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Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

# SALDANHA BAY SEA BASED AQUACULTURE DEVELOPMENT ZONE SPECIALIST ENVIRONMENTAL MONITORING

## HARD SUBSTRATE SURVEY


**August 2022**

ANCHOR
environmental

Anchor Research and Monitoring Report No. 1974/8

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# EXECUTIVE SUMMARY

## *Introduction*

The Branch Fisheries Management in the then Department of Agriculture, Forestry and Fisheries (now Department of Forestry, Fisheries and the Environment; DFFE), obtained Environmental Authorisation (EA) to establish a sea-based Aquaculture Development Zone in Saldanha Bay on 8 January 2018. In order to ensure appropriate management of the ADZ the Branch Fisheries Management appointed an independent specialist to compile a Sampling Plan for the ADZ and together with other stakeholders have facilitated the completion of numerous monitoring surveys and research projects.

Research done to date, diver observations and difficulties in obtaining grab samples at several stations in Big Bay revealed the presence of patches of exposed reef within Big Bay, specifically in the Finfish precinct of the ADZ. The reef was described as being mostly low profile <1m in height, periodically inundated with sand, however, outcrops of reef >1m in height were also reported. It was suggested that the amount of rocky substratum present in Big Bay was likely significantly more expansive than originally thought and that the full extent of the calcrete platform and the proportion of this habitat type impacted by current and future mariculture activities should be determined.

The Marine Living Resources Fund (MLRF), under the auspices of DFFE, appointed Anchor Research and Monitoring (Pty) Ltd (Anchor) to undertake specialist monitoring in compliance with the environmental Sampling Plan, Environmental Management Program and Environmental Authorisation for the Saldanha Bay ADZ. One of the specific tasks of this appointment was to undertake a study to determine the Big Bay hard substrata species community composition and diversity. This report presents an analysis of available bathymetric data and the findings of diver surveys conducted at three control and three impact sites on the Bay reef platform.

## *Methodology*

The South African Navy Hydrographic Office (SANHO) collected side scan sonar data of Big Bay in 2020 and 2021. However, very little of the ADZ precinct was surveyed leaving a significant gap in the updated bathymetry data within the ADZ. The 2020/2021 SANHO bathymetry data, however, corresponds fairly well with Flemming's (2015) distribution of the abrasion platform created using data from a 1977 side scan survey, and there is a significant amount of overlap/agreement in the extent of reef/hard substate between the two data sets. The georeferenced Flemming image was therefore used to determine the approximate area of reef within the Bay and the ADZ precinct.

During field surveys, when visibility and weather conditions allowed, a shot-line was deployed at identified reef sites and a team of scientific divers descended to the sea floor. One diver swam three 10 m video transects radiating from the shot-line centre, whilst the other diver conducted at least ten photo-quadrats (0.04 $m^2$) on reef habitat in the vicinity of the shot-line base. At least two photos were taken of each quadrat to ensure that the best possible focus was achieved, as well as to account for varying depths of fields of each photograph. Additionally, qualitative collection of biota was undertaken at all sites to aid in the identification of cryptic biota observed in video transects and photo-quadrats. Presence/absence data was extracted from the collection, photographs and video footage and multivariate statistical analysis was undertaken to investigate differences between control and impacts sites.

## *Results*

Multivariate analysis of the photographic data indicated that there are differences in the community composition between Impact and Control reef sites, and that the community composition of the baseline site location in the undeveloped Finfish precinct is more similar to that of Impact sites. Similar patterns are seen in the results of the video footage multivariate analyses.

Multivariate dispersion tests showed that the presence of aquaculture operations (Impact sites) and close proximity to aquaculture (Finfish baseline) increased the variability in macrofaunal photo quadrat assemblages relative to areas without aquaculture operations (Control sites). Suggesting that the disturbance as a result of aquaculture increases the species diversity at sites within the ADZ.

This pattern of increased diversity at impacted/disturbed sites is consistent with the ecological theory of disturbance on the diversity of tropical reefs. Where a peak in diversity is observed at intermediate levels of disturbance, with diversity dropping at both low and high disturbance pressure due to competition and mortality, respectively.

## *Findings Summary*

Based on the analyses of the existing bathymetry survey data and the reef survey data the following key findings and recommendations are made:

1. Based on available bathymetry data there is approximately 5 047 890.99 $m^2$ of reef within Big Bay, 29.2% of this reef area falls within the boundaries of the ADZ precinct, i.e., 6.3% of the total Big Bay reef area is found in the finfish precinct and 22.9% in the Bivalve precinct. The majority of the sea floor below the designated Finfish area is covered by reef (~79.9%), while 31.4% of the designated bivalve area consists of hard substrate, this is concentrated in the SW of the section.
2. Due to the fact that the Big Bay ADZ precinct was not surveyed in the recent SANHO data, historical data which appears to have a slightly reduced reef extent as compared to the SANHO data, was used to calculate the reef area and estimates are likely conservative.
3. Confirming the current day reef extent with higher confidence will require a similar resolution bathymetry survey of the ADZ precinct to be conducted in order to tie in with the 2020/2021 SANHO data.
4. The high proportion of reef in the finfish precinct is cause for concern, as finfish aquaculture is known to have a higher impact on the sea floor than bivalve aquaculture. It is therefore suggested that no Finfish aquaculture be undertaken at this site and that the Finfish sites in Outer Bay be utilized.
5. The ability to identify species in both the photographic quadrats and the video footage was dependent on the water visibility. Higher levels of uncertainty occur with higher levels of turbidity. It is suggested that all future survey data be collected on a single day to ensure standardised photo and video quality.
6. Multivariate and univariate data show that the community composition of Control and Impact reef sites differ significantly. Additionally, the benthic community structure at the Baseline reef site, located within the unused Finfish precinct, is more similar to that of impacted reef sites located within the Shellfish ADZ precinct. This suggests that the proximity of this site to the bivalve aquaculture has caused some level of disturbance/alteration of benthic conditions.

7. Community diversity at the Impacted reef sites is higher than at the Control sites, suggesting that at the present level of aquaculture development there is a balance between disruption of competition and mortality as a result of disturbance.
8. The intermediate disturbance hypothesis states that there is a tipping point at which the mortality as a result of disturbance is greater than the benefit of reduced competition. This point has not yet been reached in the Big Bay ADZ, but continuous monitoring of the reef fauna at Control and Impact sites is required to ensure early warning of this point being reached.
9. The use of photograph quadrats informs the identification of video footage and provides better imagery of accurate species identification. However, video transects consistently record higher species diversity, and mobile species such as the economically important west coast rock lobster, which are not often captured in photographs as they retreat when the quadrat is initially dropped, were better represented in video footage. Additionally, video footage provides a more accurate indication of the reef profile.
10. It is suggested that future surveys should include both video and photographic data and that the possible addition of lobster counts be included to monitor the population status of this commercially important species. Should diving conditions allow, it would be desirable for future analysis to include quantitative abundance or percentage cover data.

