa Bay is considered to be the prevailing coastal scale environmental condition processes, as evidenced by the 2014 red tide bloom which extended from Hermanus to East London (G. Pitcher, DAFF, pers. comm, 2016). There is some evidence that estuarine and sewage nutrient inputs into Algoa Bay and limited bay circulation under calm conditions fuel more dense blooms in the bay (Bornman and Goschen, 2016; Appendix 3). However, the nutrient input from fish farms is so minuscule compared to the processed sewage nutrient input into the bay, and dispersion so rapid, that the fish farm impact would be negligible and is considered Very Low at both sites.

Appellants expressed concern regarding the Final EIR High impact rating of chemical pollutants at Algoa 1 and 5. The Final EIR noted disinfectants, antifoulants and therapeutic chemicals (medicines) are typically used in sea cage fish culture; and that these chemicals are often directly toxic to non-target organisms and may remain active in the environment for extended periods. The effects of chemical pollution arising from fish cages on Algoa 1 and Algoa 5 was anticipated to be highly localised in the vicinity of the fish cages in Algoa Bay. Bioaccummulation of chemicals up the food chain, and the potential implications for wider natural processes (e.g. successful breeding of sea birds) were also discussed in the Final EIR (CapeEAPrac, 2013). The significance and consequence of this impact were both rated as Medium (without mitigation) at Algoa 1, and due to the conservation significance, High (without mitigation) at Algoa 5. The current assessment (MOM model outputs) indicates high dispersal rates by strong intermittent currents, which would rapidly dilute and disperse any chemical pollutants. The quantity of chemicals used is also potentially very small and occasional. In the absence of mitigation, the intensity and overall significance of the impacts is currently assessed as Medium at both sites, as both sites have very similar fauna and the impacts and consequences would be similar (Table 1).

3.1.7 IMPACT ON RECREATIONAL ACTIVITIES

Due to security and public safety concerns, any proposed fish farm in Algoa bay will need to exclude other users from what was previously public sea space. As a result of the lack of sheltered sea space off South Africa's coast, most of the areas suitable for cage culture are already heavily utilised for recreational activities. Exclusion from the ADZs will have implications for scuba-diving, yachting, water-sports and ski-boat angling.

One hundred percent of the Algoa 1 site and 50% of the Algoa 5 size is used for yachting. It was acknowledged in the Final EIR that yachting may be affected by ADZ development within Algoa Bay, however, the relatively large area utilized by yachts within Algoa Bay and relatively small proposed ADZ areas, means that these activities should not be mutually exclusive. The impact on and risk to yachting remains as in the Final EIR (CapeEAPrac, 2013), and is assessed as Low at both Algoa 1 and 5.

The impacts on ski-boat angling and water-sport also remains as in the Final EIR (CapeEAPrac, 2013) and is also assessed as Low at Algoa 1; and Low and Very Low, respectively, at Algoa 5 (Table 1).

The Final EIR includes mitigation measures to reduce the threat of sharks to water-sport participants (CapeEAPrac, 2013). As mentioned in the Final EIR, there is no prior knowledge of how large sharks may alter distribution patterns in relation to ADZ development, or how effective mitigation measures to try reduce human interaction with sharks will be. Being situated closer inshore and nearer to beaches, the potential to attract sharks and the risks to water-sport participants are considered in the current assessment as Medium for Algoa 1, but Low for Algoa 5 (Table 1). This is reflected in the specific assessment of the threat of sharks to humans, and appropriate mitigation measures are included in that section.

The visual impact of an industrial fish farm in a nature scape is also a concern to recreational users and was adequately assessed in the Final EIR (CapeEAPrac, 2013). The visual impact ratings thus remain as Moderate (with mitigation) at Algoa 1 and Low (with mitigation) at Algoa 5.

Scuba-diving is a well-established recreational activity in Algoa Bay, particularly off Port Elizabeth. Although none of the 18 popular Algoa Bay dive sites overlap with a proposed ADZ, appellants have expressed concern regarding risks from settleable waste and elevated nutrient levels at those sites close to the ADZ. With five popular dive sites situated 500-1000m from the border of Algoa 1, the Final EIR rated the significance of the risk to these areas as High (without mitigation) (CapeEAPrac, 2013). This was largely due to the potential risks from high levels of dissolved and particulate organic waste affecting nearby reef areas. With Algoa 5 being more remote and further offshore, the impact on scuba-diving from this site was rated as Very Low. MOM model results (Appendix 2) indicate intermittent currents at Algoa 1 are strong enough to flush possible deposits on the bottom (current Sigma or standard deviation value >3cm.s-1). This conclusion is supported by the environmental monitoring programme observations conducted at the I&J pilot cage aquaculture site which found no measurable accumulation of deposits below the fish cages (Winter, 2006). In the current assessment, the significance of the impact is therefore considered as Medium (Table 1 - see Organic pollutants section) at the Algoa 1 site, largely due to the possibility of short term effects on water clarity on nearby reefs, but this can be mitigated by a reduction of the footprint of the site, and excluding the area close to recreational dive sites. With Algoa 5 being more remote and further offshore, the impact here remains as originally assessed in the Final EIR - Very Low (Table 1).

3.1.8 IMPACT ON COMMERCIAL FISHERIES

A number of commercial fisheries operate in Algoa Bay, and the potential economic impacts to these fisheries through loss of catch was one of the main appeal issues. The Final EIR assessed the impact resulting from user conflict on two of these fisheries, namely the squid and the shark longline fisheries.

The Final EIR showed that the Algoa 1 site clearly overlaps with an important squid (*Loligo reynaudi*) fishing ground, with nearly 8 % of the entire South African average annual effort and just over 1 % of the average annual catch reported from the grid block that overlaps the proposed ADZ (CapeEAPrac, 2013). The discrepancy between effort and catch in this catch reporting block was reported as largely due to the fact that vessels shelter from SW winds in the lee of Cape Recife, even during times when catches may be poor. According to the Final EIR, discussions with industry members suggested that the southern half of the proposed Algoa 1 is an important squid fishing ground and the industry would be strongly opposed to exclusion from this area. It was shown that Algoa 5 overlaps with a less important, but not insignificant fishing ground (accounting for nearly 1 % of average annual fishing effort).

Also described in the Final EIR, was the shark longline fishery, which targets smooth hound, soupfin, smooth hammerhead *Sphyrna zygaena*, bronze whaler, blacktip *Carcharhinus limbatus*, dusky *Carcharhinus* obscures and cow sharks *Notorynchus* *cepedianus* (CapeEAPrac, 2013). The Final EIR indicated that currently, demersal shark longlining is restricted to coastal waters (up to 100 m depth), and are permitted to fish up as far as East London, and use longlines with up to 3 000 hooks. It was noted that there are a total of six rights holders in the demersal shark longline fishery, one of which operates in the Algoa Bay area, using a single vessel. Both Algoa 1, and particularly Algoa 5, where reported to overlap with areas where the shark longline operator is active, with ~8% of the average annual reported catch and effort taking place within grid blocks that overlap with the proposed ADZs. As noted in the text of the Final EIR and remaining the same in the current assessment, the impact on the squid and shark longline fisheries is assessed as Medium, with one potential mitigation measure being reducing the size of the ADZs. If the Socio-economic Report (Britz et al, 2016) recommendation that much smaller areas are required for commercial aquaculture is accepted (210Ha for Algoa 1 and 420Ha for Algoa 5), then the impact on fisheries could be reduced to Very Low (Table 1).

Two other potentially impacted fisheries operating in the bay, identified in the "Marine Specialist Report (MSR): Description of the affected environment and existing marine users", are the small pelagic purse-seine (Anchor Environmental, 2013). The small pelagic purse-seine fishery was described as targeting shoals of small pelagic fish that occur near the surface at night. It was explained that boats tend to fish overnight, landing their catches in the early mornings, and that Port Elizabeth boats can travel as far as Plettenberg Bay, though seldom go that far. The viable range was reported to extend from Bird Island in the east to Jeffrey's Bay in the west, with the cost of diesel as well as concerns about deterioration of the fish on board being the limiting factors. It was found that the proposed ADZ areas only cover a small portion of the reporting grids. The mobility of the target species was noted and it was concluded that the fishery should still have access to the shoals as they move away from the ADZ. Proclamation of either or both the proposed ADZs within Algoa Bay would appear to have a minor effect on the Algoa Bay small pelagic fishery in terms of loss of fishing grounds, and the significance of the impact is considered Low in the current assessment. It was noted in the MSR that should any future finfish cage operation use frozen fish food at any stage of production however, there is a small but potentially highly significant risk of disease introduction that could decimate small pelagic stocks (Anchor Environmental, 2013). As such the avoidance of frozen food has been included as a possible mitigation measure. If the Socio-economic Report recommendation that much smaller areas are required for commercial aquaculture is accepted (210Ha for Algoa 1 and 420Ha for Algoa 5), then the impact on the purse seine fishery could be reduced to Very Low (Table 1).

A description of the traditional line fishery was provided in the "Marine Specialist Report: Description of the affected environment and existing marine users" (Anchor Environmental, 2013). The traditional line fishery is a boat-based fishery in which fish are caught on lines with no more than 10 baited hooks per line. The fishery operates inshore where fish are accessible on day or short overnight trips and in water shallow enough to be caught using manual labour with hand lines or rods and reels. In total, only 2-3% of the average annual reported catch and effort for the Algoa Bay area is for grid blocks that include the proposed ADZs. The MSR concluded that, given that the ADZs include none (Algoa 1) or very little (Algoa 5) reef substratum, it appears that they will have little negative effect on the commercial line fishery in terms of loss of fishing ground (Anchor Environmental, 2013). The significance of this impact is therefore assessed as Very Low in the present assessment. It was noted in the MSR that the same concerns about the possible introduction of diseases or genetic contamination of wild stocks by cultured fish (many potential cultured species are also targets of the line fishery), also apply to the traditional line fishery.

3.1.9 ADDO ELEPHANT NATIONAL PARK MPA

The Final EIR concluded that, given the predicted medium and high significance impacts on marine vertebrates, particularly on sea birds, seals, sharks and cetaceans associated with the St Croix and Bird islands, as well as the position within a proposed MPA (thus contrary to conservation objectives) the development of Algoa 5 as an ADZ was not recommended (Anchor Environmental, 2013). The economic viability of this site, due to its exposed position and distance from port was also questioned. The Greater Addo Elephant National Park has a major conservation planning and implementation project over the last two decades. As described on the official SANParks website (www.sanparks.org), the coastal area of Addo Elephant National Park stretches between Sundays River Mouth and Bushman's River Mouth. It incorporates the Alexandria Dunefield – the largest (covering approximately 15 800 hectares) and least degraded coastal dunefield in the southern hemisphere, and Bird and St. Croix Islands. A larger MPA of an envisaged 120 000 hectares is proposed for Algoa Bay. This MPA will be the first to incorporate a bay environment, exposed rocky headlands and offshore islands. The proposed Algoa 5 ADZ falls within the proposed Addo Elephant MPA.

The Marine Impact Assessment Report rated the possible negative impacts on the conservation objectives as High, with specific concerns raised such as attraction of sharks and other predators to the area, cetacean and bird entanglement in nets around cages, nutrient input from cages (smothering benthic invertebrates and algal growth), general water quality deterioration, disease transfer, genetic pollution and organic and chemical pollutants and their impact on the MPA and associated fauna (Anchor Environmental, 2013). The original assessment concluded that threats from disease and parasite transfer, genetic impacts on wild stocks, organic and chemical pollutants emanating from the farm and interactions with piscivores to be particularly concerning. These impacts were all rated as High to Very High. The current report has modified some of these ratings based on the following conclusions:

- Provided that only indigenous fish species are farmed (dusky kob, silver kob, yellowtail), the disease causing organisms and parasites will originate from the wild fish populations which possess a natural resistance to these pathogens. Furthermore, the transmission of parasites to wild stock coming into contact with caged fish will likely be a localised effect, and is therefore unlikely to compromise the ecology and productivity of wild fish populations and the associated fisheries.
- The suggested downscaled farm production, from the order of 50,000t to an initial phase ca 1000-3000t, would go a long way towards reducing the number of escapees, and hence the potential further loss of genetic diversity in collapsed wild fish stocks.
- The MOM model indicates that at a projected production of 3000t fish per year, there will be efficient dispersal and assimilation of waste from the fish farm due to the high intermittent current speeds at Algoa 5. If the model assumptions are valid, there will thus be:
    - Good water quality (as indicated by dissolved oxygen, ammonia and phosphorus concentrations) in the vicinity of the fish cages.
    - No accumulation of settled particulate matter on the bottom.
    - A non-significant impact on the benthic infauna.
- Organic waste and chemical pollutants will likely be adequately dispersed, with limited build-up below cages. The strong currents will rapidly dilute and disperse any chemical pollutants, and the effects of chemical pollution arising from fish cages are anticipated to be highly localised, in the vicinity of the fish cages. The MOM model outputs also suggest a downscaled production (~3000t) will result in limited waste emanating from a farm. If the model assumptions are valid, it is anticipated waste will not impact sensitive habitats, shoreline reefs, blue flag beaches or Island groups.

The impact rating for threats from disease and parasite transfer have therefore been revised to Medium (Table 1). Considering genetic impacts on wild stocks, the impact is now assessed as Low to Very Low. (Table 1). Impacts of organic and chemical pollutants are both considered Medium (Table 1). The high impact of the Algoa 5 ADZ on piscivores remains as assessed in the original report. The close proximity of Algoa 5 ADZ to Seal and bird Islands, and its position within known feeding areas for some piscivores, suggests the impact will be High. However the suggested reduction of the footprint of Algoa 5 ADZ, with two areas or 210Ha each would reduce the proximity to the islands. Impacts on cetaceans from threats of entanglement (Medium) and changes in habitat use (Low); and the potential threat to humans from sharks (Low) also remain unchanged.

Two additional impacts have been assessed in the current report, namely algal blooms from nutrient loading and the impacts on benthic fauna and flora. As indicated by the model outputs, the nutrient input from a downscaled fish farm is so minuscule and dispersion so rapid that the fish farm impact would be negligible. Furthermore, the model outputs indicate no significant impact on the benthic environment in terms of bottom dissolved oxygen concentration and deposition of particulates. The threat of smothering of benthic invertebrates, algal growth and water quality (dissolved O_2, nitrogen and phosphorous concentrations) are considered Low (Table 1).

Downscaling the production of the fish farm (to ~3000t) and the resultant reduction in the size of the ADZ would significantly reduce the footprint of the Algoa 5 site. Other mitigation measures aimed at reducing impacts are listed in detail in the assessment table that follows. Broadly, these measures include:

- Reducing the footprint of the Algoa ADZ to two areas of 210Ha each, such that a further buffer is created between the islands and the ADZ.
- Limiting, as far as possible, those factors that could increase the attraction of piscivores to the area (e.g. prompt removal of dead fish)

- Increased visibility of mooring lines and nets.
- Mesh size limits
- Maintain infrastructure
- Regular inspection of stock
- Monitoring (farm specific, e.g. stock health; and ecosystem specific e.g. environment, shark movement patterns)
- Use of appropriate feeds and therapeutants

The results from this report, and the suggestion to reduce the footprint of the proposed ADZ alleviate many of the initial concerns, and the significance of the impact on the proposed MPA is reduced to Medium (Table 1).

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
Fauna: Interactions with piscivorous marine animals (general) *Piscivores are frequently attracted to the large concentrations of fish and food in sea cages, as well as attracted to other concentrations of fish also drawn by the cages or waste food settled on the substratum. Attempts to get to the caged fish not only lead to a stress response in cultured fish, but can also result in damaged nets and even entanglement of piscivores.*	**Impact**	
	Due to the extensive foraging range of most large marine predators, interactions cannot be completely mitigated by site selection away from prey colonies, however the overall significance of the impact is assessed as **Low**.	The proximity to the seal and bird Islands and within known feeding areas for some piscivores (penguins, gannets, dolphins), suggests that potential impacts will be more significant at this site and are assessed as **High** without mitigation.
	Effective Monitoring / Mitigation Strategy	
	Essential mitigation measures at both sites: • Install and maintain suitable predator nets (sufficient strength, visibility and mesh size, above and below water line). • Install visual deterrents (e.g. tori line type deterrents for birds). • Store feed so piscivores cannot access it, and implement efficient feeding strategy. • Remove any injured or dead fish from cages promptly. • During harvesting of stock, ensure that minimal blood or offal enters the water. • Implement mitigation measures as for entanglement impacts. • Develop a protocol for dealing with problem piscivores in conjunction with experts and officials (DAFF, DEA etc.) • Maintain a record of all interactions with piscivores as per recommended Environmental Management Programme (EMPr).	Recommended mitigation measures at Algoa 5: • Risk-averse site selection and avoidance of Algoa 5.
	Risk/Consequence	
	Low	**High** (without mitigation)

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
		Medium (with mitigation)
	Confidence regarding severity of impact and risk ratings	
	Impact and risk without mitigation: **Medium** (Monitoring required to confirm frequency of interactions) Impact and risk with mitigation: **Low** (Monitoring required to assess the effectiveness of mitigation)	
Fauna: Sharks and the potential threat to humans *Sharks could be attracted to fish farms, and could continually return as a result of "food reward". The food reward factor is not necessarily from farmed fish, but rather those fish also attracted to the caged fish.*	**Impact**	
	As both sites are more than 2 km offshore, a fish farm could potentially lure sharks, such as Great Whites, away from beaches, or increase the prevalence of passing/migrating sharks. However, this would be negated by the possible increased residency time of sharks in the vicinity of bathing beaches as they are continually attracted to the fish farm and easily find prey (other fish also attracted to the fish farm) within the immediate area. A large degree of uncertainty exists relating to the potential impacts of fish farms on shark presence and residency times within Algoa Bay. There is a severe lack of data and understanding of the site and species specifics, and indeed individual shark behavioural responses to such a development.	
	The significance of the impacts is assessed as **Medium** at Algoa 1.	The significance of the impact is assessed as **Low** at Algoa 5. As Algoa 5 is more remote there could possibly be less of an impact and threat to humans.
	Effective Monitoring / Mitigation Strategy	
	Essential mitigation measures at both sites: • The only effective way to address this is with extensive monitoring of shark movement patterns both at the ADZ sites, and at the popular bathing beaches inshore, **before and after** the stocking of cages. • **Baseline data** would have to extend for **at least 12 months** to cover seasonal variation in shark movement patterns (preferably longer to include inter-annual variation).	

Table 1: Ecological Assessment

<table>
<tr><th>ISSUE</th><th>ALGOA BAY 1</th><th>ALGOA BAY 5</th></tr>
<tr><td rowspan="4"></td><td colspan="2">Risk/Consequence</td></tr>
<tr><td>Medium</td><td>Low</td></tr>
<tr><td colspan="2">Confidence regarding severity of impact and risk ratings</td></tr>
<tr><td colspan="2">Impact and risk without and with mitigation: Low</td></tr>
<tr><td rowspan="4">Fauna: Cetaceans-entanglement and habitat use

The entanglement of marine mammals and occasionally other species such as turtles and birds in fish cage infrastructure are rare but do occur. Algoa Bay is an important cetacean habitat. Cetaceans may be able to avoid entanglement in fish cage infrastructure, but the mere presence of sea cages, as well as work boats continually travelling between land and the farm, may adversely affect habitat use and may have chronic negative effects on populations (as well as ecotourism activities).</td><td colspan="2">Impact</td></tr>
<tr><td>Key habitat areas for southern right whales, humpback dolphins and bottlenose dolphins were identified between PE Port and Cape Recife. These areas are adjacent to, but mostly inshore of the proposed Algoa 1 ADZ. The overall significance of the entanglement impact is assessed as Medium (without mitigation) to Low (with mitigation). The overall significance of the habitat use impact is assessed as Low.</td><td>A long coastal strip from just east of the Sundays River estuary mouth to Woody Cape was identified as a key habitat for southern right and humpback whales and bottlenose dolphins. This area lies inshore and to the east of the proposed Algoa 5 ADZ. However, it should be noted that humpback whales (along with Brydes whales and common dolphins) were associated with deeper water i.e. a more offshore group whose distributions may more frequently overlap with the proposed ADZs. The overall significance of the entanglement impact is assessed as Medium (without mitigation) to Low (with mitigation). The overall significance of the habitat use impact is assessed as Low.</td></tr>
<tr><td colspan="2">Effective Monitoring / Mitigation Strategy</td></tr>
<tr><td colspan="2">Essential mitigation measures (entanglement) at both sites:

• Do not locate ADZs in important cetacean habitats (fortuitously this is the case).

• Ensure all mooring lines and nets are highly visible (use thick lines and bright antifoulant coatings).

• Keep all lines and nets tight through regular inspections and maintenance.</td></tr>
</table>

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5

	• Ensure that mesh size on primary and secondary nets does not exceed 16 cm stretched mesh, use square mesh. • Establish a rapid response unit to deal with cetacean entanglements (collaboration with the South African Whale Disentanglement Network). Essential mitigation measures (habitat use) at both sites: • Keep a log of all cetaceans recorded in the vicinity of fish farms including behavioural observations • Establish a cetacean monitoring programme in order to detect potential changes in cetacean habitat use in the broader Algoa Bay **Risk/Consequence** Entanglement-**Medium** (without and with mitigation) Habitat use-**Low** (without and with mitigation) **Confidence regarding severity of impact and risk ratings** Entanglement Impact and risk without mitigation: **Medium** (probability of entanglement inferred from reported studies elsewhere) Impact and risk with mitigation: **Medium** (effectiveness of mitigation in local context is not known) Habitat use Impact and risk without mitigation: **Medium** (Monitoring required to confirm potential impacts on cetacean habitat use) Impact and risk with mitigation: **Low**
Fauna: Disease	**Impact** Wild fish in Algoa Bay will likely come into close contact with farmed fish resulting in the transmission of organisms and parasites that may cause disease. The significance of this impact and consequence were rated in the Marine Impact Assessment Report as high to very

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
The high stocking densities in fish aquaculture leads to the spread of infectious diseases and parasites. The spread of diseases amongst stock can not only result in large losses, but also transmission to wild stocks.	high. If aquaculture species which are not part of the receiving ecosystem are used, there is indeed a high risk that wild fish will become infected with new disease causing organisms to which they have no natural resistance. Provided that only indigenous fish species are farmed (dusky kob, silver kob, yellowtail), the disease causing organisms and parasites will originate from the wild fish populations. Under natural conditions, these potential disease causing organisms are not normally pathogenic as they have coevolved with the host fish species which possess a natural resistance. They may become pathogenic when the fish's immune systems are compromised by environmental stress. This is likely under aquaculture conditions, where fish are concentrated at high densities and stressful conditions, promoting higher disease causing organism and parasite loads. Farmed fish therefore are inherently more prone to these disease vectors inducing pathogenic symptoms. It is possible that wild fish in close proximity to farm cages may pick up higher parasite loads due to the shedding of parasite transmission stages by the farmed fish. This effect is likely to be highly localised to wild fish which come into the proximity of the farm and is therefore unlikely to compromise the ecology and productivity of wild fish populations and the associated fisheries, a concern which was raised in the Marine Impact Assessment report. The treatment of cultured stock is possible (unlike wild stocks), however chemical treatment is not without further environmental impacts, whilst build-up of antibiotic and chemical resistance is becoming increasingly problematic. Although mitigation measures are not entirely effective, the overall significance of the impact at both sites is estimated as **Low** to **Very Low**.	
	Effective Monitoring / Mitigation Strategy	
	Essential mitigation measures at both sites: • Use only aquaculture species which are present in the receiving ecosystem. • Maintain strict bio-security measures within hatchery, holding tanks and sea cages. • Ensure all fry undergoes a health examination prior to stocking in sea cages. • Regularly inspect stock for disease and/parasites as part of a formalised stock health monitoring programme and take necessary action to eliminate pathogens through the use of therapeutic chemicals or improved farm management. This will require focussed research effort into the identification, pathology and treatment of diseases and parasites infecting farmed species, both within culture and wild stocks. • Maintain comprehensive records of all pathogens and parasites detected as well as logs detailing the efficacy of treatments applied. These records should be made publicly available to facilitate rapid responses by other operators to future outbreaks. • Locate cages stocked with different cohorts of the same species as far apart as possible, if possible stock different species in cages successively.	

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
	• Treat adjacent cages simultaneously even if infections have not yet been detected. • Keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediates hosts and or pathogens. **Risk/Consequence** **Low** (without mitigation) **Very Low** (with mitigation) **Confidence regarding impact and risk ratings** Impact and risk without mitigation: **Medium** Impact and risk with mitigation: **High**	
Fauna: Genetic impacts on wild stocks *Escape of fish from sea cages that may be established in South African is inevitable given that escape from fish farms is a common event globally. Farmed fish that are typically spawned from a limited number of brood stock have reduced genetic diversity compared to wild stocks.*	**Impact** Concerns were noted in the Marine Impact Assessment Report regarding swamping of native fish populations by fish farm escapees. The risk of genetic contamination is accentuated by the collapsed status of many South African linefish species (that will likely be used in cage farming). The significance and impact were originally assessed as very high. However, the suggested downscaled farm production, from the order of 50,000t to an initial phase ca 1000-3000t, would go a long way towards reducing the number of escapees, and hence the potential further loss of genetic diversity. The impact rating for Algoa 1 after mitigation for mass farmed fish escapes is considered **Low** due to the more sheltered nature of this site. For an initial pilot operation of 1000t with the maximum production volume reduced to from 30,0000 to 9000 tons the risk is reduced to **Very Low.**	The impact rating for Algoa 5 after mitigation is considered **Medium** significance as a result of this site been significantly more exposed to winter storms and the probability of escapes due to cage system failure is considered higher. Essentially the effectiveness of the two mitigation measures to reduce escapes and recover escapees is considered to be lower at this site. If the maximum production volume is reduced to from 75,0000 to 18000 tons the risk is reduced to **Low.**

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
	Effective Monitoring / Mitigation Strategy	
	• Reduce the maximum production volume of the ADZs.	
	Risk/Consequence	
	Medium (without mitigation) **Low** (with mitigation)	
	Confidence regarding severity of impact and risk ratings	
	Impact and risk without and with mitigation: **Low** (as monitoring would be required to determine any changes in genetic diversity in wild stocks due to the influence of escaped culture stock)	
Benthic fauna and flora (reef) *Although not included in the exclusionary or precautionary criteria used for initial site selection, it is recommended that identified reef be excluded from ADZs within Algoa Bay.*	**Impact**	
	No reefs, as indicated by depth profiles (21.3-39.7m) and grab samples, occur at Algoa 1. Depth profiles at Algoa 5 indicate this site is for the most part featureless (22.4-37.6m), except for two areas (in the north-west corner and roughly centre) that may indicate the presence of reef. Grab samples confirm the presence of rocky reef in the north-west corner. Model outputs suggest a fish farm with a production of ~3000 tons will not result in a significant impact on the benthic environment in terms of bottom dissolved oxygen concentration and deposition of particulates. The significance of this impact is considered **Low**.	
	Effective Monitoring / Mitigation Strategy	
		• Exclude any reef areas - reduction of footprint
	Risk/Consequence	
	Low	

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
	Confidence regarding severity of impact and risk ratings	
	Impact and risk without mitigation: **High** (modeling outputs)	
Organic pollutants: Waste *Untreated wastes resulting mainly from uneaten food and faeces of fish in sea cages are discharged directly into the sea and are a significant source of nutrients. Sediments and benthic invertebrate communities under fish farms usually show chemical, physical and biological changes attributable to nutrient loading.*	**Impact**	
	The footprint and potential scale of development of the proposed Algoa 5 ADZ is considerably larger than that for the proposed Algoa 1 ADZ, whilst reef area was also identified within the Algoa 5 ADZ. However, the comparatively high wave and current energy of the Algoa Bay sites (considering globally most aquaculture takes place in more sheltered waters) suggests adequate dispersal and limited build-up below cages. Indeed, the modeling results too suggest limited waste emanating from a farm with a production of ~3000 tons. For these reasons, the original rating of the significance of the impact (High) noted in the Marine Impact Assessment Report is reduced to **Medium**.	
	Effective Monitoring / Mitigation Strategy	
	Essential mitigation measures at both sites: • Use species and system-specific feeds in order to maximize food conversion ratios (and minimize waste) • Monitor fish feeding behaviour and particulate matter deposition, adapt the feeding strategy to maximise feeding efficiency and minimise particulate matter fallout. • Sensible site selection, namely sufficient depth, current speeds and suitable sediment type (partly achieved in SEA, but reducing the size of Algoa 5 to exclude identified reef and inclusion of a buffer zone is recommended). • Prior to any development on either site, conduct a hydrodynamic modelling exercise of waste dispersal using detailed current profiling data (12 months of data should be available from January 2014). Model different levels of ADZ development and predicted waste discharge and ensure that the waste plume does not impact on sensitive habitats such as the Algoa Bay shoreline, important reefs and Island groups. • Undertake ongoing, detailed water quality and benthic monitoring, including baseline surveys at control and impact sites, and decrease the ADZ carrying capacity should the environmental quality indicator be exceeded outside of the accepted sacrificial footprint. Monitoring data to be evaluated by the Environmental Liaison Committee.	

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
	• Reduction in proposed maximum ADZ biomass. Provision for fallowing and cage rotation. Buffer zones between farms. **Risk/Consequence** **Medium** (without mitigation) **Low** (with mitigation) **Confidence regarding severity of impact and risk ratings** Impact and risk without mitigation: **Medium** (as monitoring required to determine the intensity of impact) Impact and risk with mitigation: **Low**	
Algal blooms *Nutrient loading, of the water column along with the reduction of dissolved O_2 concentrations, as a result of fish cages has been implicated in conditions that stimulate harmful algal blooms, which pose a threat to human health and shellfish mariculture operations. The south coast of South Africa, including Algoa Bay, has been shown to be susceptible to red tides, as demonstrated by the massive bloom of the dinoflagellate* Lingulodinium polyedrum *during the summer of 2013/14 [covering several hundred kms]. However, this bloom was shown to be a coastal rather than bay phenomenon and the development of such a bloom is unlikely to be influenced in anyway by wastes from a fish farm sited at Algoa 1.*	**Impact** The main driver of blooms is prevailing large scale coastal environmental conditions processes. There is some evidence that local sewage nutrient inputs into Algoa Bay and limited bay circulation under calm conditions fuel more dense blooms. The nutrient input from the fish farms is so minuscule, and dispersion so rapid, that the fish farm impact would be negligible and is **Very Low**. **Effective Monitoring / Mitigation Strategy** Not required **Risk/Consequence** **Low** **Confidence regarding severity of impact and risk ratings** Impact and risk without mitigation: **High** (modelling results indicate background unionized ammonia levels are note exceed as flushing by	

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
	currents is adequate to disperse waste from a farm with a production of ~3000 tons)	
Chemical pollution *Disinfectants, antifoulants and therapeutic chemicals (medicines) are typically used in sea cage fish culture. These chemicals are often directly toxic to non-target organisms and may remain active in the environment for extended periods.*	**Impact** The effects of chemical pollution arising from fish cages on Algoa 1 and Algoa 5 are anticipated to be highly localised in the vicinity of the fish cages in Algoa Bay. The high dispersal rates by currents will rapidly dilute and disperse any chemical pollutants. The quantity of chemicals used is potentially very small and occasional. Without mitigation, the intensity and overall significance of the impacts is regarded as **Medium** at both sites. Although the Marine Impact Assessment Report rates the significance at Algoa 5 as High, both sites have very similar fauna and the impacts and consequences would too be similar. **Effective Monitoring / Mitigation Strategy** Essential mitigation measures at both sites: • Use only approved veterinary chemicals and antifoulants • Do not apply antifoulants on site (at sea) • Where effective use environmentally friendly alternatives • Use the most efficient drug delivery mechanisms that minimise the concentrations of biologically active ingredients entering the environment • Use the lowest effective dose of therapeutants • Monitoring **Risk/Consequence** **Medium** (without mitigation)	Optional mitigation measures at Algoa 5: • Risk-averse site selection and avoidance of Algoa 5

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
	Low (with mitigation)	
	Confidence regarding severity of impact and risk ratings	
	Impact and risk without mitigation: **Medium** (monitoring required to determine the intensity of impact) Impact and risk with mitigation: **Low** (effectiveness of mitigation not known)	
Recreational: Scuba diving *Due to security concerns, fish farms will need to exclude other users from what was previously public sea space. As a result of the lack of sheltered sea space off South Africa's coast, most of the areas suitable for cage culture are already heavily utilised for recreational activities. The visual impact of an industrial fish farm in a nature scape is also a concern and the possibility of organic particulate waste settling on reefs.*	**Impact**	
	None of the 18 popular dive sites overlap with a proposed ADZ.	
	Five of these sites are however, 500-1000m from the border of Algoa 1. Settleable waste, based on a Mossel Bay study, was expected to sink to the sea floor within 200 m of the cages. This study did indicate that elevated levels of dissolved nutrients would likely occur up to 2 km from the fish cages, with nitrate levels expected to be above background concentrations 8-12km from the site under certain oceanographic conditions. As such the Marine Impact Assessment Report stated the significance of this impact as high. Model results indicate intermittent currents at Algoa 1 are strong enough to flush possible deposits on the bottom (current Sigma or standard deviation value >3cm.s^{-1}). This conclusion, is supported by the environmental monitoring programme observations conducted at the I&J pilot cage aquaculture site which found no measurable accumulation of deposits below the fish cages. The significance of the impact is therefore assessed as **Medium** (see Organic pollutants section) at the Algoa 1 site.	Due to the distance from popular dive sites and the fact that Algoa 5 is located within the MPA where diving is controlled/permited, the significance of the impact is assessed as **Very Low** at Algoa 5.
	Effective Monitoring / Mitigation Strategy	
	Essential mitigation measures at both sites:	

Table 1: Ecological Assessment

<table>
<tr><th>ISSUE</th><th>ALGOA BAY 1</th><th>ALGOA BAY 5</th></tr>
<tr><td rowspan="5"></td><td colspan="2">Reduce footprint of Algoa Bay 1 closest to the reef areas
Implement mitigation measures to try reduce organic and chemical pollution.
Implement recommended benthic monitoring and adaptive management as per EMPr monitoring components.</td></tr>
<tr><td colspan="2">Risk/Consequence</td></tr>
<tr><td>Medium (without mitigation)
Low (with mitigation)</td><td>Low (without and with mitigation)</td></tr>
<tr><td colspan="2">Confidence regarding severity of impact and risk ratings</td></tr>
<tr><td colspan="2">Impact and risk without mitigation: High (Model outputs)
Impact and risk with mitigation: Low (Effectiveness of mitigation unknown)</td></tr>
<tr><td rowspan="4">Recreational: Yacht sailing

It is acknowledged that yachting may be affected by ADZ development within Algoa Bay, however, the relatively large area utilized by yachts within Algoa Bay and relatively small proposed ADZ areas, means that these activities should not be mutually exclusive.</td><td colspan="2">Impact</td></tr>
<tr><td>One hundred percent of the Algoa 1 site is used by yachting. The significance of the impact is assessed as Low.</td><td>More than 50% of site used by yachting, and there are no plans to restrict this activity within the MPA. The significance of the impact is assessed as Low.</td></tr>
<tr><td colspan="2">Effective Monitoring / Mitigation Strategy</td></tr>
<tr><td colspan="2">Essential mitigation measures at both sites:
Install navigational markers and lights as required by SAMSA regulations.
Include position of ADZs on navigational charts.
Ongoing consultation with user groups to keep them informed of the ADZ developments.</td></tr>
</table>

Table 1: Ecological Assessment

<table>
<tr><th>ISSUE</th><th>ALGOA BAY 1</th><th>ALGOA BAY 5</th></tr>
<tr><td rowspan="6"></td><td colspan="2">Risk/Consequence</td></tr>
<tr><td colspan="2">Low (without and with mitigation)</td></tr>
<tr><td colspan="2">Confidence regarding severity of impact and risk ratings</td></tr>
<tr><td colspan="2">Impact and risk without mitigation: High
Impact and risk with mitigation: High</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="10">Recreational: Water sports

Due to security concerns, fish farms will need to exclude other users from what was previously public sea space. As a result of the lack of sheltered sea space off South Africa's coast, most of the areas suitable for cage culture are already heavily utilised for recreational activities such as water sports. The visual impact of an industrial fish farm in a nature scape is also a concern, as is the possible increased risk to watersport participants from sharks (see Fauna: Sharks and potential threats to humans).</td><td colspan="2">Impact</td></tr>
<tr><td>The significance of the impact is assessed as Low.</td><td>The significance of the impact is assessed as Very Low.</td></tr>
<tr><td colspan="2">Effective Monitoring / Mitigation Strategy</td></tr>
<tr><td colspan="2">Essential mitigation measures for both sites:
• Ongoing consultation with user groups to keep them informed of the ADZ developments.</td></tr>
<tr><td colspan="2">Risk/Consequence</td></tr>
<tr><td>Medium (without and with mitigation)</td><td>Low (without and with mitigation)</td></tr>
<tr><td colspan="2">Confidence regarding severity of impact and risk ratings</td></tr>
<tr><td colspan="2">Impact and risk without mitigation: Low (Confidence in the risk rating is low, as when considering risk to watersport participants from sharks, no prior knowledge of how large sharks may alter distribution patterns in relation to ADZ development exists)
Impact and risk with mitigation: Low (Effectiveness of mitigation unknown)</td></tr>
</table>