# TABLE OF CONTENTS

# GLOSSARY

| | |
|---|---|
| Abundance | Refers to the number of individuals of a specific species. |
| Aquatic | Relating to or living in water. |
| Benthic | Pertaining to the environment inhabited by organisms living on or in the estuary bottom. |
| Biodiversity | The variety of plant and animal life in a particular habitat. |
| Biota | Living organisms within a habitat or region. |
| Bivalve | A large class of molluscs that have a hard shell made of two parts or 'valves'. |
| Community | A naturally occurring group of native animals/plants that interact in a unique habitat. |
| Diversity | The number of different species that are represented in a given community. |
| Environment | The external circumstances, conditions and objects that affect the existence of an individual, organism or group. These circumstances include biophysical, social, economic, historical and cultural aspects. |
| Invertebrate | An animal without a backbone (e.g., a starfish, crab, or worm). |
| Species | A category of biological classification ranking immediately below the genus, grouping related organisms. A species is identified by a two-part name; the name of the genus followed by a Latin or Latinised un-capitalised noun. |
| Species richness | The number of different species represented in an ecological community. It is simply a count of species and does not take into account the abundance of species. |
| Turbidity | A measure of the loss of transparency of a water column as a result of the total suspended particles within the water |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| Anchor | Anchor Research and Monitoring (a subsidiary of Anchor Environmental Consultants) |
| ADZ | Aquaculture Development Zone |
| DFFE | Department of Forestry, Fisheries and the Environment |
| GPS | Global Positioning System |
| EA | Environmental Authorisation |
| EMP | Environmental Management Plan |
| IDH | Intermediate Disturbance Hypothesis |
| MDS | Multidimensional Scaling |
| MLRF | Marine Living Resources Fund |
| SANHO | South African Navy Hydrographic Office |
| SE | Standard error |

# 1 INTRODUCTION

## 1.1 Background

An Aquaculture Development Zone (ADZ) comprises areas of land or water selected for their suitability for specific aquaculture sectors. ADZs are intended to boost investor confidence by providing 'investment ready' platforms with strategic environmental approvals and management policies already in place, allowing commercial aquaculture operations to be set up without the need for lengthy, complex and expensive approval processes.

The Branch Fisheries Management in the then Department of Agriculture, Forestry and Fisheries (now Department of Forestry, Fisheries and the Environment; DFFE), obtained Environmental Authorisation (EA) to establish a sea-based ADZ in Saldanha Bay on 8 January 2018. Appeals against the authorisation were lodged to the then "Minister of Environmental Affairs" and the authorisation was upheld as per the letter dated 7th June 2018. The Saldanha ADZ provides opportunities for existing aquaculture operations to expand and new ones to be established, providing economic benefits to the local community through job creation and regional economic diversification.

In order to ensure appropriate management of the ADZ the Branch Fisheries Management appointed an independent specialist to compile a Sampling Plan for the ADZ which was reviewed by local and international stakeholders and experts (DAFF 2018). A substantial body of work has been undertaken in compliance with the stipulations in the EA and the Environmental Management Plan (EMP) for the Saldanha Bay ADZ and work conducted by independent specialists includes, dispersion modelling, baseline macrofauna and physicochemical surveys (2020) and a benthic macrofauna monitoring survey (2021) and annual benthic chemical surveys (2021-2022).

Following the baseline survey, it was shown that patches of exposed reef are present in Big Bay, specifically in the Finfish precinct of the ADZ. The reef was described as being mostly low profile <1m in height, periodically inundated with sand, however, outcrops of reef >1m in height were also reported (Mostert *et al.* 2020). It was reported that the amount of rocky substratum present in Big Bay was likely significantly more expansive than originally thought and that the full extent of the calcrete platform and the proportion of this habitat type impacted by current and future mariculture activities should be determined. Additionally, it was suggested that the ADZ monitoring programme be updated to include suitable methods for monitoring potential aquaculture impacts on this habitat type.

The Marine Living Resources Fund (MLRF) a Schedule 3A Public Entity established in terms of the Public Finance Management Act, 1999 (Act No 1 Of 1999), under the auspices of Department of Forestry, Fisheries and the Environment (DFFE), appointed Anchor Research and Monitoring (Pty) Ltd (Anchor) to undertake specialist monitoring in compliance with the environmental Sampling Plan, Environmental Management Program and Environmental Authorisation for the Saldanha Bay ADZ, for a period of two years (2021/2022). One of the specific tasks of this appointment was to undertake a study to determine the Big Bay hard substrata species community composition and diversity. This report presents the findings of diver surveys conducted at three control and three impact sites on the Bay reef platform.

# 2 APPROACH & METHODOLOGY

Previous sampling experience and bathymetry data sourced from electronic navigation charts of marine areas (e.g., Navionics), Anchor's library of bathymetry data of Saldanha Bay as well as historical (Flemming 2015) and recent (SANHO) bathymetry charts were used to identify areas of possible hard substrata falling within the ADZ. Hard substrata/reef areas identified outside Big Bay precinct that serve as control sites were confirmed based on data sourced from the South African Navy Hydrographic Office (SANHO) by DFFE (including side scan sonar data collected between 2020 and 2021). A data release agreement was signed on 3 March 2022 for hydrographic data for Big Bay, and the bathymetric data received. This data was processed, and results are displayed below.

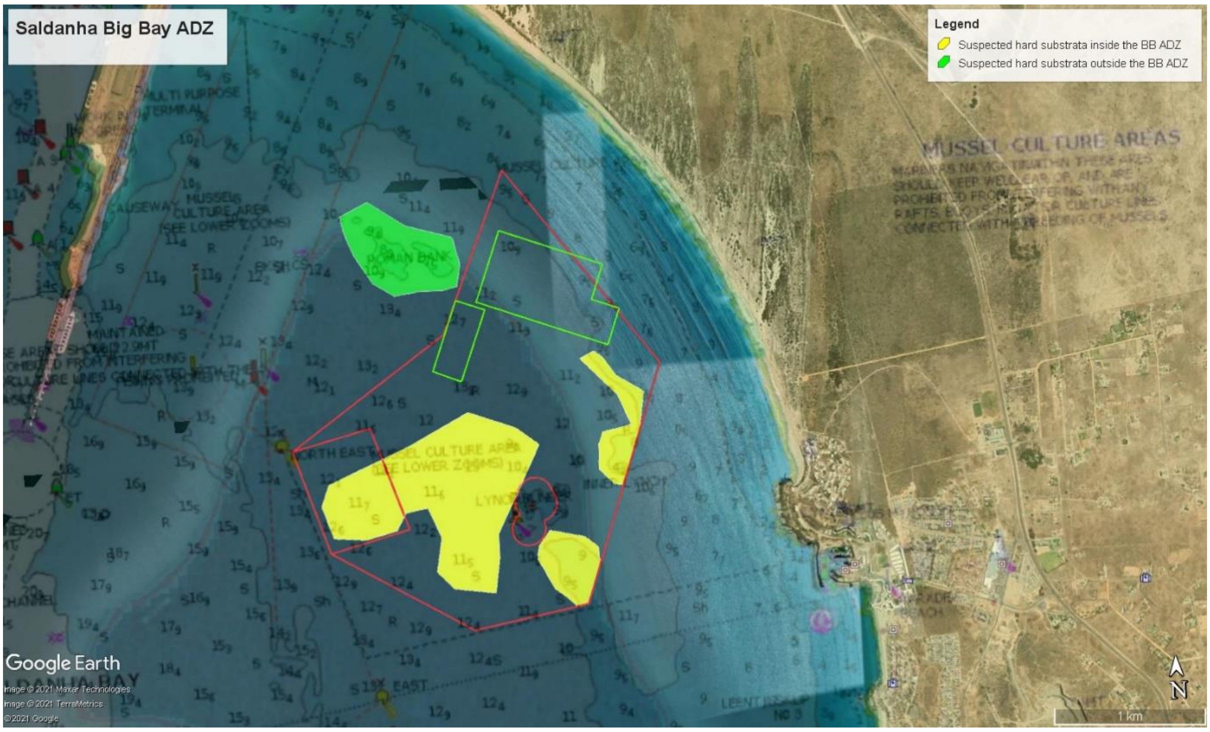


**Figure 1. Navionics overlay showing the changes in depth profile in Big Bay, examples of potential hard substrata as indicated by shallower than expected depths or changes in depth contours for the Big Bay ADZ are highlighted in yellow shading, while potential hard substrata habitat to be surveyed outside the Big Bay ADZ is highlighted with green shading. The shaded areas were targeted for hard substrata sampling by scientific divers.**

During field surveys, when visibility and weather conditions allowed, a shot-line was deployed at identified reef sites and a team of scientific divers descended to the sea floor. If no or only very limited hard substrate was found, divers ascended and moved to another site, but if sufficient hard substrate was encountered sampling was undertaken and the location marked on the GPS. The rocky reef dive survey of three sites located inside the ADZ (Impact sites) took place on 26 November 2021, and the three control sites were surveyed on 11 January 2022 (Table 1). Notably the site initially called Impact 1 due to its location within the ADZ precinct is in fact a control site or a finfish baseline site, as no finfish aquaculture has yet been undertaken.

**Table 1. Co-ordinates (in decimal degrees) and naming scheme of the reef monitoring survey sites from Big Bay.**

| Field name | Corrected Names | Site | Latitude | Longitude | Treatment | Treatment 2 |
|---|---|---|---|---|---|---|
| Impact 1 | FF Baseline | FF1 | -33.040680 | 18.007110 | Control | FF Baseline |
| Impact 2 | Impact 2 | I2 | -33.040980 | 18.013030 | Impact | Impact |
| Impact 3 | Impact 3 | I3 | -33.044670 | 18.014920 | Impact | Impact |
| Control 1 | Control 1 | C1 | -33.034880 | 18. 003470 | Control | Control |
| Control 2 | Control 2 | C2 | -33.054020 | 17. 997571 | Control | Control |
| Control 3 | Control 3 | C3 | -33.046700 | 18.005830 | Control | Control |

The scientific diver team consisted of two divers, one diver swam three 10 m video transects radiating from the shot-line centre, whilst the other diver conducted at least ten photo-quadrats (0.04 $m^2$) on reef habitat in the vicinity of the shot-line base (Figure 2). At least two photos were taken of each quadrat to ensure that the best possible focus was achieved, as well as to account for varying depths of fields of each photograph. Additionally, qualitative collection of biota was undertaken at all sites to aid in the identification of cryptic biota observed in video transects and photo-quadrats. Specimens were scraped into sample bags brought to the surface, preserved on ice and then frozen back in the laboratory for later identification.

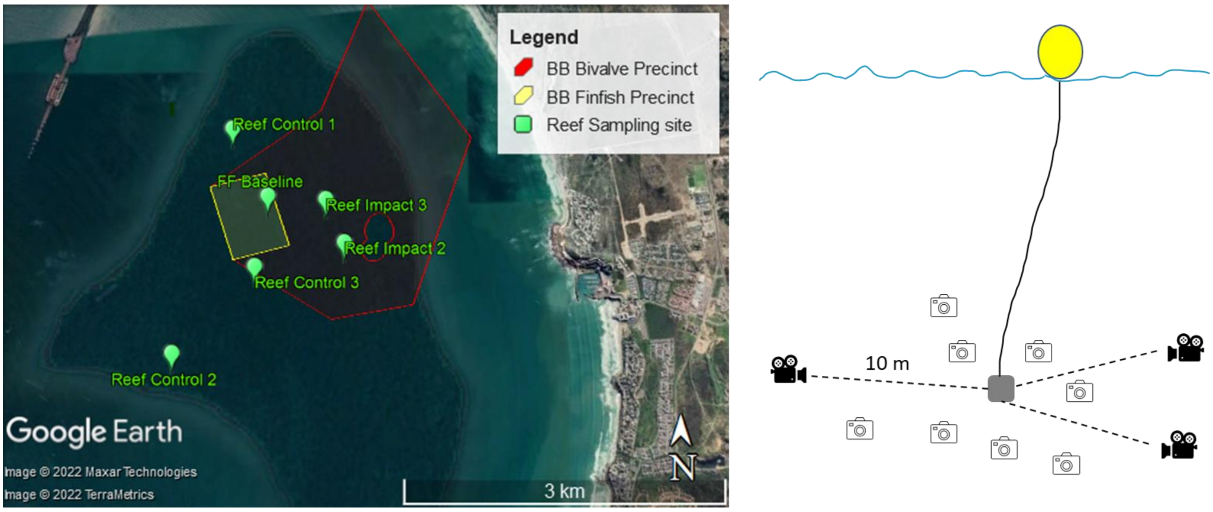


**Figure 2. Location of the reef survey sites in Big Bay and diagram of the survey method.**

All photographic and video footage species identification was undertaken by a single taxonomist to avoid any identification bias. Any ambiguous identifications were confirmed by a benthic invertebrate and/or a coral taxonomist. For purposes of this initial survey only presence/absence data was recorded and the abundance or percentage cover of species was not determined. The statistical program, PRIMER 6 (Clarke and Warwick 1993), was used to analyse the photographic and video footage presence/absence data separately. Data were converted to a similarity matrix using the Bray-Curtis similarity coefficient. Multidimensional Scaling (MDS) plots were constructed in order to find 'natural groupings' for the treatments (Impact/control). Multivariate dispersion of samples within treatments was calculated using the PERMDISP function.

# 3 RESULTS

## 3.1 EXISTING BATHYMETRY DATA

Although the marine specialist report for the Saldanha ADZ EIA considered subtidal reef habitat to be scarce in Saldanha Bay, and only identified Lynch blinder and North Bay blinder as important reef areas (Pulfrich 2017), reports from divers of calcrete rock surrounding sampling sites during the baseline survey (Capfish 2019), difficulties in obtaining grab samples at several stations in Big Bay during 2020 (Anchor) sediment surveys, and observations by Anchor divers deploying water quality monitoring instruments and collecting benthic macrofauna samples, indicated patches of hard substratum/reef in several areas of the Big Bay ADZ precinct. A subsequent literature review revealed the existence of an extensive abrasion platform (areas of exposed calcrete rock) throughout much of Big Bay (Flemming 2015).