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
Recreational: Ski-boat anglers *Due to security concerns, fish farms will need to exclude other users from what was previously public sea space. As a result of the lack of sheltered sea space off South Africa's coast, most of the areas suitable for cage culture are already heavily utilised for recreational activities such as boast angling.*	**Impact** The significance of the impact is assessed as **Low** at both sites. **Effective Monitoring / Mitigation Strategy** Essential mitigation measures at both sites: • Install navigational markers and lights as required by SAMSA regulations. • Include position of ADZs on navigational charts. • Ongoing consultation with user groups to keep them informed of the ADZ developments. **Risk/Consequence** **Low** (without mitigation) **Very Low** (with mitigation) **Confidence regarding severity of impact and risk ratings** Impact and risk without mitigation: **High** Impact and risk with mitigation: **High**	
Commercial fishery: Squid *Squid* Loligo vulgaris reynaudii *was historically targeted by a (mostly foreign) demersal trawl fishery and landed as by-catch in the South African inshore trawl fishery. A dedicated jig fishery for*	**Impact** The Algoa 1 site clearly overlaps with an important squid fishing ground with nearly 8 % of the entire South African average annual effort and just over 1 % of the average annual catch reported from the grid block that overlaps the proposed ADZ. The discrepancy between effort and catch in this catch reporting block is largely	Algoa 5 overlaps with a less important, but not insignificant fishing ground (accounting for nearly 1 % of average annual fishing effort). As noted in the text of the Marine Assessment Report, the significance of the impact is assessed as **Medium**. With a reduction

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
squid, mostly concentrated in the Eastern Cape of South Africa, was initiated in 1984, and the landed catch is now worth more than R180 million per year.	due to the fact that vessels shelter from SW winds in the lee of Cape Recife, even during times when catches may be poor. Discussions with industry members suggests that the southern half of the proposed Algoa 1 is an important squid fishing ground and the industry would be strongly opposed to exclusion from this area. As noted in the text of the Marine Assessment Report, the significance of the impact is assessed as **Medium**. With a reduction in Algoa 1 area to Algoa option 1 North 210ha, the impact is reduced to **Very Low.**	in Algoa 5 area to 420ha, the impact is reduced to **Very Low.**
	Effective Monitoring / Mitigation Strategy	
	Optional mitigation measures at both sites: • Reduce the size of the ADZs	
	Risk/Consequence	
	Medium (without mitigation) **Very Low** (with mitigation)	
	Confidence regarding severity of impact and risk ratings	
	Impact and risk without mitigation: **High** Impact and risk with mitigation: **High**	
Commercial fishery: Shark longline *In the Algoa Bay area, the fishery targets smooth hound, soupfin,*	**Impact** Both Algoa 1, and particularly Algoa 5 (some 5 % of the annual average catch made within this reporting block), overlap with areas where the shark longline operator is active with ~8% of the average annual reported catch and effort taking place within grid blocks that overlap with the proposed ADZs. As noted in the text of the Marine Assessment Report, the significance of the impact is assessed as	

Table 1: Ecological Assessment

<table>
<tr><th>ISSUE</th><th>ALGOA BAY 1</th><th>ALGOA BAY 5</th></tr>
<tr><td rowspan="7">smooth hammerhead Sphyrna zygaena, bronze whaler, blacktip Carcharhinus limbatus, dusky Carcharhinus obscures and cow sharks Notorynchus cepedianus. Currently, demersal shark longlining is restricted to coastal waters (up to 100 m depth), and are permitted to fish up as far as East London, and use longlines with up to 3 000 hooks. There are a total of six rights holders in the demersal shark longline fishery. One of these operates in the Algoa Bay area, using a single vessel.</td><td colspan="2">Medium.</td></tr>
<tr><td colspan="2">Effective Monitoring / Mitigation Strategy</td></tr>
<tr><td colspan="2">Optional mitigation measures at both sites:
• Reduce the size of the ADZs</td></tr>
<tr><td colspan="2">Risk/Consequence</td></tr>
<tr><td colspan="2">Medium (without mitigation)
Very Low (with mitigation)</td></tr>
<tr><td colspan="2">Confidence regarding severity of impact and risk ratings</td></tr>
<tr><td colspan="2">Impact and risk without mitigation: High
Impact and risk with mitigation: High</td></tr>
<tr><td rowspan="4">Commercial fishery: Pelagic purse-seine

The small pelagic purse-seine fishery targets shoals of small pelagic fish that occur near the surface at night. The boats tend to fish overnight, landing their catches in the early mornings. Port Elizabeth boats can travel as far as Plettenberg Bay, though seldom go that far. Location is decided on the basis of communication between vessels and skippers local knowledge. The viable range is reported to extend from Bird Island in the east to Jeffrey's Bay in the west, with the cost of diesel as well as concerns about deterioration of the fish on board being the limiting factors.</td><td colspan="2">Impact</td></tr>
<tr><td colspan="2">The proposed ADZ areas only cover a small portion of the reporting grids, and given the mobility of the target species, the fishery should still have access to the shoals as they move away from the ADZ. Proclamation of either or both the proposed ADZs within Algoa Bay would appear to have a minor effect on the Algoa Bay small pelagic fishery in terms of loss of fishing grounds, and the significance of the impact is assessed as Low. Should any future finfish cage operation use frozen fish food at any stage of production however, there is a small but potentially highly significant risk of disease introduction that could decimate small pelagic stocks.</td></tr>
<tr><td colspan="2">Effective Monitoring / Mitigation Strategy</td></tr>
<tr><td colspan="2">Optional mitigation measures at both sites
• Avoid the use of frozen fish food</td></tr>
</table>

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
	Risk/Consequence	
	Low (without mitigation) **Very Low** (with mitigation)	
	Confidence regarding severity of impact and risk ratings	
	Impact and risk without mitigation: **High** (Fishing block data available and risk of disease from imported frozen pilchards from other ecosystems is well-known).	
Commercial: Traditional line-fishery The South African commercial line fishery is a boat-based fishery in which fish are caught on lines with no more than 10 baited hooks per line. The fishery thus operates inshore where fish are accessible on day or short overnight trips and in water shallow enough to be caught using manual labour with hand lines or rods and reels.	**Impact**	
	In total, only 2-3% of the average annual reported catch and effort for the Algoa Bay area is for grid blocks that include the proposed ADZs. Given that the ADZs include none (Algoa 1) or very little (Algoa 5) reef substratum, it appears that they will have little negative effect on the commercial line fishery in terms of loss of fishing ground. The significance of this impact is assessed as **Very Low**. *The same concerns about the possible introduction of diseases or genetic contamination of wild stocks by cultured fish (many potential cultured species are also targets of the line fishery), where raised in the Marine Impact Assessment Report and should be noted.*	
	Effective Monitoring / Mitigation Strategy	
	See essential mitigation measures for Disease and Genetic contamination of wild stocks.	
	Risk/Consequence	
	Low (without mitigation) **Very Low** (with mitigation)	
	Confidence regarding severity of impact and risk ratings	

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
	Impact and risk without mitigation: **High**	
Proposed Addo Elephant MPA *The coastal area of Addo Elephant National Park stretches between Sundays River Mouth and Bushman's River Mouth. It incorporates the Alexandria Dunefield – the largest (covering approximately 15 800 hectares) and least degraded coastal dunefield in the southern hemisphere, and Bird and St. Croix Islands. A larger MPA of an envisaged 120 000 hectares is proposed for Algoa Bay. This MPA will be the first to incorporate a bay environment, exposed rocky headlands and offshore islands.*	**Impact**	
		The proposed Algoa 5 ADZ falls within the proposed Addo Elephant MPA. SANParks, the main proponents of this MPA, have indicated that they in principle do not support the concept of commercial mariculture within MPAs, however it must be noted that an ADZ has been included in the draft regulations currently out for public comment. This negative impact on the conservation objective is rated as **High** significance as it both compromises the functioning and management of the proposed MPA and also sets a precedent for MPAs elsewhere in South Africa. No effective mitigation exists, other than the No-go option for Algoa 5. SANParks does not support the view that a farm that does not disturb the current environment will have a limited impact. One of the primary objectives of the MPA is to rebuild depleted fish stocks. Specific concerns raised include attraction of sharks and other predators to the area, cetacean and bird entanglement in nets around cages, nutrient input from cages, (smothering benthic invertebrates and algal growth), general water quality deterioration, disease transfer, genetic pollution and organic and chemical pollutants and their impact on the MPA and associated fauna.
	Effective Monitoring / Mitigation Strategy	
		Optional mitigation measures: • No go option OR • Reducing the footprint of the ADZ such that a further buffer is created between the islands and the ADZ.

Table 1: Ecological Assessment

ISSUE	ALGOA BAY 1	ALGOA BAY 5
	Risk/Consequence	
		Medium (with mitigation)
	Confidence regarding severity of impact and risk ratings	
		Impact and risk without mitigation: **Medium**

4. REFERENCES

Anchor Environmental (2011) *'Strategic Environmental Assessment: Identification of potential aquaculture development zones for finfish cage culture.'* Draft for Public Comment. Report prepared for Department of Agriculture, Forestry and Fisheries, Cape Town.

Anchor Environmental (2013) 'Draft Marine Specialist Report: Marine Aquaculture development zones for finfish cage culture in the Eastern Cape: Impact Assessment Report.' Cape Town.

Bornman TG and Goschen WS (2016) Characteristics of the *Lingulodinium polyedrum* red tide in Algoa Bay and its implications for mariculture. SAEON Elwandle Coastal Node, Port Elizabeth. Unpublished report.

Britz PJ, Hosking S, Schoonbee W and Johnson G. *Comparative Assessments For The Development of the Proposed Sea-Based Aquaculture Development Zone Located Within Algoa Bay, Eastern Cape Province.* A report for the Department of Agriculture, Forestry and Fisheries by Rhodes University, August 2016.

CapeEAPrac (2012) *Amended Final Scoping Report. Algoa Bay Sea-Based Aquaculture Development Zones Port Elizabeth*. Cape Environmental Assessment Practitioners (Cape EAPrac). Prepared for the Applicant: Department of Agriculture, Forestry and Fisheries (DAFF).

CapeEAPrac (2013) *Final Impact Assessment Report and Environmental Management Programme.* Algoa Bay Sea-Based Aquaculture Development Zones Port Elizabeth. Cape Environmental Assessment Practitioners (Cape EAPrac). Prepared for the Applicant: Department of Agriculture, Forestry and Fisheries (DAFF).

Department or Environmental Affairs (2016). *Draft Notice Declaring The Addo Elephant Marine Protected Area Under Section 22a Of The National Environmental Management: Protected Areas Act, 2003 (Act No. 57 of 2003)*. Government Gazette Notice: No. R. 116 by Department Of Environmental Affairs: National Environmental Management: Protected Areas Act, 2003 (Act No. 57 of 2003). 3 February 2016.

Stigebrandt A, Aure J, Ervik A and Hansen PK (2004). Regulating the local environmental impact of marine fish farming. III. A model for estimation of the holding capacity in the Modelling-Ongrowing Fish Farm – Monitoring system. *Aquaculture* 234: 239-264.

Winter, D (2006). *Environmental monitoring programme pertaining to the proposed ongrowing of finfish in sea cages near the Port Elizabeth harbour*. IECM Report C142. Integrated Environmental and Coastal Management, Nelson Mandela Metropolitan University.

APPENDIX 1. OCEANOGRAPHY OF THE PROPOSED ALGOA BAY ADZ: SITE 5

1. EXECUTIVE SUMMARY

This report presents the full 12 months of Acoustic Doppler Current Profiler (ADCP) data collected at the Algoa Bay Aquaculture Development Zone (ADZ) site 5 between 31 January 2013 and 4 February 2014. A thorough review of existing literature on ocean circulation in Algoa Bay is presented to contextualise the new measurements. The new Algoa 5 ADCP data (processed from raw data) are presented in the form of directional current roses and velocity frequency plots, as done in the MSR (July 2013). These showed the near-surface (5.5 m) principal flow axis to be along 90−275° which is not aligned with the curved bathymetry of the embayment, and hence has an onshore component when currents flow westward of ~15%. This contrasts the previously published results in the MSR (July 2013) based on only 4.5 months, which showed a much greater skewed westward proportion of 25%. In principle this lessens waste dispersion towards the coast as previously anticipated. The near-bottom data (23.5 m) depicted a greater onshore−offshore flow component being principally aligned along 120−300° axis. Whereas the 4.5-month dataset indicated a dominant onshore flow of 16%, the 12-month data showed only 10% with the dominant flow being offshore which bodes well for removal bottom wastes. Seasonal variability in the current regime was most noticeable between summer and winter with dominant westward flow during the former and conversely eastward flow during the latter – both a consequence of the prevailing easterly and westerly seasonal winds. The statistics from the 12 month ADCP dataset were used to inform the Modelling–Ongrowing fish farm–Monitoring System (separate report). Time series plots highlighted the current regime at Algoa 5 to comprise mostly of alternating east−west flows, typically lasting 2−3 days but on occasion was observed for 20 days. The intrusion of cold upwelled water as low as 11°C into this site occurs during the summer months of November to April, and is almost identical in nature to that of Algoa 1. These results are very similar to a study undertaken 30 km further east (Roberts, 2010). While the wave data showed the average significant wave height to be 1.25 m at Algoa 5, the maximum of 5.12 m highlights this site to be more exposed to swell than Algoa 1 which is in the lee of Cape Recife when a south-westerly swell is running.

Prof Michael Roberts

August 2016

2. SCOPE

The scope of the oceanography component of the TOR was to:

1. Ensure all relevant literature is highlighted and synthesised to strengthen that in the Marine Specialist Report (MSR) (July 2013)
2. Complete the ADCP data analysis for Algoa 1 and 5 to cover the full 12 months of instrument deployment for
    a. Currents
    b. Water temperature
    c. Waves
3. Use these up-dated datasets to estimate the dispersion and assimilation of waste from a proposed 3000 t fish farm at both Algoa 1 and 5 using the *Modelling–Ongrowing fish farm–Monitoring System* (MOM – Stigebrandt et al., 2004). These results will be published in a separate report.

3. PREVIOUS CIRCULATION STUDIES NOT INCLUDED IN THE MSR JULY 2013

This reference builds onto that already mentioned in the MSR (July 2013) and goes into the circulation of Algoa Bay in more detail.

Most of the current measurements made in Algoa Bay have focused on the western sector and addressed harbours, coastal erosion or pollution activities. In an early, unpublished study during 1964–1965 by the Port Elizabeth Municipality (detailed in Roberts 1990), in preparation for the Fishwater Flats sewage pipeline, a large number of near-surface drogues set at 3 m were released at distances of 1 km, 2 km, 3 km and 4 km from the coast under various wind conditions. The data showed that nearshore surface currents near the Swartkops River flowed mainly alongshore, were strongly correlated with wind direction, and the north-eastward flow was twice as dominant as that of the south-westward flow. A later study (1967–1968) in the same vicinity (CSIR 1970), using a moored surface buoy system and a primitive current meter deployed near the bottom 1 km offshore, reported similar results, with surface velocities reaching 23 cm s^{-1}. The bottom current was not only found to be weaker, with a maximum velocity of 8 cm s^{-1}, but a dominant south-westward flow indicated dissimilar patterns between surface and bottom. The importance of wind as a driving force of the surface and near-surface layers in the nearshore region of Algoa Bay was again confirmed by Roberts (1990) using small drogues set to depths of 0 m, 1 m, 2 m, and 4 m and released farther south near the Paapenkuils Canal. The author reported maximum velocities in the surface layer (0 m) to range between 50 cm s^{-1} and 100 cm s^{-1} under strong south-westerly winds.

Later, Schumann et al. (2005) reported data from five vector-averaging current meters (VACMs) deployed near the seabed in depths of 8–17 m to the south of the Paapenkuils Canal in 1989. The one deployed near the canal (1 km offshore) for 46 days showed a strongly dominant northerly flow parallel with the shore with average speeds of 4 cm s, but with little correlation with wind. The VACM deployed in the south on Philips Reef (17 m deep) showed an omni-directional flow with an average speed of 7 cm s–1 (5% having speeds >20 cm s). Schumann et al. (2005) also reported data from two moorings 5 km and 9 km offshore in 1995 in 17 m and 40 m for 53 days. The latter had single-point current meters at depths of 25 m and 35 m. Both moorings showed dominantly south to south-westward flow. Average speed at the shallower mooring (17 m) was 6 cm s with a maximum of <20 cm s^{-1}. Average speed measured by the top meter (25 m) at the deeper site was 10 cms^{-1} with a maximum of >40 cm s^{-1}, whereas the near-bottom meter (35 m) yielded 8 cm s^{-1} and >35 cm s^{-1} respectively. Importantly, whereas all current meter data reported by Schumann et al. (2005), i.e. inshore and offshore, showed some tidal forcing by the M2 semi-diurnal tide (12.42 h) and an inertial component (21.4 h), little correlation with wind was found. Coastal-trapped waves have been shown to influence current patterns off East London (Schumann and Brink 1990). Similar analyses by Schumann et al. (2005), however, were inconclusive with respect to currents in Algoa Bay, and rather indicated that the dominant south-southwest current pattern deeper in the bay was influenced by entrainment of shelf water into the Agulhas Current. However, using ships' drift (Harris 1978) and surface drift cards (Lutjeharms et al. 1986), the main current in Algoa Bay was shown to flow north-eastwards, with south-westwards being the next most important direction, and, importantly, that the currents followed the wind with speeds between 20 cm s^{-1} and 40 cm s^{-1}. Goschen and Schumann (1988) recorded a north-eastward flow in Algoa Bay in sync with the wind and with surface current speeds of about 50 cm s^{-1} in the middle of Algoa Bay. Overall, only the current meter studies reported in Schumann et al. (2005) do not show a good correlation between current and wind, even those in shallow water.

More recently Roberts (2010) undertook an 8-month ADCP study which focused on the nearshore waters (5–25 m) along the extensive eastern sector of Algoa Bay, a distance of 50 km between the Sundays River and Woody Cape, where no current measurements had previously been made. Despite the superior ADCP technology used, there were problems caused by rip currents, which consequently led to the exclusion of data for the top layer (0–9 m) of the water column. Despite this, the time-series collected by the ADCP mooring has provided important insight into the dynamics of the nearshore current in the bay, and, in the absence of rip activity, more than likely represents the behaviour of the entire water column.

The data have clearly shown a dominant alternating eastward–westward alongshore current pattern, typically prevailing for 1–3 days in each direction, but at times lasting as long as seven days. A frequency analysis showed eastward flow to almost equal westward flow at a depth of 10 m, with the near-bottom layer having a greater tendency towards the west. The maximum velocity measured by the ADCP was 75 cm s^{-1} at 10 m and 65 cm s^{-1} at 19 m, with averages of 17.6 cm s^{-1} and 10.8 cm s^{-1} respectively. However, given the spectrum of velocities in their Figure 5, a maximum velocity in the near-surface layer of up to 100 cm s^{-1} can be expected during strong wind events. The alternating flow pattern observed there is similar to that reported by

Schumann et al. (2005) from current meter records set at the Paapenkuils Canal and from offshore moorings reported, except the former showed greater dominance in a northward flow and the latter a strong bias in flow to the south-southwest. Velocities in the Roberts (2010) study were greater than those reported by Schumann et al. (2005). Unlike data from the current meter studies in the western sector of Algoa Bay, when plotted in stick vector format, these data exhibited a good correlation between current and wind direction. This indicates that wind is a primary driving force of the nearshore current along this stretch of the coast, which does not concur with the findings of Schumann et al. (2005). It is surprising that this correlation is not supported to a similar degree by the Pearson *r* analysis (r = 0.45). This could be a result of topographical influences such as shoreline orientation relative to open water in the case of wind direction data from Bird Island. However, occasionally there is a breakdown in the positive correlation (see anomalies 1 and 2 in their Figure 6b).

4. DATA AND ANALYSIS

Two kinds of ADCPs were used to record data on the Algoa 1 and 5 sites. Brief details are provided below.

Site	Lat	Lon	Depth (m)	Instrument	Start Date	Service date	To date
Algoa 1	33.967	25.696	25	RDI Teledyne	31 Jan 2013 (waves not activated)	11 Jun 2013	4 Feb 2014
Algoa 5	33.753	25.881	25	YSI Argonaut 750kHz	31 Jan 2013	11 Jun 2013	4 Feb 2014

The MSR (July 2013) published data for the first 4.5-month deployment (31 January and 11 June 2013) for both Algoa 1 and 5. No wave data were captured for Algoa 1 as the instrument was not set up for this type of sampling. Data for the temperature array was visualised in Figure 22, currents as compass roses and velocity histograms in Figures 27 and 28, and wave data (Algoa 5) in terms of significant wave and period histograms in Figure 29.

For the purpose of analysing the full 12-months of hourly collected data, raw data files were retrieved from Anchor Environmental Consultant and processed. It was found that data for the second deployment for Algoa 1 was not usable as the instrument had been incorrectly set up to use only 1 ping per ensemble. The number of pings per ensemble affects the accuracy of the velocity measurements made by an ADCP and hence standard deviation. Typically, 50 pings per ensemble are used.

Consequently, the analysis focused on Algoa 5. As indicated in the table above, a *YSI Argonaut* 750 kHz ADCP was deployed in Algoa 5 at 33.75 S; 25.88 E in a depth of 25 m between 31 January 2013 and 4 February 2014 (see Figure 1a). This position was at the northern side of the selected site. A magnetic deviation of −28° was used in the processing of these data (i.e. 28° W). As shown in Figure 1b, depth within Algoa 5 ranged from 22.4 m at the north-western-most corner to 37.6 m at its southernmost offshore areas. With the exception of two small reef areas in the north-west corner and centre, the entire area is relatively even and featureless implying that currents will not be affected by topographic features other than the general curvature of the bay.

The processed data were used to produce velocity frequency plots and current roses to gain an overview of the circulation at Algoa 5, as well as seasonality. These statistics were then used for the MOM (separate report). The full 12-month hourly measured time series of direction and velocity were plotted to understand the flow dynamics. Hourly bottom temperature data collected by the ADCP was plotted as a time series and correlated with currents. Finally, the wave data in the form of significant wave height (Hs) and wave period were plotted as a time series.

4.1 OVERVIEW OF CURRENT DIRECTION AND VELOCITY

Figure 2a and 2b show the near-surface (4-6.5 m) and near-bottom (21.5-24 m) current roses for the first deployment between 31 January and 11 June 2013 (taken from MSR July 2013). As indicated in the MSR (2013), currents through most of the water column flowed predominately towards the west (25%), with a significant east flowing component (16%). Not stressed however, is that this amounts to an onshore component at this location (see Figure 1a). Northward currents which are directly onshore were found to be small in the near-surface layer (<5%). Interestingly, onshore flow is further enhanced at the bottom (Figure 2b) with the principal flow in a WNW direction. Current velocity decreased with depth through the water column. Near the bottom (16-25 m), currents were less than 10 cm s^{-1} for 70-80% of the time, whilst near surface currents (<11.5 m) were greater than 10 cm s^{-1} for 40-45% of the time and fairly regularly exceeded 30 cm s^{-1} (maximum = 51 cm/sec).

Figures 2c and 2d show velocity frequency plots and current roses for the full 12-month deployment at Algoa 5. Comparison with the 4.5-month deployment show a more even distribution of west-east aligned principal currents in the near-surface (~15%). This makes sense as the former short data set was skewed with the inclusion of summer easterly winds which drive the surface layer westwards. The 12-month data set includes a full winter with counter westerly winds. Also noticeable is a secondary prominent WSW–ENE axis which is more aligned with the curved coast and bathymetry, and consequently lessens the onshore component. Directly north winds (onshore) were found to be similar to the short dataset (<5%).

As shown in Table 1, comparison of the velocity histograms does not show significant differences between the 4.5-month and 12-month data sets.

TABLE 1: NEAR-SURFACE VELOCITIES

Dataset	Calm	0-5	5-10	10-15	15-20	20-25	25-30	>30
4.5 months	0	24	30	20	13	6	3	4
12 months	0	19	28	23	14	8	4	2

Table 2 shows the comparisons for the near-bottom layer, and similarly shows minor differences.

TABLE 2: NEAR-BOTTOM VELOCITIES

Dataset	Calm	0-5	5-10	10-15	15-20	20-25	25-30
4.5 months	0	38	41	16	4	1	0
12 months	0	34	41	18	6	1	1.5

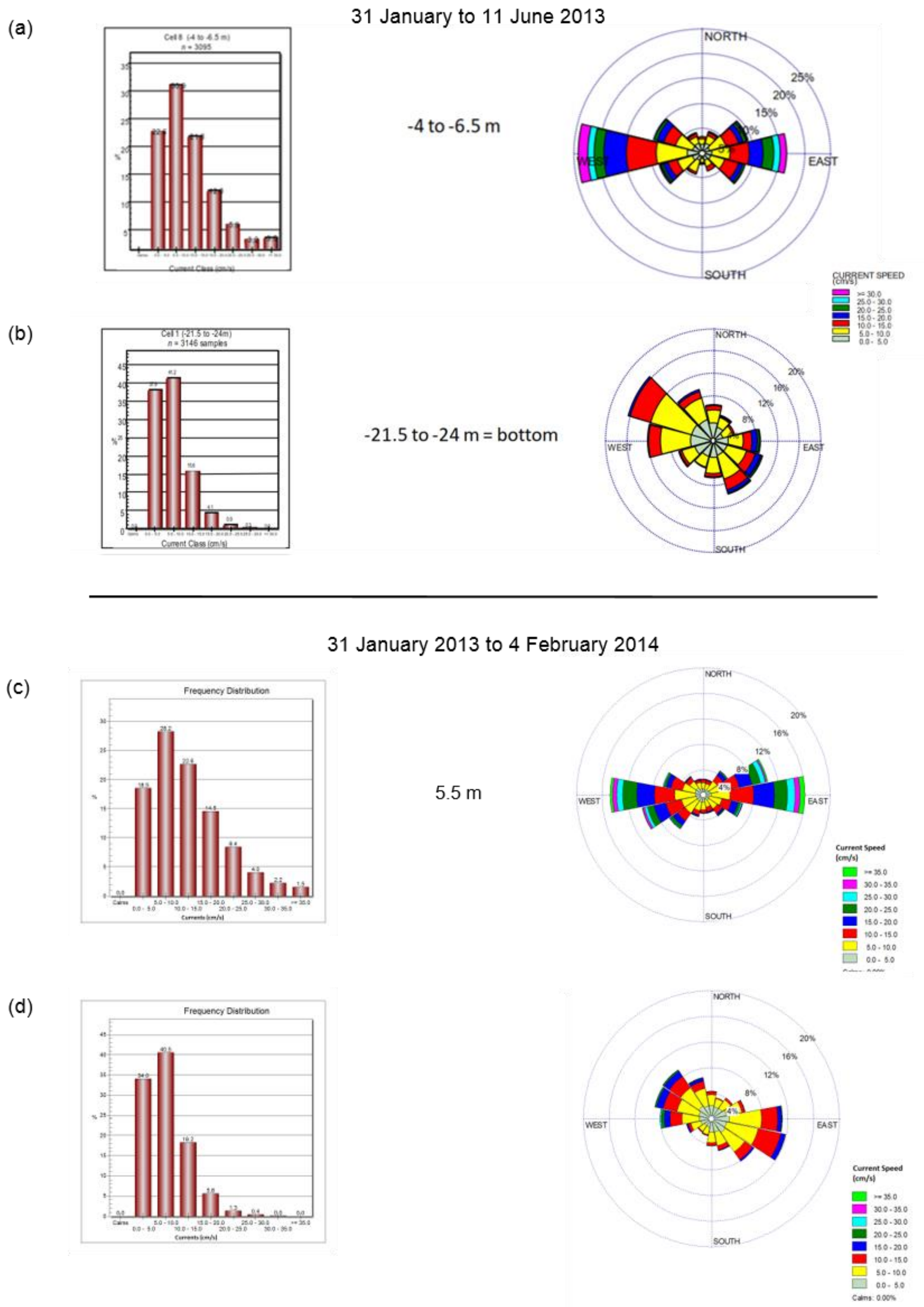


FIGURE 2: COMPARISON OF CURRENT STRENGTH (FREQUENCY) PLOTS AND DIRECTION ROSES ON ALGOA 5. NEAR-SURFACE (A) AND (B) BOTTOM BINS FOR THE INITIAL 4.5 MONTHS. NEAR-SURFACE (C) AND (D) BOTTOM BINS FOR THE FULL 12-MONTH DATASET.

4.2 SEASONALITY OF CURRENTS

Near-surface layer

Semi-seasonal plots of the 12-month dataset are shown in Figures 3 (near-surface current roses), Figure 4 (near-surface velocity frequency), Figure 5 (near-bottom current roses), and Figure 6 (near-bottom velocity frequency). As expected, the prominent differences are observed in the near-surface currents between late summer and winter (Figure x) where the current regime is dominated by W–WSW (39%) and E–ENE (34%) currents respectively.

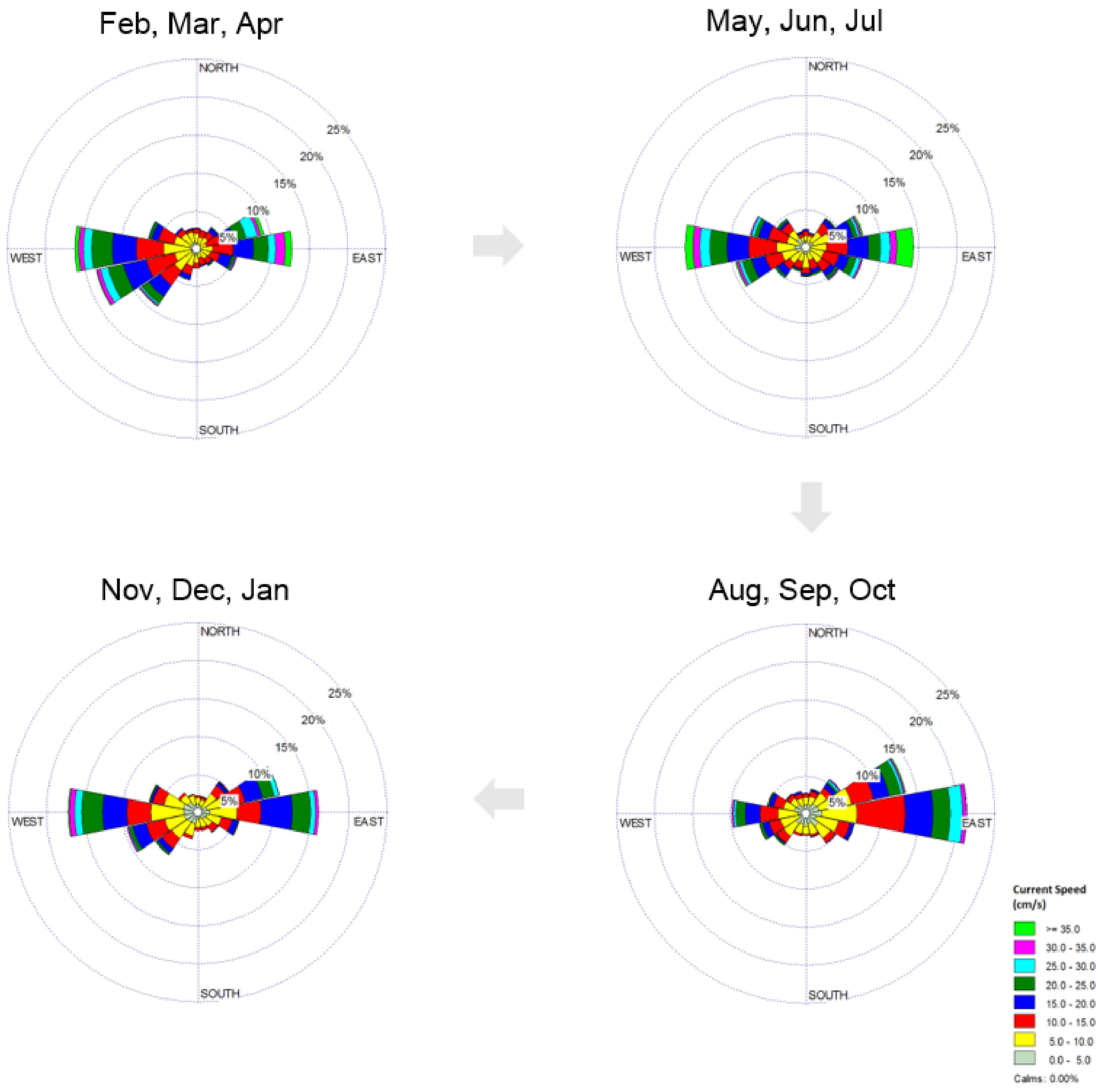


FIGURE 3: SEASONAL CURRENT ROSES FOR ALGOA 5

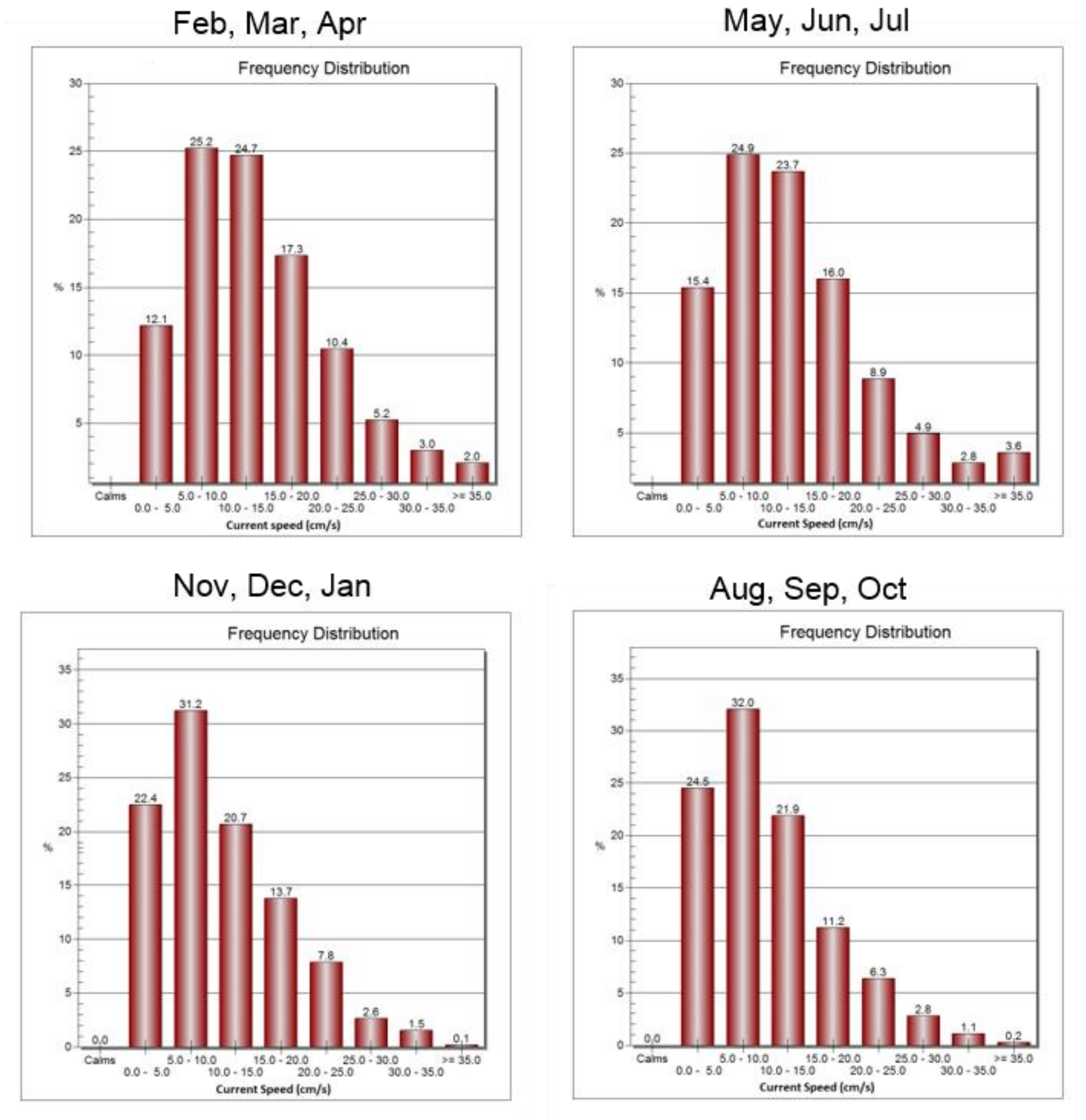


FIGURE 4: SEASONAL NEAR-SURFACE VELOCITY FREQUENCIES FOR ALGOA 5. NOTE THE Y-AXIS SCALE IS NOT THE SAME FOR THE BOTTOM PLOTS

The maximum velocity during this period of monitoring was 53 cm s^{-1} in the near-surface layer. The seasonal frequencies plots in Figure 4 show similar velocity spectrums in the first and last 6 months respectively, i.e. [Feb, Mar, Apr] spectrum is similar to that for [May, Jun, Jul] and [Aug, Sep, Oct] is similar to [Nov, Dec, Jan]. The vast majority of velocities (>85%) range between 5–20 cm s^{-1}. No absolute calms (0 cm s^{-1}) were measured but sluggish water movement of 0.1 to 5 cm s^{-1} were found to range between 12% and 25%, with the former in late summer and latter in late winter.