Side-scan sonar and seismic data collected in 1977 and supported by *in situ* diver observations indicated the occurrence and distribution of specific seabed features such as rock outcrops on a calcrete abrasion platform (Flemming 1977, 2015) in the centre of what is now Big Bay (Figure 3).

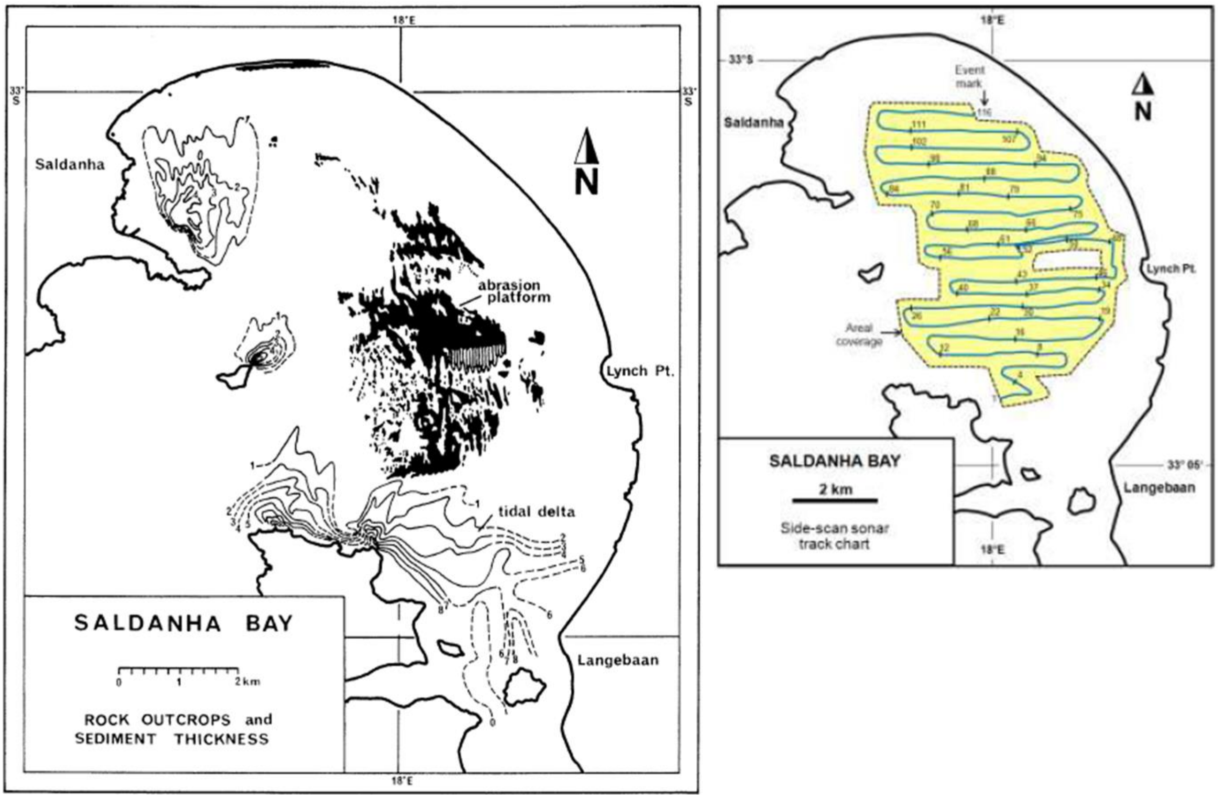


**Figure 3. Location of rock outcrops on the abrasion platform (black, left) determined by the side-scan sonar of Saldanha Bay, taken following the track shown on the right. Source: Flemming (2015).**

More recently, the South African Navy Hydrographic Office (SANHO) collected side scan sonar data of the Bay in 2020 and 2021. However, very little of the ADZ precinct was surveyed, likely because the skipper of the survey vessel was restricted by Bivalve infrastructure and could not navigate through the long lines. Therefore, there is a significant gap in the data within the ADZ precinct (Figure 4).

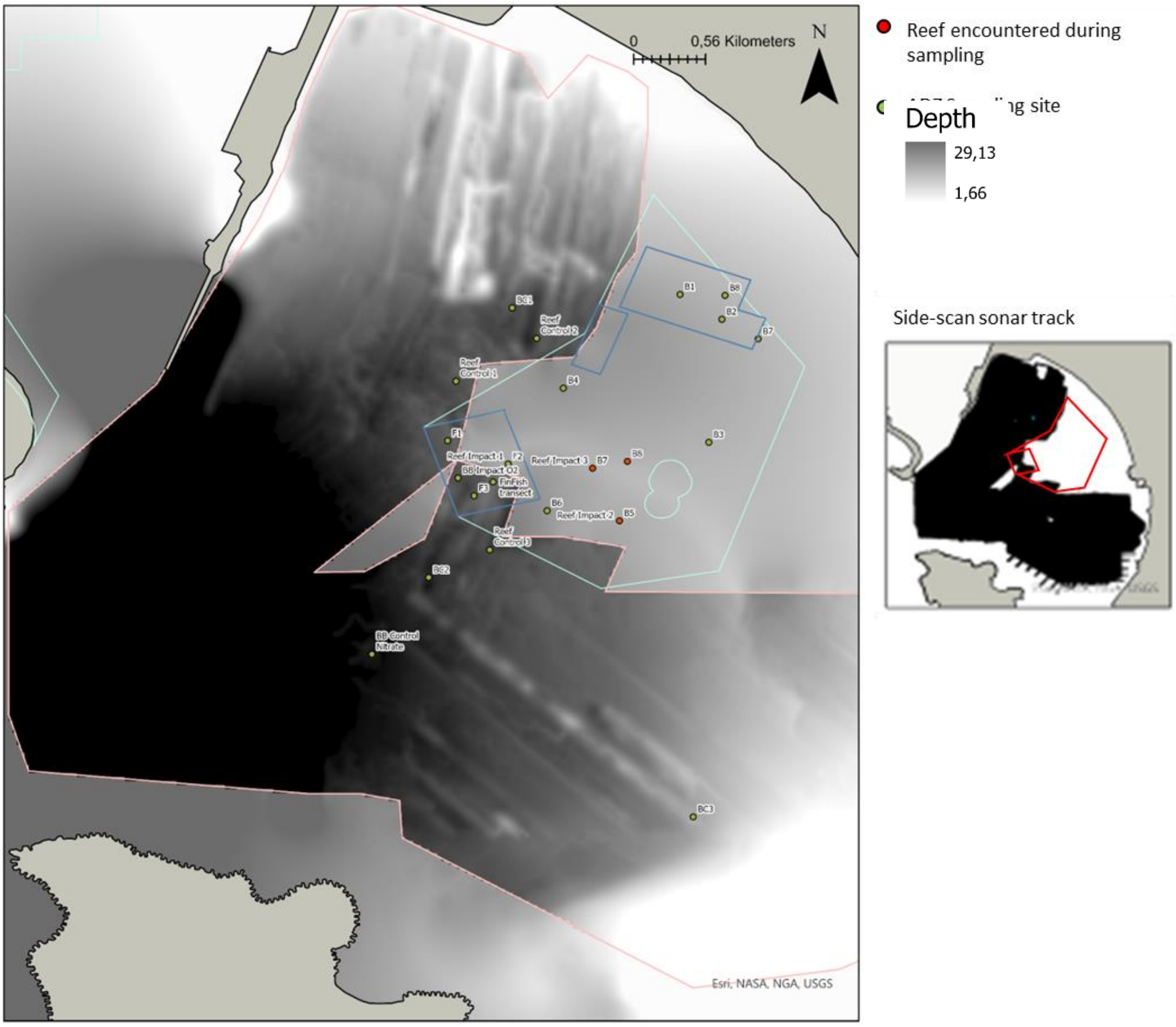


**Figure 4.** **Bathymetry of Big Bay determined using data sourced from the South African Navy Hydrographic Office (SANHO) collected between 2020 and 2021.**