Near-bottom layer

Interestingly, the principal flow axis in the near-bottom layer is along 300°−120°, resulting in a prominent (~40%) onshore component during late spring-early summer (Nov, Dec, Jan) and dominant (~45%) offshore component in late winter (Aug, Sep, Oct). Orthogonal flow to this axis which is aligned more closely with the bathymetry, only accounts for some 25%.

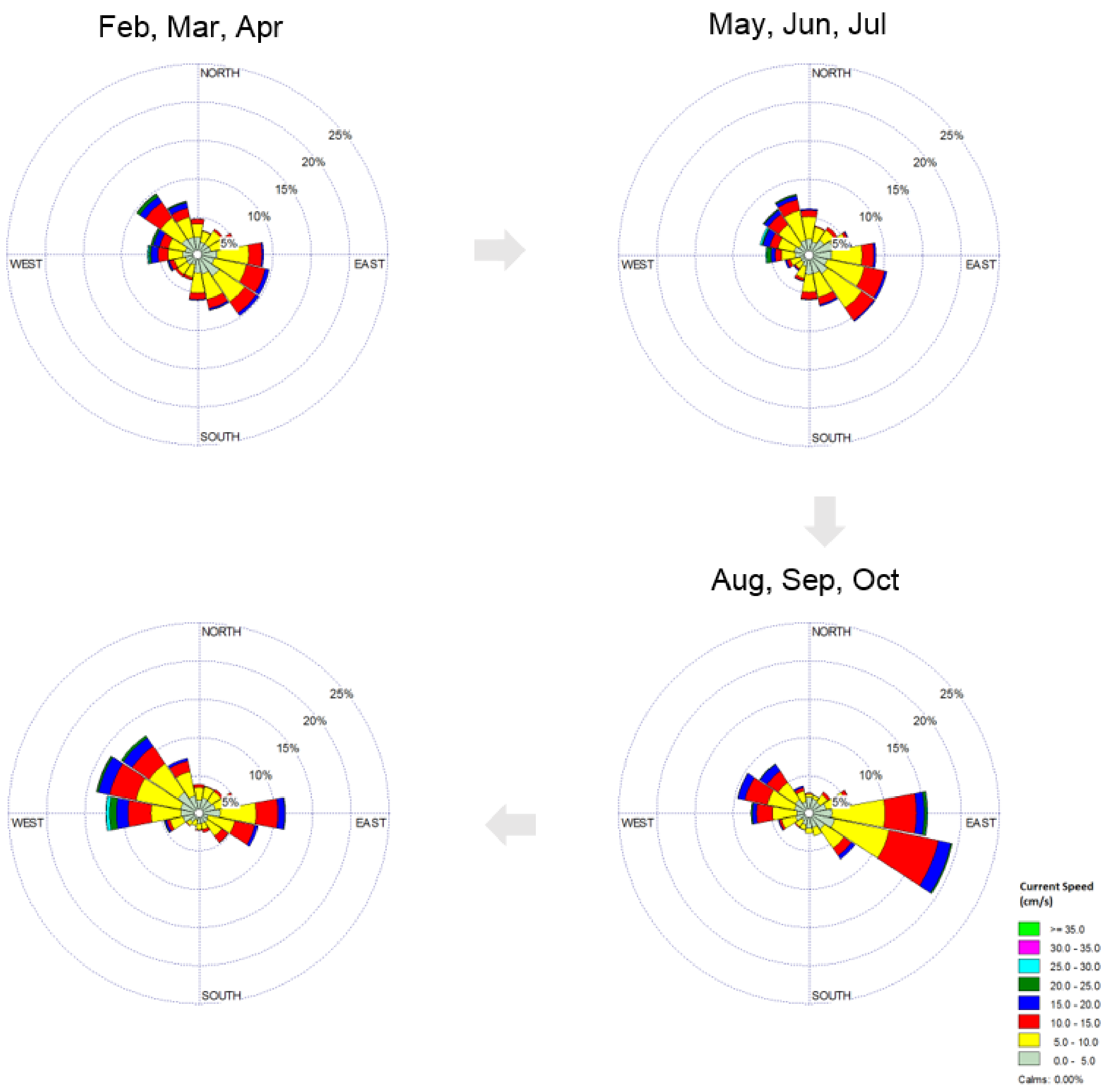


FIGURE 5: SEASONAL CURRENT ROSES FOR ALGOA 5

Near-bottom velocity frequency

Figure 6 shows the seasonal velocity frequencies for the above current roses. The velocity profile is similar for all seasons with 80% of flows being < 10 cm s^{-1}. Bottom velocities < 5 cm s^{-1} occurred around 35% of the time.

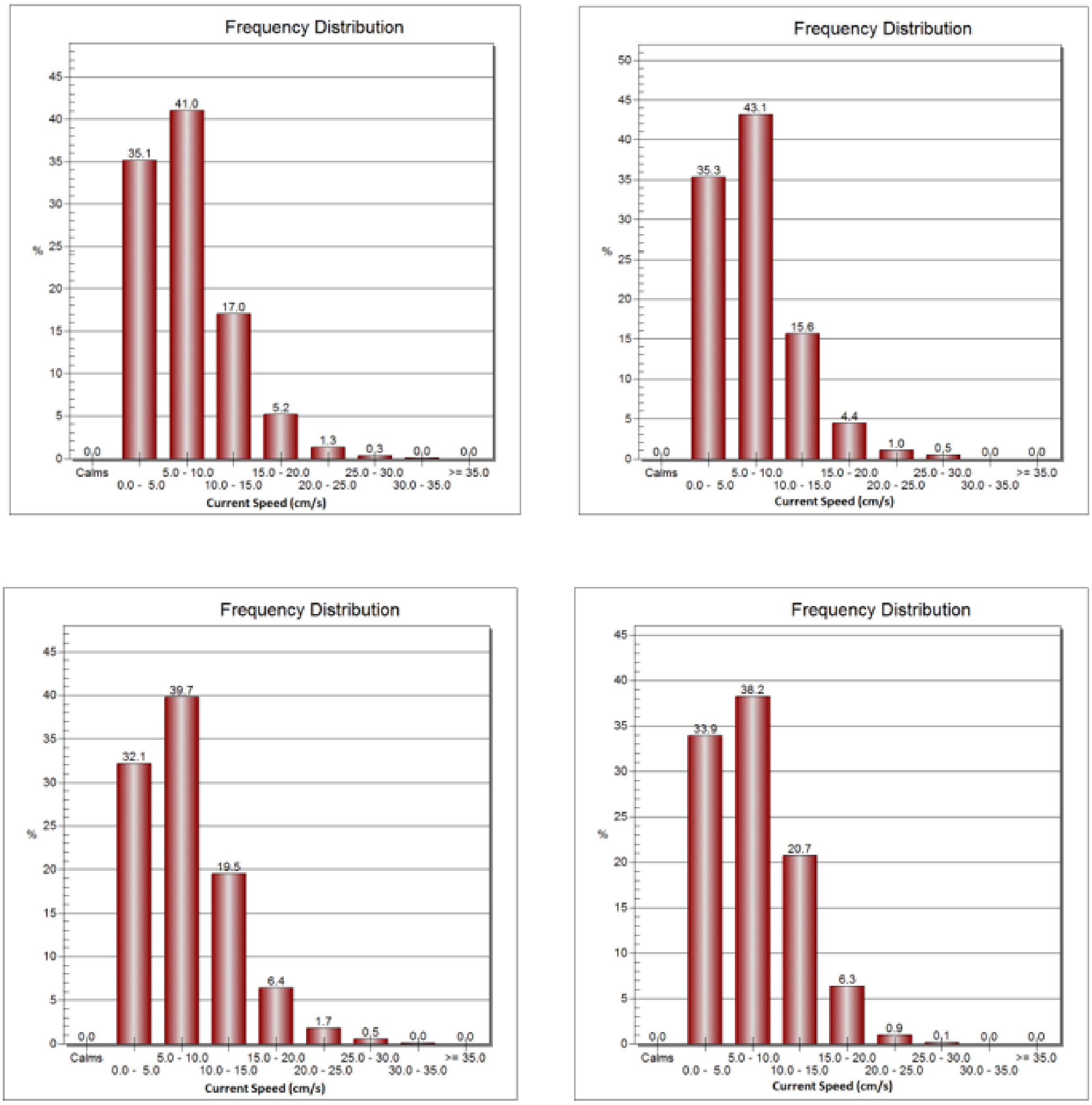


FIGURE 6: SEASONAL NEAR-BOTTOM VELOCITY FREQUENCIES FOR ALGOA 5. NOTE THE Y-AXIS SCALE IS NOT THE SAME FOR THE BOTTOM PLOTS

4.3 TIME SERIES OF CURRENTS

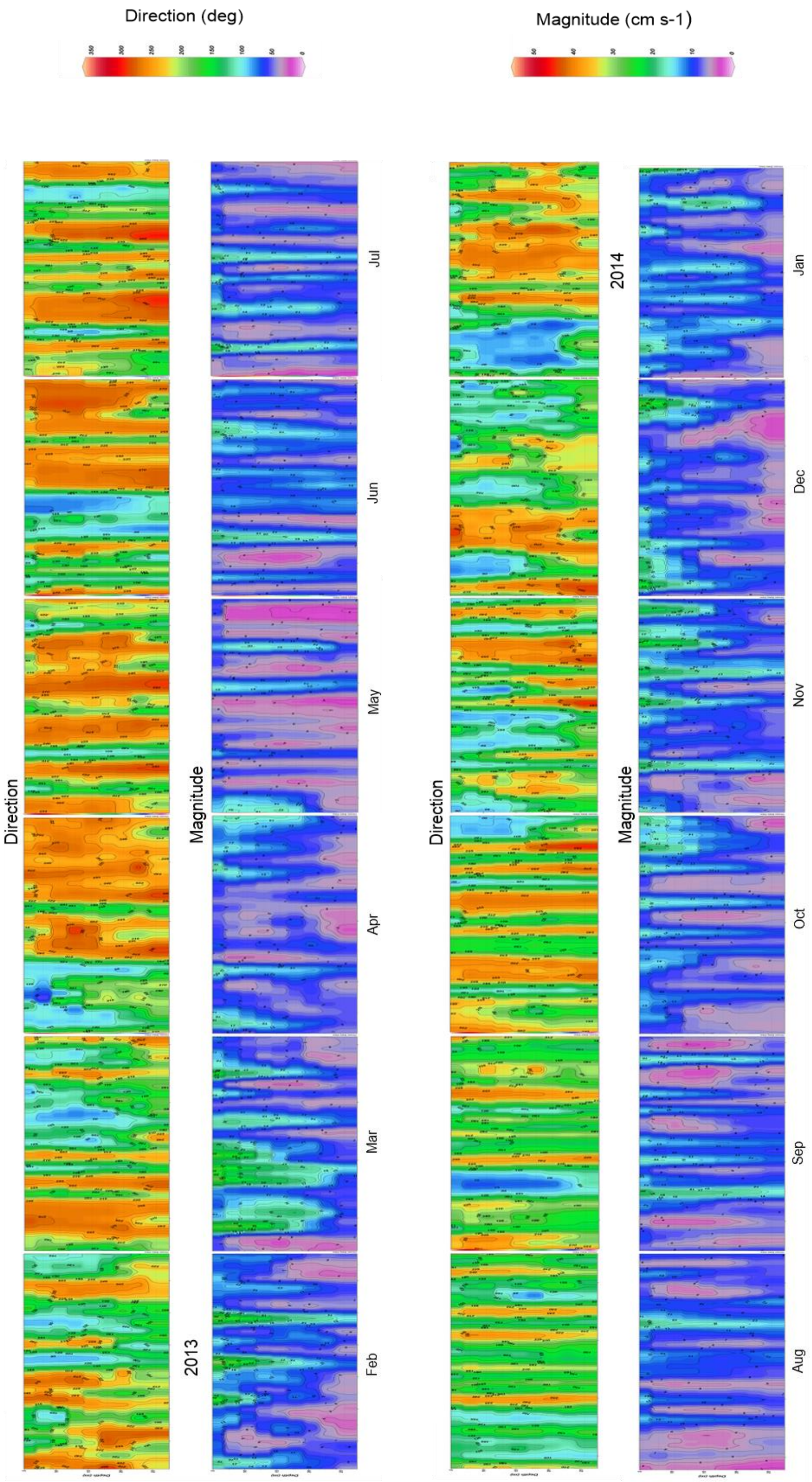


FIGURE 7: 12-MONTH TIME SERIES OF ADCP MEASURED CURRENTS AT ALGOA 5.

Figure 7 depicts the 12-month time series of the ADCP measured currents and provides information on the dynamics that is complimentary to the current roses. It is clear that the current regime comprises mostly of alternating east−west flows along the east−west axis. These alternating flows typically last 2-3 days, but as seen in April 2013, can exceed 20 days (orange-brown colour indicating westward flow) in exceptional cases. Current direction was mostly near-unidirectional throughout the water column. High velocities in the upper water column were associated with both westward and eastward flows. Seldom however did these 'high' velocity events reach the bottom. On occasion however, differing top and bottom currents were observed. The period of April, May, June and July standout as having more westward current than the remainder of the time series.

4.4 BOTTOM TEMPERATURE

The full 12-month near-bottom temperature dataset measured by the ADCP is shown in Figure 8. As seen by the low temperatures of <14°C, there is little doubt that cold upwelled water reaches the Algoa 5 ADZ site during the summer months, despite it being well away from the known upwelling areas at the extremes of the bay. Upwelling is caused by (north-)easterly winds mostly prevalent between the months of November and April, and originates on the western side of Cape Recife and off Port Alfred. Plumes of cold surface water are commonly observed in satellite SST imagery. In both cases, the cold upwelled water moves westwards from the upwelling centres. Certainly in the case of the former location, westerly winds are known to push this upwelled water eastward around Cape Recife accounting for the low water temperatures off Summerstrand. Upwelling is seldom observed between May and October when the South Indian Ocean and South Atlantic Ocean High Atmospheric Pressure cells move northward and the easterly winds fade along the South African south coast.

Comparison of the Algoa 5 temperature trace with that of Algoa 1, indicates not only very similar cold water events (i.e. temperatures), but also very similar timing of these events. This lack of delay suggests that the same body of cold water impacts both sites simultaneously, and therefore cannot be cold upwelled water advected eastwards or westwards into the bay from the main upwelling centre of Cape Recife and Port Alfred. Rather, it would appear that easterly winds and their offshore surface layer transport draw cold bottom water from the nearby shelf.

Figure 9 shows the near-bottom temperature for the month of March during substantial upwelling (dashed line box in Figure 8). Of interest here is that low bottom temperatures are associated with westward flow which, as demonstrated by Roberts (2010), is most likely driven by the easterly wind. This supports the observations made above with respect to Figure 8, and that it is one nearby body of cold bottom water which upwells at both Algoa 1 and 5. In other words, the easterly wind causes offshore Ekman transport in the upper layer which is then replaced by colder bottom from the greater shelf. Also of interest, is that the upwelling events are correlated with stronger bursts of current (green colour in Figure 9c) — although for some reason the first burst had less impact on bottom temperature than the others.

Six-months (Jan – Jun 2013) of temperature data, as presented in the Marine Specialist Report, is given in Figure 10a. It is clearly shown that upwelling is mostly restricted to the lower half of the water column in Algoa 5, but occasionally during intense upwelling cold water does reach the surface (Events 1-2). Events 3 and 4 show cold water moving above 10 m. However, this is one set of relatively short observations. Also included (Figure 10b) is a temperature plot from Goschen et al. (2012) which shows temperature data collected from a thermistor array 8 km away from near St Croix (also in Algoa 5). Note here that upwelled water does reach the surface and the entire water column is cold (12-14°C).

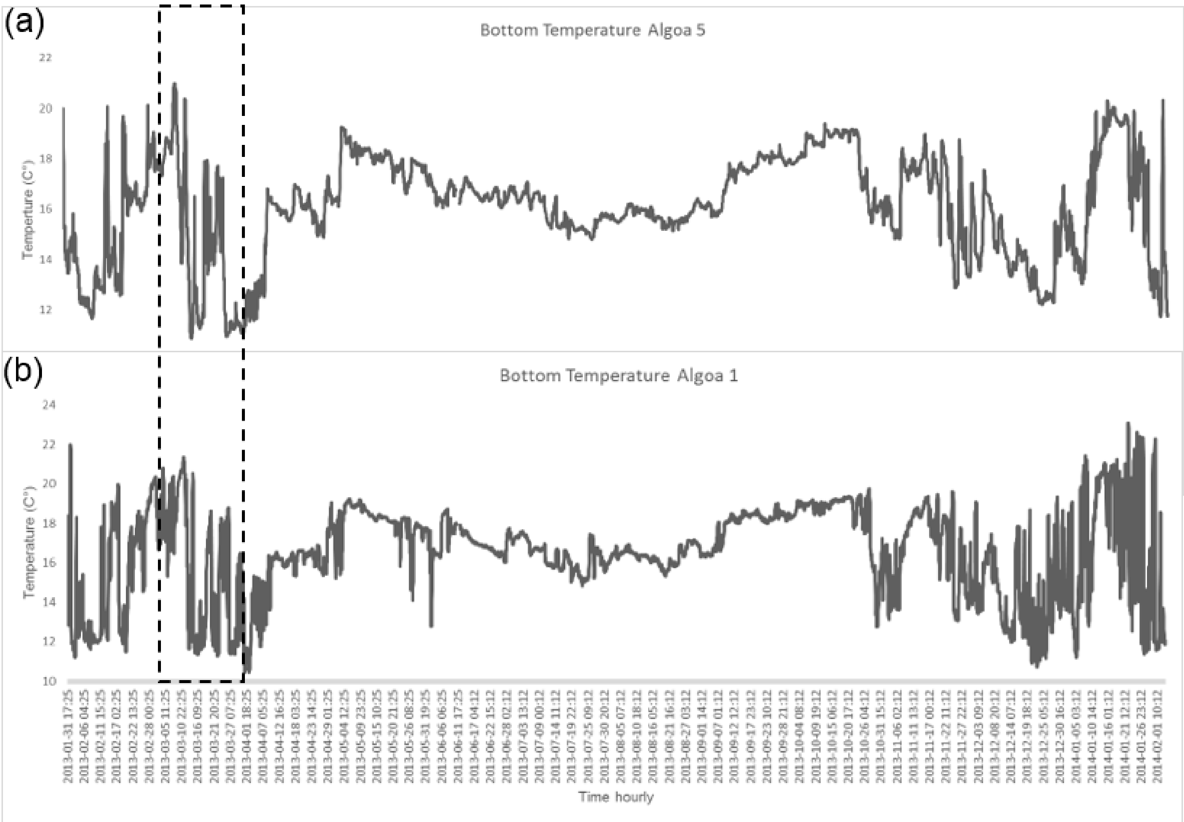


FIGURE 8: BOTTOM TEMPERATURE MEASURED BY THE (A) ALGOA 5 ADCP AND (B) ALGOA 1 AT THE SAME AT A DEPTH OF 23.5 M. THE DASHED LINE BOX HIGHLIGHTS THE MONTH OF MARCH WHICH IS SHOWN IN FIGURE C IN EXPANDED FORM.

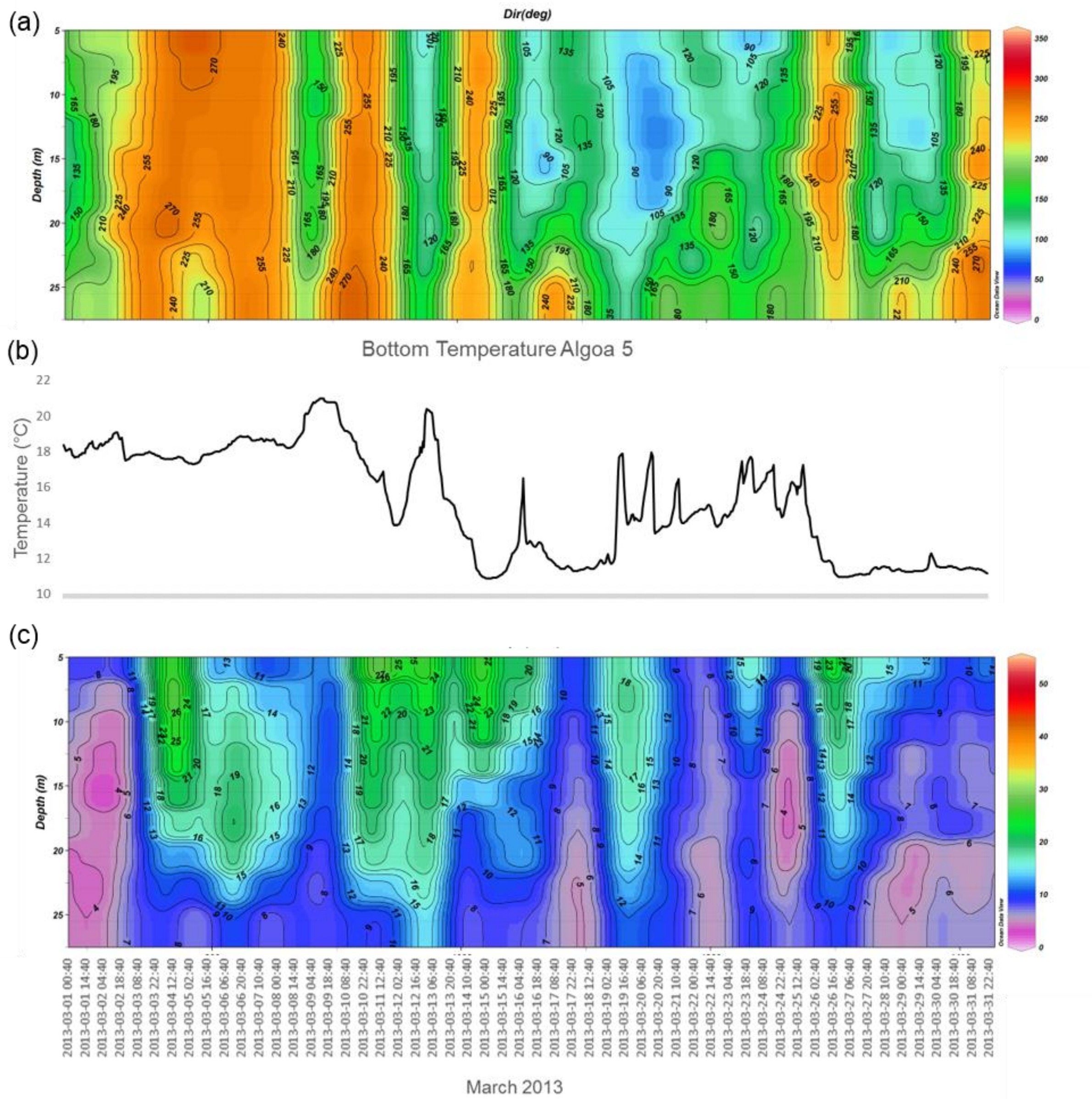
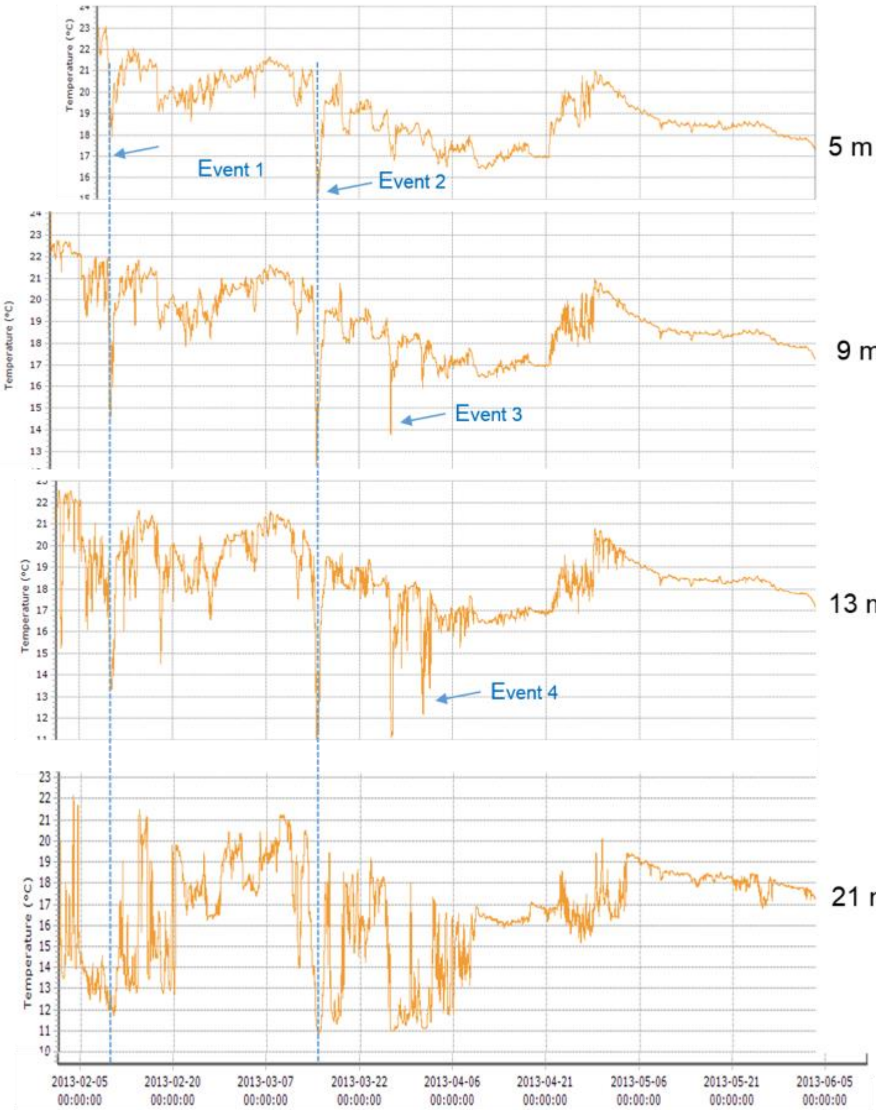
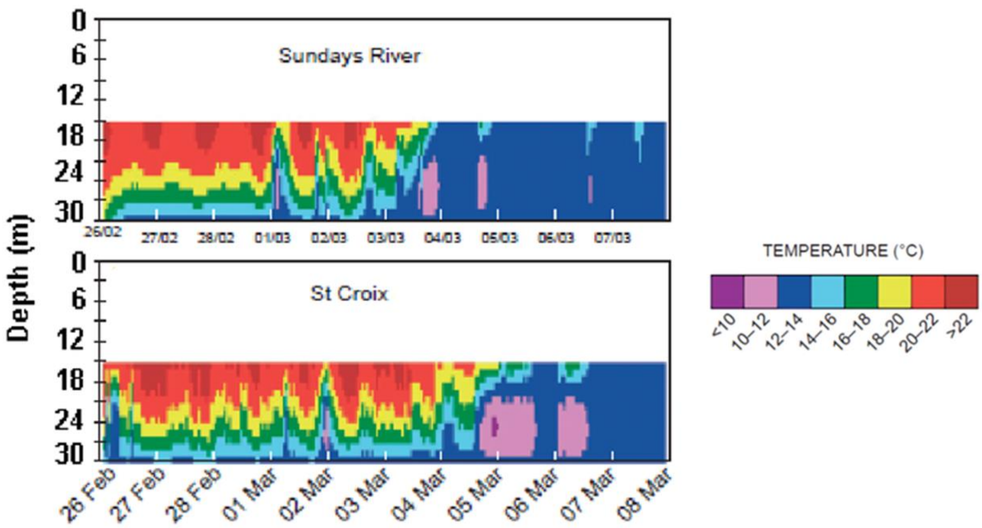


FIGURE 9: COMPARISON OF CURRENTS WITH NEAR-BOTTOM TEMPERATURE FOR MARCH 2013



(a)



(b)

FIGURE 10: (A) SIX-MONTHS OF TEMPERATURE DATA SHOWING UPWELLING EVENTS AT ALGOA 5. (B) SST MEASURED THROUGHOUT THE WATER COLUMN ADJACENT TO ST CROIX ISLAND (TAKEN FROM GOSCHEN ET AL., 2012).

4.5 WAVES

The 12-month wave data set is depicted in Figure 11. Average Significant Wave Height (Hs) is 125 cm. Maximum is 512 cm. It is important to note that the significant wave height (Hs) is defined traditionally as the mean wave height (trough to crest) of the highest third of the waves (H1/3). This implies that actual individual rouge waves will exceed the maximum Hs.

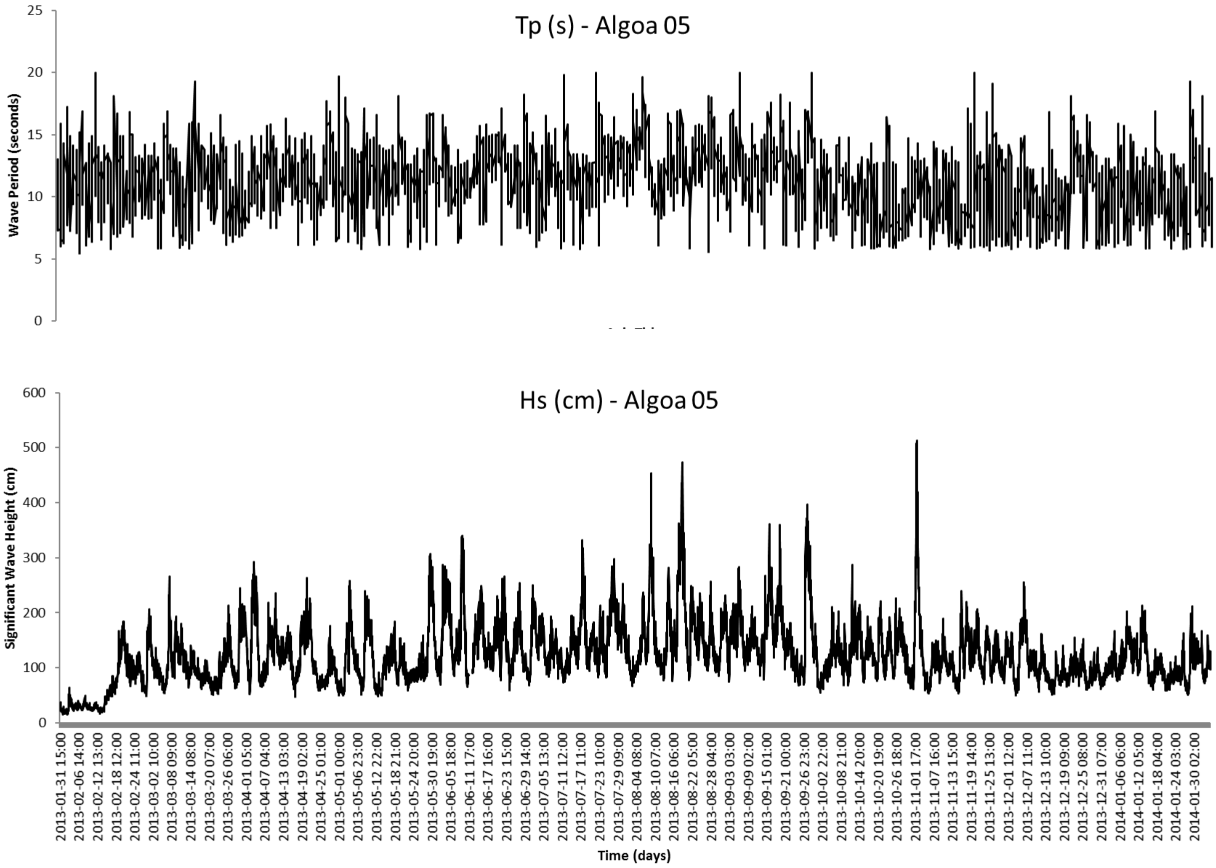


FIGURE 11: WAVE DATA COLLECTED BY THE ADCP AT ALGOA 5. (TOP PANEL) WAVE PERIOD. (BOTTOM PANEL) SIGNIFICANT WAVE HEIGHT (CM)

5. REFERENCES

CSIR (1970) Algoa Bay coastal erosion investigation. Parts I and II. Hydraulic Research Unit, NMERI, CSIR, Stellenbosch, MEG 913 and 914

Goschen WS, Schumann EH (1988) Ocean current and temperature structures in Algoa Bay and beyond in November 1986. *South African Journal of Marine Science* **7**: 101-116

Goschen WS, Schumann EH (1994) An Agulhas Current intrusion into Algoa Bay during August 1988. *South African Journal of Marine Science* **14**: 47-57

Goschen WS, Schumann EH (1995) Upwelling and the occurrence of cold water around Cape Recife, South Africa. *South African Journal of Marine Science* **16**: 57-67

Goschen, WS, Schumann, EH, Bernard, KS, Bailey, SE, and Deyzel, SHP (2012). Upwelling and ocean structures off Algoa Bay and the south-east coast of South Africa. African Journal of Marine Science, 34(4): 525-536.

Harris TFW (1978) Review of coastal currents in South African wasters. *South African National Scientific Programmes Report* **30**: 1-103

Lutjeharms JRE, Baird D, Hunter IT (1986) Seeoppervlak dryfgedrag aan die Suid-Afrikaanse suidkus in 1979. *South African Journal of Science* **82**: 324-326.

Roberts MJ (1990) Dispersion of a buoyant effluent discharged into the nearshore waters of Algoa Bay. MSc Thesis, University of Port Elizabeth 287 pp

Roberts MJ, van den Berg M (2005) Currents along the Tsitsikamma coast, South Africa, and potential transport of squid paralarvae and ichthyoplankton. *African Journal of Marine Science* **27**: 375-388

Roberts MJ. 2010. Coastal currents and temperatures along the eastern region of Algoa Bay, South Africa, with implications for transport and shelf–bay water exchange. African Journal of Marine Science, 32(1): 145–161.

Schumann EH (1987) The coastal ocean off the east coast of South Africa. *Transactions of the Royal Society of South Africa* **46**: 215-228

Schumann, E. H., and K. H. Brink, 1990. Coastal-trapped waves off the coast of South Africa: generation, propagation and current structures. Journal of Physical Oceanography, 20(18), 1206-1218.

Schumann EH, Martin JA (1991) Climatological aspects of the coastal wind field at Cape Town, Port Elizabeth and Durban. *South African Geographical Journal* **73**: 48-51

Schumann EH, Ross GJB, Goschen WS (1988) Cold water events in Algoa Bay and along the Cape south coast, South Africa, in March/April 1987. *South African Journal of Science* **84**: 579-583

Schumann EH, Churchill JRS, Zaayman H (2005) Oceanic variability in the western sector of Algoa Bay, South Africa. *African Journal of Marine Science* **27**: 65-8

APPENDIX 2. MOM MODELLING FISH FARM WASTE DISCHARGE AND DISPERSAL.

BACKGROUND

This report addresses the need for a modelling study to determine waste discharge and dispersal at the potential (Aquaculture Development Zone) ADZ sites Algoa 1 and Algoa 5. The Final EIR assessed the impacts to water quality and the benthic environment from organic waste to be high at both sites. Organic waste and the potential impacts to water quality and benthic habitats were a major concern highlighted in the appeals.

THE MODELLING–ONGROWING FISH FARM–MONITORING SYSTEM

The Modelling–Ongrowing fish farm–Monitoring system (MOM), described by Stigebrandt et al. (2004), has been developed to estimate the holding capacity of sites for fish farming. Expressed in terms of maximum fish production per month, the holding capacity is estimated with three basic environmental requirements in mind: (1) the benthic fauna at a farm site must not be allowed to disappear due to accumulation of organic material; (2) the water quality in the cages must be kept high; and (3) the water quality in the areas surrounding the farm must be maintained. The holding capacity of the farm is determined from the lowest of the three above estimates. The MOM model consists of four process-based sub-models (Figure 1): a fish model, a dispersion model, a benthic model and a water-quality model for the cages.

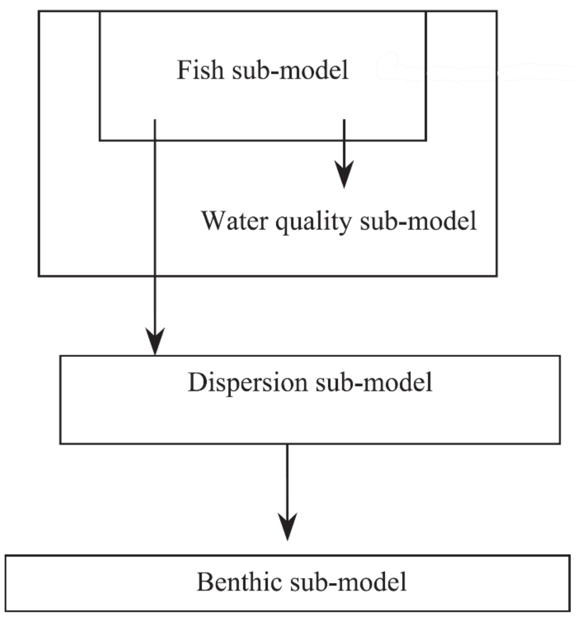


FIGURE 1: OVERVIEW OF THE MOM MODEL SYSTEM, TAKEN FROM STIGEBRANDT ET AL. (2004). THE OUTPUT PARAMETERS FROM THE FISH SUB-MODEL ARE USED AS INPUT PARAMETERS TO THE WATER QUALITY SUB-MODEL, THE DISPERSION SUB-MODEL AND THE REGIONAL WATER QUALITY MODEL. THE DISPERSION SUB-MODEL DELIVERS INPUT PARAMETERS TO THE BENTHIC SUB-MODEL. ALL SUB-MODELS REQUIRE INPUT PARAMETERS DESCRIBING VARIOUS ENVIRONMENTAL CONDITIONS AT THE FARM SITE.