The available SANHO bathymetry data from Big Bay corresponds well with Flemming's (1977) distribution of the abrasion platform, and if overlain on top of the latter, there is a significant amount of overlap/agreement in the extent of reef/hard substate (Figure 5). Given this, and the lack of recent SANHO data inside the ADZ precinct, Flemming's data was used to calculate the estimated area of reef occurring in both the finfish and Bivalve sections of the Big Bay ADZ precinct. These areas were calculated by first georeferencing Flemmings (2015) image, creating a raster, then extracting per interest area, converting to polygon, projecting using the Projected Coordinate System: Africa_Albers_Equal_Area_Conic and calculating geometry to acquire area in meters squared.

Based on this the total reef area in Big Bay is approximately 5 047 890.99 m2, 29.2% of this reef area falls within the boundaries of the ADZ precinct, i.e., 6.3% of the total Big Bay reef area is found in the finfish precinct and 22.9% of the total Big Bay reef area is in the Bivalve precinct. The majority of the sea floor below the designated Finfish area is covered by reef (~80%, see inset of Figure 5), while 31% of the designated bivalve area consists of hard substrate, this concentrated in the SW of the section.

It is noteworthy that there appears to be more reef visible in the SANHO data which is not captured in Flemmings 1977 distribution map, particularly the north-south ridges to the North West of the ADZ area and the NW-SE ridge features to the South and SW of the ADZ area (Figure 5). Therefore, it is likely that the calculations of reef areas provided are conservative – i.e., there is probably more reef in Big Bay than Flemming's map indicates, both within and outside the ADZ. Confirming this will require a similar resolution bathymetry survey of the ADZ precinct to be conducted in order to tie in with the 2020/2021 SANHO data.

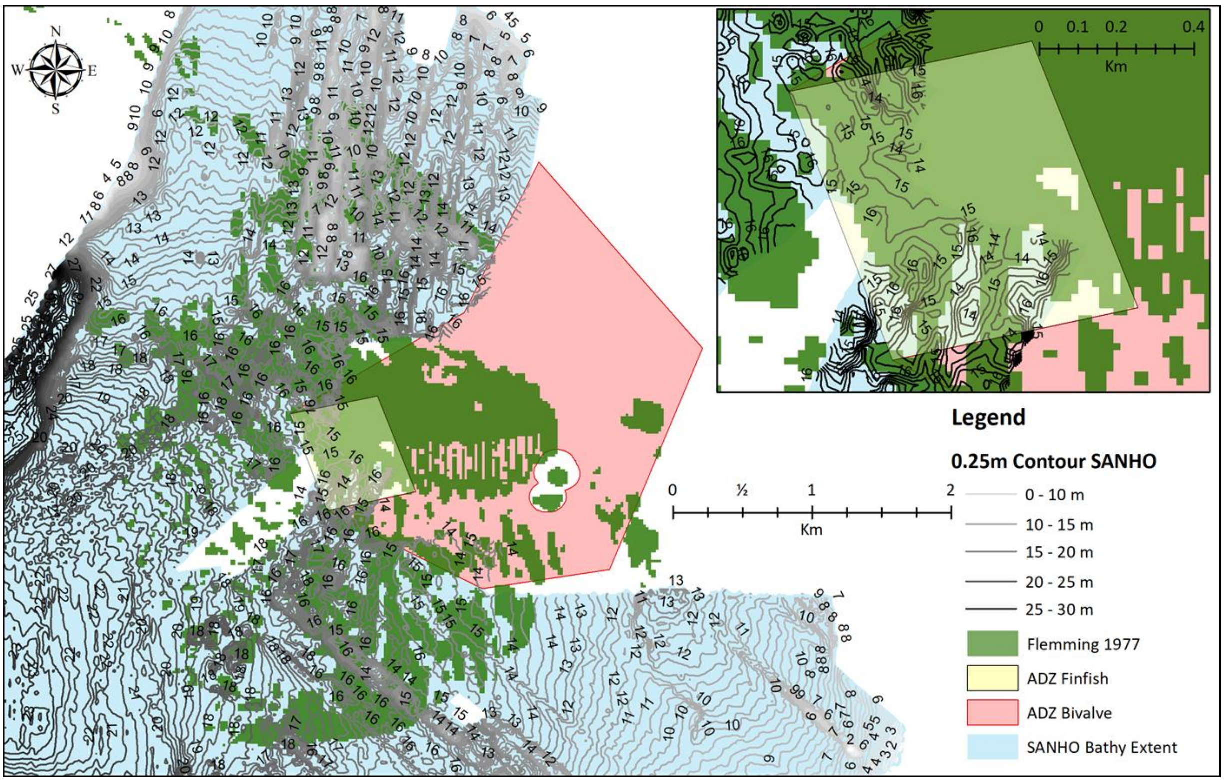


**Figure 5. 2020 and 2021 Bathymetry data (SANHO) overlain on top of Flemming's (2015) representation of the abrasion platform based on a 1977 side scan sonar survey. Inset = close up of Finfish section.**

## 3.2 Reef survey initial observations

The ability to identify species in both the photographic quadrats and the video footage was dependent on the visibility within the water column on the day on which the surveys were conducted. There was greater water clarity on 26 November 2021, while turbidity was higher i.e., there were more suspended particles in the water column, on 11 January 2022. The latter caused more back scatter of torch light in both photos and videos, making identification more difficult with greater uncertainty (Figure 6). To avoid this in future surveys, it is suggested that all six sites be surveyed on the same day, thus standardising photo and video quality. Highly mobile species such as the West Coast rock lobster *Jasus lalandii* were not often captured in photo quadrats as they move away once the quadrat is placed, therefore this species is likely underrepresented in the photographic data, rock lobsters were seen more frequently in the video transects.