The turnover and transformation of organic matter at the farm site is computed by a general fish sub-model, described in Stigebrand (1999), that deals with the fundamental aspects of fish metabolism and growth. Excess feed and faeces from the fish, will be dispersed, settling under or within some distance from the farm. The dispersion sub-model, described in Stigebrandt and Aure (1995), calculates the spatial distribution of particle sedimentation under a fish farm as a function of the cage size, the distance between cages and their configuration. The sedimentation from each of the cages is computed and as well as areas of local accumulation as a result of overlap. The benthic sub-model, described in Stigebrandt and Aure (1995), computes the maximum rate of sedimentation of organic matter that does not lead to extinction of the benthic infauna. The sub-model determines the current speed required to provide an oxygen flux to the sediment that will be sufficient to retain an infauna consisting of more tolerant species. The water quality sub-model computes the maximum fish production that keeps the oxygen concentration above, and the ammonium concentration below, a critical value with the estimated minimum flushing rate.

The fish farm holding capacity is determined by parameters for the following criteria: (1) the benthic fauna at a farm site must not be allowed to disappear due to accumulation of organic material; (2) the water quality in the cages must be kept high; and (3) the water quality in the areas surrounding the farm must be maintained.

The MOM model system was deemed suitable to estimate waste discharge and water quality at the two proposed ADZs, Algoa 1 and Algoa 5. Estimates were modeled based on a farm configuration consisting of 35 cages, and an annual production of ~3000t. Current and temperature data, were not available at the time the Final EIR was compiled, have been incorporated into the model, as well as area specific data obtained from literature sources. This provides a robust benchmark of the projected organic waste generated from the fish farm and its rate of dispersion. If a fish farm were to be developed, actual monitoring data could be fed into the model to validate and refine its outputs.

MODEL INPUTS

The following inputs were used for applying the MOM model at the Algoa 1 and Algoa 5 sites.

TEMPERATURE

Temperature is one of the variables used within the model to determine water quality within the cages. Temperature data for a depth of 5m were used to calculate monthly means, as these are the temperatures caged fish will be exposed to. Mean monthly temperature is similar at both sites, with the lowest means occurring in August and the highest in January.

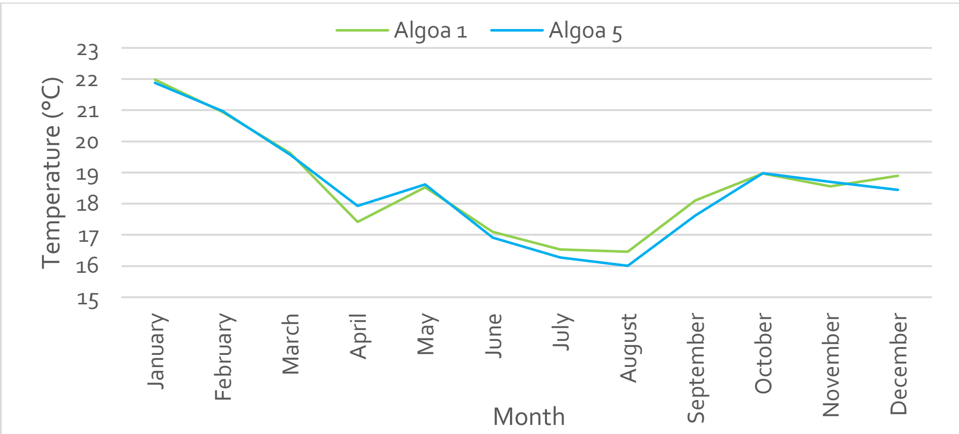


FIGURE 2: MEAN MONTHLY TEMPERATURE AT ALGOA 1 (GREEN) AND ALGOA 5 (BLUE).

LOCATION DATA AND CRITICAL CONCENTRATIONS

Current characteristics at the sites are important in determining the holding capacity of the fish farm as well as the impact on benthic fauna and flora. Acoustic Doppler Current Profiler (ADCP) data was used to calculate the current variation and dimensioning surface and bottom currents.

Six months of data (January-June 2013) were available for Algoa 1. Unfortunately, data recorded during the second deployment (June 2013-February 2014) was largely inaccurate due to only one ping per ensemble being used, and could not be used in the calculations. For the Algoa 5 site, ADCP data was available for the period January 2013-February 2014.

The fluctuating component of the current, which determines the dispersion of particulate matter, was calculated using data from ~15m depth (just below the cages). A measure of this is the standard deviation (Sigma) which is estimated from the variance. This required using current components perpendicular to the main axis of the fish farm, in order to facilitate maximum water flow through the farm. Therefore, the ideal main axis of the fish farms at Algoa 1 and 5 were first determined using the highest frequency of current directions.

At Algoa 1, currents flowed in a Southeasterly and Southerly direction for the highest proportion of time (57%). In order to facilitate flushing of the farm, the main axis of a farm should therefore be orientated West-East. For the Algoa 5 site, current flow was either East or West for over 50% of the time. The main axis of the farm should therefore be orientated North-South. Subsequently, North-south current components, and west-east current components were used to calculate the Sigma current at Algoa 1 and 5, respectively.

The fluctuating component also determines whether resuspension of sediment will occur in the farm area (Sigma >3.5 $cm.s^{-1}$ suggests that current speeds of more than 10 $cm.s^{-1}$ occur in the area, which have been found by Cromey et al. (2002) and Stigebrandt and Aure (1995) to be the threshold current speed value for the resuspension of organic matter). The Sigma current is used within the model to determine dispersion, as dispersion increases with the variability of the current (Stigebrandt et al., 2004).

The surface dimensioning current determines flushing of the farm and hence water quality within the cages. The dimensioning current speed in the surface water was calculated based on the longest time it takes for the water to pass through the group of cages. Near surface current data (recorded at ~5m) were used. Within the model, the surface dimensioning current speed is also used to determine the lowest and highest concentrations of oxygen and ammonium in the fish cages. A theoretical reduction factor of 0.7 was applied to simulate the effect of the cages and algal growth on water flow through the farm (current resistance).

Oxygen supply to the bottom, a prerequisite in the model for the respiration of benthic animals, depends on the current regime in the bottom layer. The dimensioning current in the bottom layer was determined from the minimum mean speed recorded in a two-hour period, using all of the current data.

The MOM model estimates the maximum holding capacity of a fish farm site by ensuring water quality is maintained both within, and below, the cages. The model therefore requires inputs of site specific salinity, ammonia and bottom dissolved oxygen concentrations. Minimum allowable dissolved oxygen concentration within the cages and near the bottom, as well as the minimum unionised ammonia concentration tolerated by farmed fish are also required. Holding capacity is then determined by these limits, ensuring these limits are not exceeded. Salinity levels in the western sector of Algoa Bay generally stay around the oceanic average of about 35.2 and there is limited variability in the bay (see Goschen and Schumann, 2011). Minimum bottom dissolved oxygen concentration in Algoa Bay is ~3 $mg.l^{-1}$ (Roberts, 2005).

Although no ammonium concentration data are available for the two sites, a previous study recorded ammonia levels of 0.1-0.3 $mg.l^{-1}$ in coastal areas some distance from sewage outfall zones in Algoa Bay (Emmerson et al. 1983). The more conservative estimate of 0.3 $mg.l^{-1}$ is used in the model. As the dusky kob *Argyrosumus japonicus* is a potential aquaculture species, as far as possible, inputs and concentrations relevant to *Argyrosomus* sp. have been used in the model.

A. japonicus are well adapted to hypoxia. In mild hypoxia (75% saturation=5.23 $mg.l^{-1}$), although maximum swimming speed is not reduced, the metabolic capacity is (Fitzgibbon et al. 2007). Fitzgibbon et al (2007) suggest that even mild hypoxia may reduce growth productivity, and an absolute minimum dissolved oxygen level within the cages has been set at 5.23 $mg.l^{-1}$. A study by Kir et al. (2015) showed *A. regius* is more sensitive to ammonia than other marine fish species cultured on the Mediterranean and Eastern Atlantic coasts. Kir et al. (2015) identified the safe levels of NH_3 for *A. regius* to be 0.10, 0.07 and 0.04 mg.l^{-1} at 18, 22 and 26°C respectively ($P < 0.05$). From these results, the conservative estimate of 0.04 mg.l^{-1} is used in the model. The lowest acceptable bottom oxygen concentration beneath the cages was set as the minimum dissolved bottom oxygen concentration recorded in Algoa Bay, ~3 mg.l^{-1} (Roberts, 2005).

	Algoa 1	**Algoa 5**
Water depth at farm (m)	30.5	30
Sigma-current std dev (cm.s^{-1})	6.48 (Farm with W-E orientation)	5.15 (Farm with N-S orientation)
Dimensioning current, surface layer (cm.s^{-1})	0.52 (2 rows), 0.65 (3 rows) Farm with W-E orientation	0.39 (2 rows), 0.52 (3 rows) Farm with N-S orientation
Dimensioning current, bottom layer (cm.s^{-1})	0.5	0.35
Salinity-typical in summer (o/oo)	35.2	
Oxygen concentration, bottom layer (mg.l^{-1})	3	
Ammonium concentration in environment (mg.l^{-1})	0.3	
Lowest acceptable oxygen concentration in cages (mg.l^{-1})	5.23	
Highest acceptable UIA concentration in cages (mg.l^{-1})	0.04	
Lowest acceptable oxygen concentration at the bottom (mg.l^{-1})	3	

FARM DATA

Maximal biomass for the farm was set as 3000 tons. The side length of the cages was calculated as the diameter of the circular cage X 0.89. Distance between cages and depth of cages were set at 20 m and 15 m respectively. The food conversion factor (i.e. the weight of feed used to produce 1 kg of fish) has been set as 1.6 (Willem Schoonbee- Aquaculture Consulting and Management Services; pers. comm.). Two scenarios regarding the number of rows of cages have been used within the model, namely two and three rows. A total number of 35 cages was set in the model.

Maximal biomass (ton)	3000
Side-length of cages (m)	17.80 ≈ 18
Distance between cages (m)	20
Depth of cages (m)	15
Reduction factor for through-flow (0-1)	0.7
Food factor, factual	1.6
Number of cage-rows (1, 2 or 3)	2,3
Number of cages	35

FISH AND FOOD DATA

The protein, fat, carbohydrate and ash content, and sinking speed of feed were provided by Willem Schoonbee of Aquaculture Consulting and Management Services. Willem Schoonbee also provided information on the start and end weights of cultured fish, and the protein and fat content of the fish. The mean settling velocities for small and large *A. regius* faeces were used (Pérez et al. 2014). Settling rates were not significantly different between the two size categories. Settling velocities generally increased with particle size. Particles with slow (mean 0.25 $cm.s^{-1}$) settling velocities dominated samples whilst particles with medium settling velocities (mean 1.69 $cm.s^{-1}$) had the highest mass distribution. As such both these settling velocities were tested in the model.

Food	
Protein content (0-1)	0.45
Fat content (0-1)	0.13
Carbohydrate content (0-1)	0.1
Ash content (0-1)	0.08
Sinking speed ($cm.s^{-1}$)	2,3
Fish	
Start weight (g)	5
End weight (g)	2500
Protein content (0-1)	0.23
Fat content (0-1)	0.02
Sinking speed of faeces ($cm.s^{-1}$)	0.25,1.69

RESULTS AND DISCUSSION

For both sites and number of cage rows (2/3), maximum carbon influx to the sediment was projected to be neglible, as the current speed Sigma is greater than 3.5 $cm.s^{-1}$. It is therefore assumed that possible deposits on the bottom are flushed by intermittent strong currents. This conclusion is supported by the environmental monitoring programme observations conducted at the I&J pilot cage aquaculture site which found no measurable accumulation of deposits below the fish cages (Winter, 2006).

The model calculated outlets per 1 tonne of fish production to the cages to be 38.08 kg dissolved Nitrogen (ammonia) and 6.35 kg Phosphorus. Outlets to the sediment (as particulate matter) were calculated to be 41.01 kg Nitrogen, 6.84 kg Phosphorus, 159.61 kg faeces and 455.27 kg wasted food. A maximum level of 0.03 $mg.l^{-1}$ of unionized ammonia was not exceeded in the cages. As a result of the Sigma current value (>3.5 $cm.s^{-1}$) and flushing by intermittent currents, bottom dissolved oxygen concentration was not reduced within the model and particulate matter was suitably dispersed. Variations in sinking speed of food and faeces were tested and found not to alter the outlets.

Outlets per one tonne fish production	
To cages (dissolved)	
Nitrogen (kg)	38.08
Phosphorus (kg)	6.35
To the sediment (in particulate matter)	
Nitrogen (kg)	41.01
Phosphorus (kg)	6.84
Faeces (kg)	159.61
Wasted food (kg)	455.27

Maximum total production, with a 35 cage scenario, has been estimated using the following limits:

1. A minimum oxygen concentration of 5.23 $mg.l^{-1}$ in the cages

2. A maximum unionized ammonia concentration of 0.03 mg.l^{-1} in the cages
3. A minimum bottom dissolved oxygen concentration of 3 mg.l^{-1}

Unionized ammonia concentrations and bottom dissolved oxygen concentration thresholds were not exceeded, with maximum production being limited by oxygen concentration in the cages. At both sites, production increased with the addition of a third row of cages. This was largely a result of the flushing time at the sites. The addition of 38m to the total width of the farms increased flushing time by only one time-step (one hour-ADCP current data). The overall slower surface and bottom dimensioning currents, and smaller current variation at the Algoa 5 site resulted in a ~665 tonne lower maximum production compared to Algoa 1. Based on the given limits, the highest maximum annual production of 3482 tonnes was estimated for the Algoa 1 site using a three cage row setup with a West-East orientation. However, only six months of ADCP current data have been used in the calculations. It is suggested the models are re-run when either the data from the second deployment has been corrected (if possible), or new data collected.

Total estimated monthly and annual production-tonnes (35 cages)				
	Algoa 1 - 2 rows	**Algoa 1 - 3 rows**	**Algoa 5 - 2 rows**	**Algoa 5 - 3 rows**
Stocking density (kg.m^{-2})	123.46	154.32	94.8	125.66
January	301.8	377.25	229.74	304.54
February	277.71	347.13	213.61	283.16
March	250.08	312.59	191.13	253.36
April	209.55	261.94	167.49	222.03
May	229.01	286.26	177	234.63
June	204.25	255.32	154.37	204.63
July	195.15	243.94	146.66	194.42
August	194.06	242.57	143.65	190.41
September	221.27	276.58	163.39	216.59
October	237.21	296.52	182.17	241.48
November	229.56	286.95	178.14	236.13
December	235.89	294.86	174.47	231.27
Total	**2785.54**	**3481.91**	**2121.82**	**2812.65**

he model output results indicating rapid waste dispersal are not surprising, as the Algoa Bay sites are highly exposed to current and swell in comparison to the generally more sheltered sites in which cage aquaculture is undertaken in other parts of the world. For example, the Norwegian, Chilean and Scottish fjords and lochs, and sheltered bays and inlets in other parts of the world which are not exposed to oceanic swells. These environments are much more sensitive to the impacts of the accumulation fish farm organic wastes and the MOM model was originally designed to determine safe aquaculture production limits for these environments (Stigebrandt et al 2004).

CONCLUSIONS

The MOM model indicates that at a projected production of 3000t fish per year that there will be efficient dispersal and assimilation of waste from the fish farm due to the high intermittent current speeds. With the current model assumptions there will thus be:

- Good water quality (as indicated by dissolved oxygen, ammonia and phosphorus concentrations) in the vicinity of the fish cages.

- No accumulation of settled particulate matter on the bottom, and therefore a specific dispersal distance model was not run.
- A non-significant impact on the benthic infauna.

Given the limitations of the data set available it is proposed that for the initial phase a pilot program is initiated (1000 ton), and if successful this could be followed by gradual scaling up to 3000t during which time monitoring data should be collected in line with the EMP.

Should this be successful, and higher volumes are applied for in the future, robust data would be available to model an increase in organic effluent outputs, and provide further advice on mitigation if required.

REFERENCES

Cromey, C. J., Nickell, T. D., & Black, K. D. (2002). DEPOMOD—modelling the deposition and biological effects of waste solids from marine cage farms. Aquaculture, 214(1), 211-239.

Emmerson, W. D., McLachlan, A., Watling, H. R., & Watling, R. J. (1983). Some ecological effects of two sewage outfalls in Algoa Bay. Water SA, 9(1), 23-30.

Fitzgibbon, Q. P., Strawbridge, A., & Seymour, R. S. (2007). Metabolic scope, swimming performance and the effects of hypoxia in the mulloway, *Argyrosomus japonicus* (Pisces: Sciaenidae). Aquaculture, 270(1), 358-368.

Goschen, W. S., & Schumann, E. H. (2011). The physical oceanographic processes of Algoa Bay, with emphasis on the western coastal region. South African Environmental Observation Network (SAEON) and the Institute of Maritime Technology (IMT). IMT document number: PO106-10000-730002.

Kir, M., Topuz, M., Sunar, M. C., & Topuz, H. (2015). Acute toxicity of ammonia in Meagre (*Argyrosomus regius* Asso, 1801) at different temperatures. Aquaculture Research.

Pérez, Ó., Almansa, E., Riera, R., Rodriguez, M., Ramos, E., Costa, J., & Monterroso, Ó. (2014). Food and faeces settling velocities of meagre (*Argyrosomus regius*) and its application for modelling waste dispersion from sea cage aquaculture. Aquaculture, 420, 171-179.

Roberts, M. J. (2005). Chokka squid (*Loligo vulgaris reynaudii*) abundance linked to changes in South Africa's Agulhas Bank ecosystem during spawning and the early life cycle. ICES Journal of Marine Science: Journal du Conseil, 62(1), 33-55.

Stigebrandt, A. (1999). MOM (Monitoring- Ongrowing fish farms- Modelling) turnover of energy and matter by fish- A general model with application to salmon. Fisken og Havet, (5), 26.