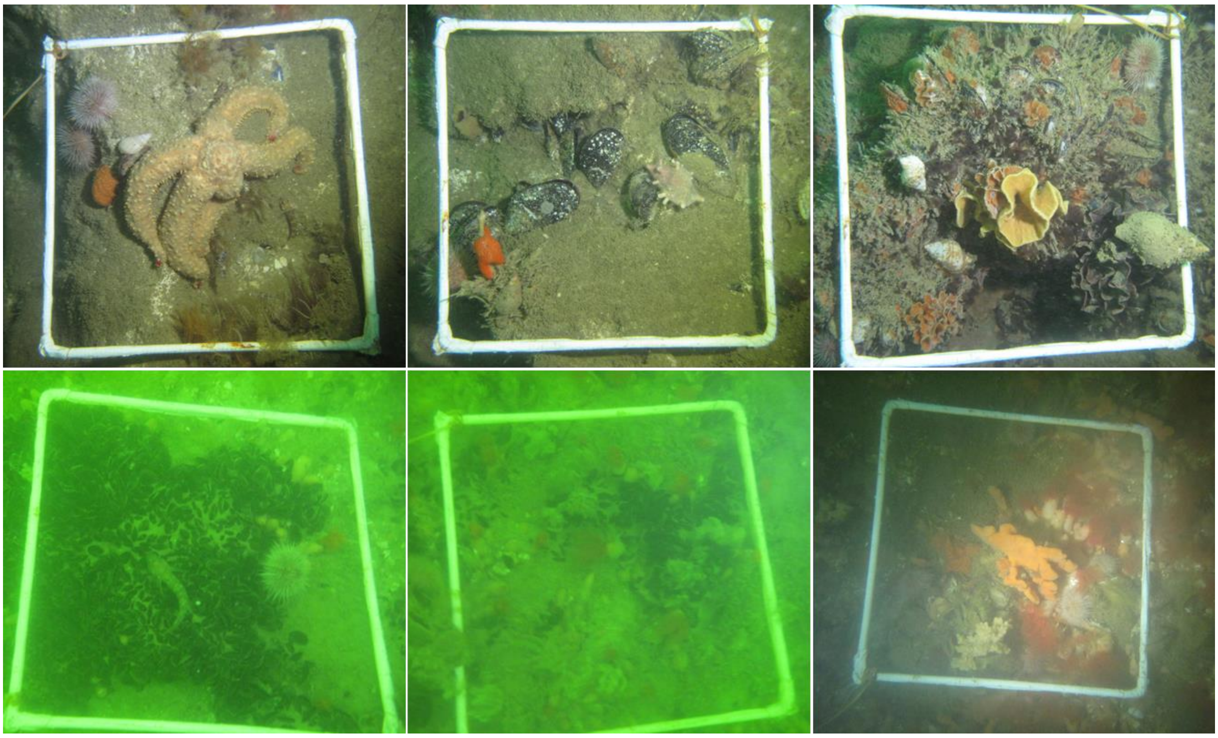

**Figure 6. Comparison of image clarity of photos taken in optimal conditions in November 2021 (Top) and images taken in above average visibility for Big Bay taken in January 2022 (bottom).**

During the data capture phase, prior to the analysis of the data, it was possible to identify significant differences between photos and videos taken at the control and impact sites. Impact sites appeared more variable with more species than control sites. Additionally, the presence of certain taxa in one or the other treatments (control/impact) were noted i.e., corals and false corals occurred at impact sites while high densities of sea cucumbers occurred at control sites. This interpretation was support by the data analyses.

## 3.3 Data analysis

An ordination plot, that displays photo quadrats from control and impact sites, based on similarities in their species composition in two-dimensional space (quadrats with similar communities are closer together) prepared from species presence/absence data, is presented in Figure 7. Visually the macrofaunal communities present at the Control sites were separate to those at Impact sites and was statistically supported by a significant difference between the two precincts (PERMANOVA $t_{1,68}$ = 3.3034; $p$ = 0.001).

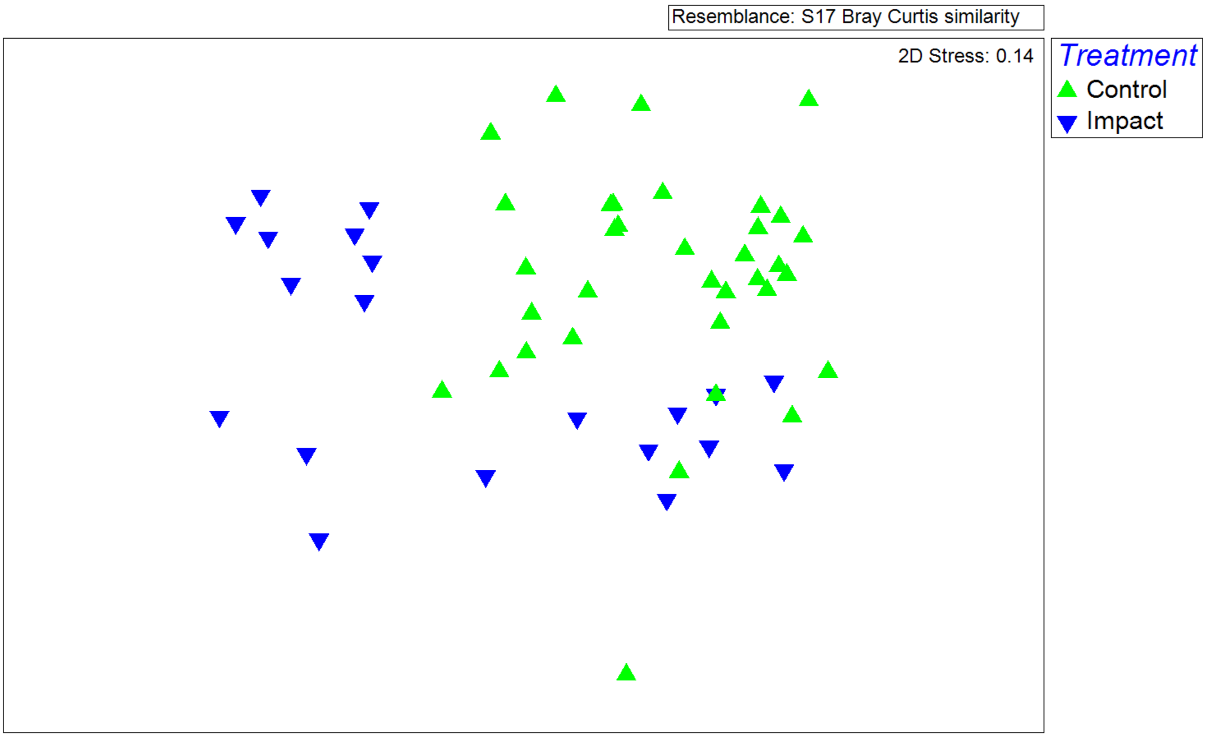


**Figure 7.** **Ordination plot comparing macrofauna species richness of photographic quadrats from control and impact reef survey sites.**

Given its location on the north-eastern edge of the ADZ Finfish precinct (Figure 2), the FF Baseline site is likely to experience some level of disturbance/deposition of organic matter from the shellfish infrastructure in the adjacent bivalve precinct and photo quadrats from this site are likely to be more similar to those from impact sites. This is supported by the MDS in Figure 8, in which finfish photo quadrats group out in between the quadrats from impact and control sites.

At the species level, the top taxa identified by SIMPER to contribute to the dissimilarity between control and impact sites included, the golden sea cucumber *Thyone aurea*, common feather star *Comanthus wahlbergii*, cape urchin *Parechinus angulosus*, ribbed mussel *Aulacomya ater*, fanworm polychaete, whelks *Burnupena sp.* and lacy false coral *Schizoretepora tessellata*. The average similarity was highest within control sites (54.85%), with a lower average similarity (29.64%) at Finfish baseline sites and the lowest similarity was observed within Impact sites at only 23.97%.