Stigebrandt, A., & Aure, J. (1995). Model for critical organic loading beneath fish farms MOM (Monitoring-Ongrowing fish farms-Modelling). Fisken og Havet (Norway).

Stigebrandt, A., Aure, J., Ervik, A., & Hansen, P. K. (2004). Regulating the local environmental impact of intensive marine fish farming: III. A model for estimation of the holding capacity in the Modelling–Ongrowing fish farm–Monitoring system. Aquaculture, 234(1), 239-261.

Winter, D. (2006) Environmental Monitoring Programme pertaining to the proposed Ongrowing of Finfish in Sea Cages near the Port Elizabeth Harbour. Report prepared for Irvin and Johnson by Integrated Environmental and Coastal Management, Nelson Mandela Metropolitan University. IECM Report C142. 13p.

APPENDIX 3. CHARACTERISTICS OF THE *LINGULODINIUM POLYEDRUM* RED TIDE IN ALGOA BAY AND ITS IMPLICATIONS FOR MARICULTURE

T.G. Bornman and W.S. Goschen, SAEON Elwandle Coastal Node, Port Elizabeth

30 August 2016

Study site

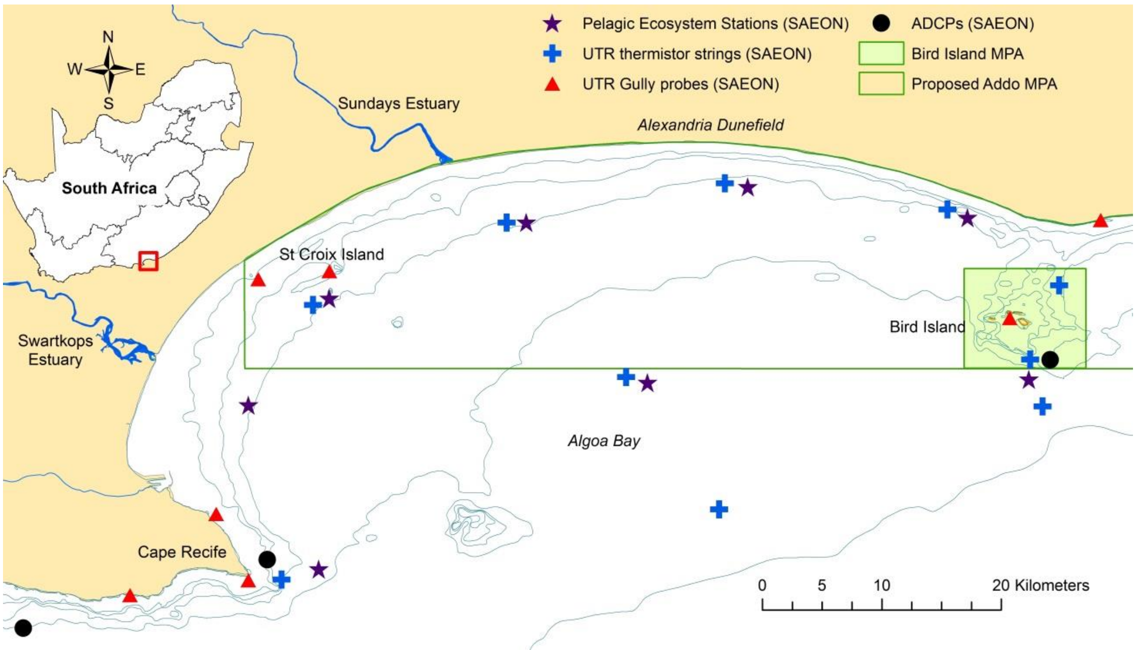


Figure 1. *Study site map of Algoa Bay showing the locations of in situ instruments and monthly sampling stations (purple stars) mentioned in the text and figures.*

TEMPERATURE

Thermistor string data (Underwater Temperature Recorders from 10 m below the surface to 30 m) at five sites in Algoa Bay over three months are shown in Figure 2 below. Figure 2 clearly shows the warm water event in January 2014 that allowed the dinoflagellates to bloom. In February 2014, the water column remained sufficiently warm, while frequent upwelling of the bottom water supplied nutrients to ensure the persistence of the subtropical species in Algoa Bay. The warm water event was present throughout Algoa Bay and it persistence was assisted by a reduced north-easterly wind component (responsible for upwelling and mixing of the surface water). Similar conditions were also recorded in December 2015, but stronger winds in January 2016 ensured that a bloom of *Lingulodinium polyedrum* was limited. These full water column marine warming events could become a more regular feature in Algoa Bay in the future.

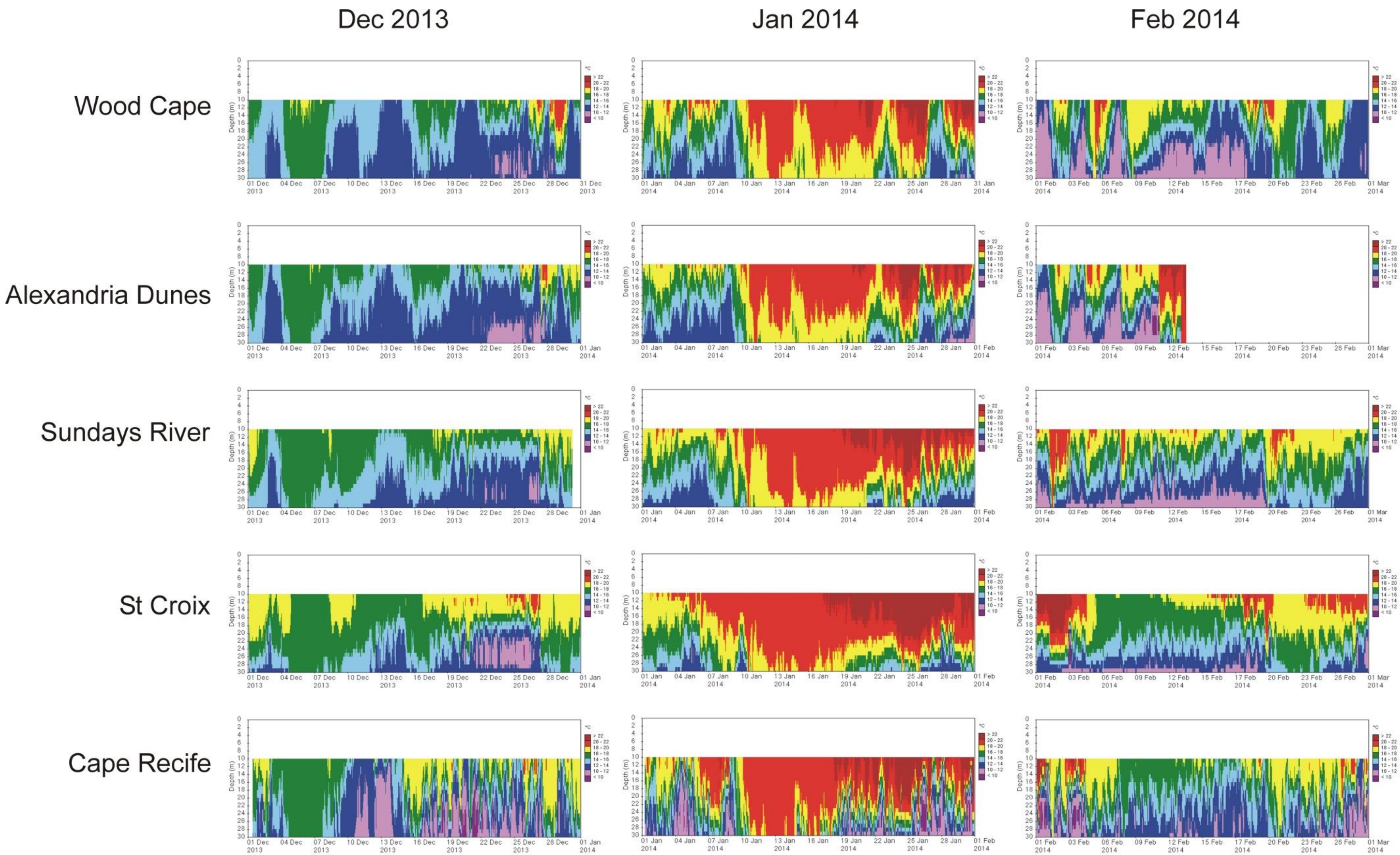


Figure 2. *Daily temperature data from thermistor strings located in 30 m at Woody Cape, Alexandria Dunefields, Sundays River, St Croix and Cape Recife.*

OXYGEN

Algoa Bay is in general well oxygenated. The HAB however caused oxygen levels to drop below 2 mg/l (Figure 3) and in some instances below 1 mg/l in the bottom waters (25 m – 30 m). These hypoxic conditions were only present during the decay of the bloom and persisted for no longer than one month. Figure 4 illustrates the oxygen concentration of the water column from Cape Recife to Bird Island and highlights the fact that the low oxygen layer was present along the entire coastline, although situated deeper at Cape Recife and Bird Island. The sites from St Croix to Woody Cape had low oxygen levels as shallow as 20 m.

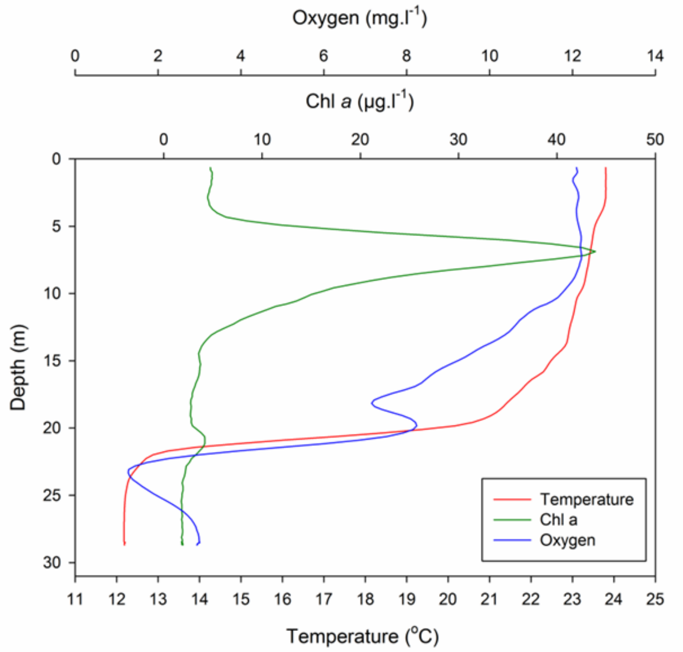


Figure 3. Oxygen, temperature and Chl-*a* profiles through the water column during January 2014 at Station 1 (opposite Swartkops), Algoa Bay

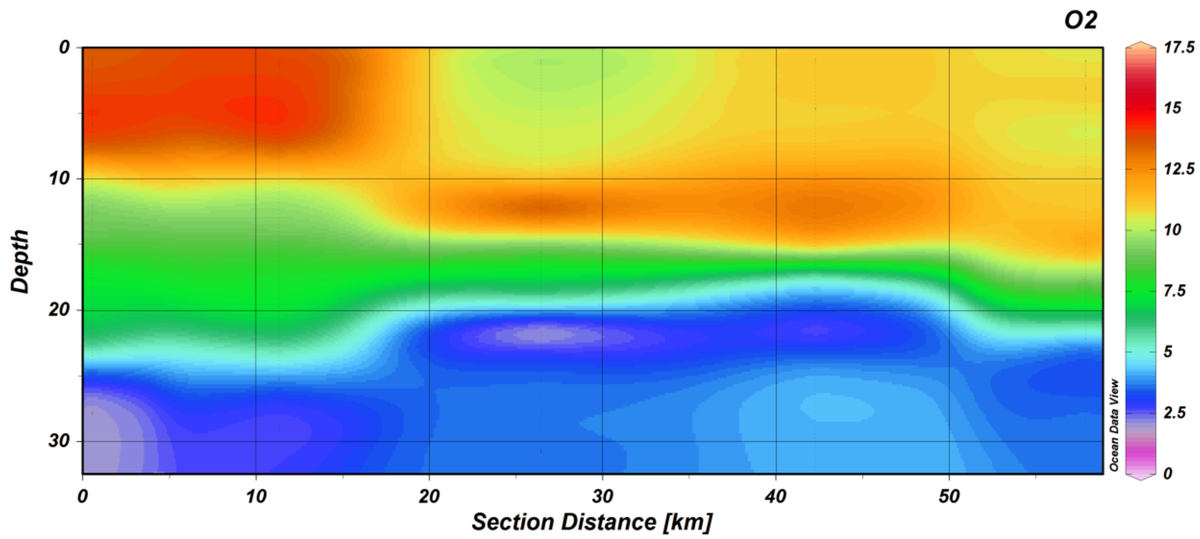


Figure 4. *Cross-section of oxygen concentrations (mg/l) through the water column along the 30 m bathyline from Cape Recife (left) to Bird Island (right).*

CHLOROPHYLL-*A*

The chlorophyll maximum in Algoa Bay is typically situated at around 15 m depth. The depth of the chlorophyll maximum during the *L. polyedrum* bloom (Figure 3 and Figure 5) was between 10 and 22 m. Figure 5 shows a transect from the Algoa Bay central station (60 m) to the Sundays River station (30 m), illustrating that the chl-*a* maximum remained at a more or less constant depth. During the bloom, the chl-*a* biomass reached levels in excess of 400 µg/l with cell counts in excess of 29,000/ml. This 10 m thick layer of dense biomass persisted during the month of February 2014 and March 2014 and only started to break down in April. However, the bloom was very patchy and constantly changed position. The two locations where the bloom always persisted were in front of the mouth of the Swartkops Estuary and the Sundays Estuary, extending as far offshore as the 40 m bathyline. It is believed that the nutrient input from these two rivers supplied sufficient nutrients to ensure the persistence of the bloom in these regions despite the bloom breaking down elsewhere in the bay.

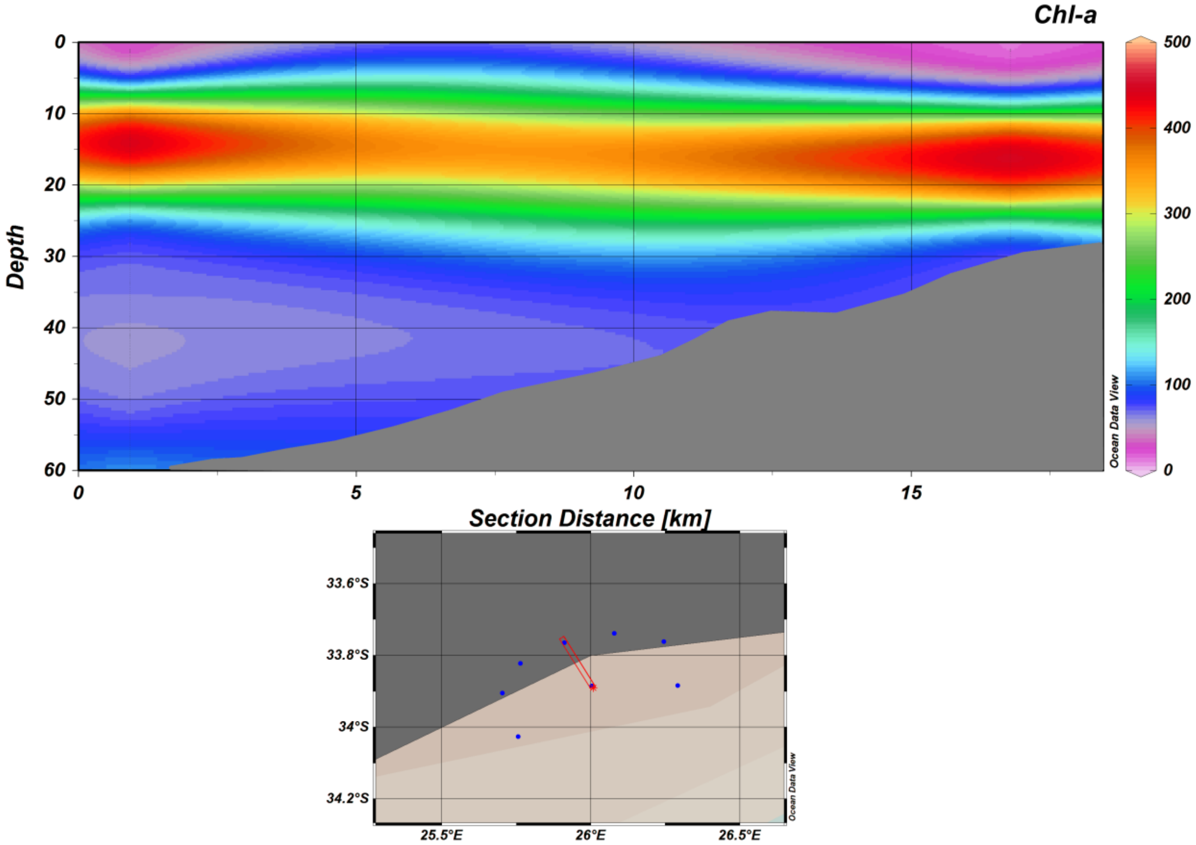


Figure 5. *Cross section of chlorophyll-a concentrations (µg/l) from the centre of Algoa Bay (60 m depth) to the Sundays River station (30 m)*

RELEVANCE TO MARICULTURE

1. Marine warm water events are on the increase globally and in South Africa. Warm water events are of particular concern within the bay as it appears to persist for longer than outside the bay. Warm water events can and do extend down to the seafloor.
2. Decaying red tide blooms will result in reduced oxygen concentrations below 20 m depth. These low oxygen concentrations appear to be of shorter duration than the blooms and warm water events, but of sufficient duration to result in fish and invertebrate kills.
3. *L. polyedrum* blooms result in very high biomass in the surface water down to 20 m. Such dense concetrations of cells may cause physical harm to fish, e.g. clogging of gills.

4. Blooms persist in the western sector of Algoa Bay due to the nutrient input from the Swartkops, Papenkuils and Sundays rivers/estuaries.
5. *L. polyedrum* can persist for longer than other endemic red tide causing dinoflagellates (e.g. *Noctiluca miliaris*) as it can use its flagella to swim down to the nutricline to feed at night and return to the surface waters during day time to photosynthesise. L. polyedrum is also a mixotroph (similar to N. miliaris) and can feed on diatoms up to 75% its own size. This enables this species to persist even in relatively oligotrophic conditions.
6. Most of the *L. polyedrum* cells would have produced a cyst at the onset of unfavourable conditions and these cysts have been documented to remain viable in the sediment for over 40 years. The liklihood of another L. polyedrum bloom is therefore high (sufficient seed material) should the specific oceanographic requirements be met, i.e. warm surface water (>20 °C), weak nutrient rich upwelling and limited mixing of the water column (low wind velocities and swell height).