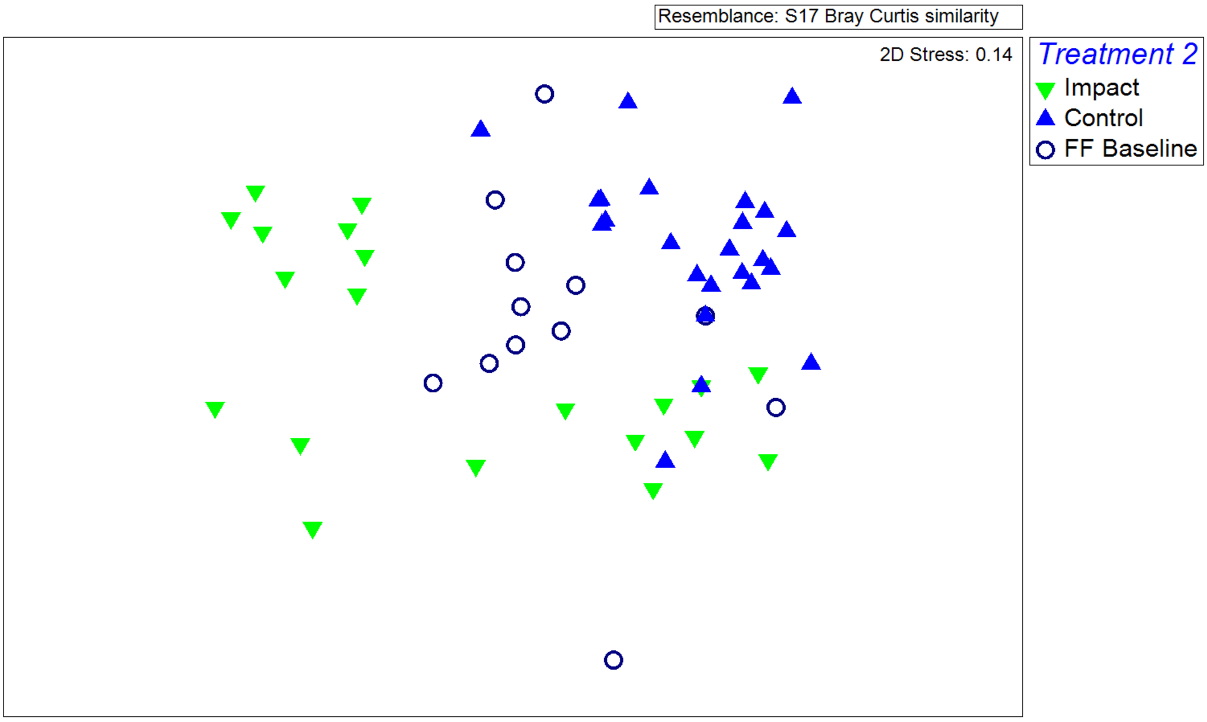


**Figure 8. Ordination plot comparing macrofauna species richness of photographic quadrats from control, Finfish baseline and impact reef survey sites.**

Multivariate dispersion tests showed that the presence of aquaculture operations (impact sites) and close proximity to aquaculture (FF baseline) increased the variability in macrofaunal photo quadrat assemblages relative to areas without aquaculture operations (control sites, Table 1). Suggesting that the disturbance as a result of aquaculture increases the species diversity at sites within the ADZ.

**Table 2. Summary statistics for multivariate dispersion tests showing average variability (+ SE) of macrofaunal communities, based on presence/absence species data, between control and impact reef sites.**

| PERMDISP | | | | |
|---|---|---|---|---|
| Macrofaunal Species composition | | | | |
| Treatment | Site | Sample size | Average dispersion | Standard Error |
| Baseline | FF1 | 12 | 47.668 | 3.1932 |
| Impact | I2 | 10 | 30.876 | 4.0264 |
| Impact | I3 | 13 | 45.466 | 4.0987 |
| Control | C1 | 14 | 24.434 | 3.7204 |
| Control | C2 | 11 | 18.34 | 2.7564 |
| Control | C3 | 10 | 32.602 | 2.8192 |

The patterns seen in species composition of video transects are similar to that of the photographic quadrats, however, the finfish baseline transects cluster closer to the impact sites than the control sites (Figure 9).

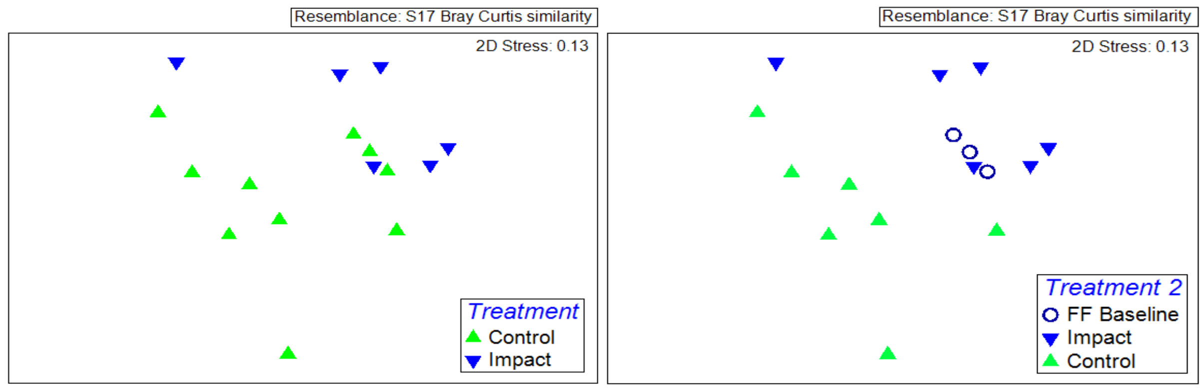


**Figure 9.** **Ordination plot comparing macrofauna species richness of video footage from control and impact reef survey sites (left) and control, Finfish baseline and impact reef survey sites (right).**

Species counts for both photographic data and video data of Control, Impact and Baseline sites within Big Bay were calculated and are shown in Table 3. Given that the photo quadrat covers an area of only 0.04 m$^2$, while the video footage covers an estimated area of 5 m$^2$ is not unexpected that the average number of species per quadrat was lower than the average number of species per video transect. Interestingly, average values at impact sites are consistently higher (more species diversity) than at Control sites.

**Table 3.** **Species counts for Control and Impact sites within Big Bay. Spp = Species.**

| Treatment | Treatment 2 | Site | Average | | Total species/site | | |
|---|---|---|---|---|---|---|---|
| | | | Spp/quadrat | Spp/video | Photos only | Videos only | Photos & videos |
| Impact | Impact | I2 | 2 | 8 | 10 | 16 | 19 |
| Impact | Impact | I3 | 6 | 18 | 26 | 29 | 35 |
| **Average at Impact sites** | | | **4** | **13** | **18** | **23** | **27** |
| Control | Control | C1 | 3 | 6 | 13 | 11 | 18 |
| Control | Control | C2 | 5 | 13 | 10 | 13 | 15 |
| Control | Control | C3 | 3 | 6 | 8 | 10 | 12 |
| **Average at Control sites** | | | **3** | **8** | **10** | **11** | **15** |
| Baseline | FF Baseline | FF1 | 6 | 16 | 27 | 23 | 30 |

This pattern of increased diversity is consistent with the ecological theory of disturbance on the diversity of tropical reefs (Connell 1978, Huges 1989, Wilkinson 1999). The Intermediate Disturbance Hypothesis predicts a peak in diversity at intermediate levels of disturbance, dropping down at both low and high disturbance pressure due to competition and extreme disturbance conditions (Figure 10).

The effects of disturbance have frequently been explained using the Intermediate Disturbance Hypothesis (IDH, Grime 1973a,b, Connell 1978, Wilkinson 1999) which proposes that diversity peaks at intermediate levels of disturbance (Shea et al. 2004). At low disturbance pressure, dominant species i.e., the golden sea cucumber and common feather star, outcompete sub-dominant species and prevent their co-existence. At high disturbance pressure, all except a few resilient species with high colonization rates are lost. Conversely, intermediate disturbance pressure removes/reduces the abundance of dominant species that cause competitive exclusion and allows for the co-existence and survival of rare/sub-dominant species in the community, i.e., coral and false coral species found in the impact sites. Intermediate intensities of disturbance can also enhance spatial heterogeneity created by patches of different successional communities, enabling early- and late-stage communities to coexist (Connell 1978, Levinton & Stewart 1982, Kelaher et al. 2003).

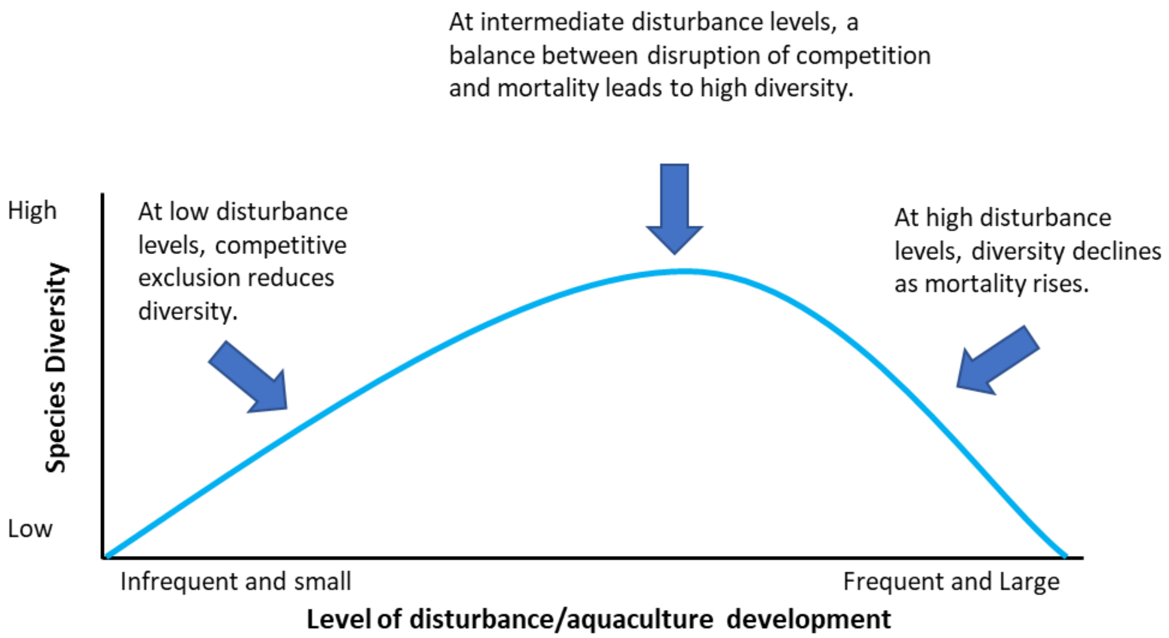


**Figure 10. Graphical representation of the Intermediate Disturbance Hypothesis.**

# 4 CONCLUSIONS & RECOMMENDATIONS

Based on the analyses of the existing bathymetry survey data and the reef survey data the following key findings and recommendations are made:

1. Based on available bathymetry data there is approximately 5 047 890.99 $m^2$ of reef within Big Bay, 29.2% of this reef area falls within the boundaries of the ADZ precinct, i.e., 6.3% of the total Big Bay reef area is found in the finfish precinct and 22.9% in the Bivalve precinct. The majority of the sea floor below the designated Finfish area is covered by reef (~79.9%), while 31.4% of the designated bivalve area consists of hard substrate, this is concentrated in the SW of the section.
2. Due to the fact that the Big Bay ADZ precinct was not surveyed in the recent SANHO data, historical data which appears to have a slightly reduced reef extent as compared to the SANHO data, was used to calculate the reef area and estimates are likely conservative.
3. Confirming the current day reef extent with higher confidence will require a similar resolution bathymetry survey of the ADZ precinct to be conducted in order to tie in with the 2020/2021 SANHO data.
4. The high proportion of reef in the finfish precinct is cause for concern, as finfish aquaculture is known to have a higher impact on the sea floor than bivalve aquaculture. It is therefore suggested that no Finfish aquaculture be undertaken at this site and that the Finfish sites in Outer Bay be utilized.
5. The ability to identify species in both the photographic quadrats and the video footage was dependent on the water visibility. Higher levels of uncertainty occur with higher levels of turbidity. It is suggested that all future survey data be collected on a single day to ensure standardised photo and video quality.
6. Multivariate and univariate data show that the community composition of Control and Impact reef sites differ significantly. Additionally, the benthic community structure at the Baseline reef site, located within the unused Finfish precinct, is more similar to that of impacted reef sites located within the Shellfish ADZ precinct. This suggests that the proximity of this site to the bivalve aquaculture has caused some level of disturbance/alteration of benthic conditions.
7. Community diversity at the Impacted reef sites is higher than at the Control sites, suggesting that at the present level of aquaculture development there is a balance between disruption of competition and mortality as a result of disturbance.
8. The intermediate disturbance hypothesis states that there is a tipping point at which the mortality as a result of disturbance is greater than the benefit of reduced competition. This point has not yet been reached in the Big Bay ADZ, but continuous monitoring of the reef fauna at Control and Impact sites is required to ensure early warning of this point being reached.
9. The use of photograph quadrats informs the identification of video footage and provides better imagery of accurate species identification. However, video transects consistently record higher species diversity, and mobile species such as the economically important west coast rock lobster, which are not often captured in photographs as they retreat when the quadrat is initially dropped, were better represented in video footage. Additionally, video footage provides a more accurate indication of the reef profile.
10. It is suggested that future surveys should include both video and photographic data and that the possible addition of lobster counts be included to monitor the population status of this

commercially important species. Should diving conditions allow, it would be desirable for future analysis to include quantitative abundance or percentage cover data.

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# 6 APPENDIX: Reef species list

**Table 4. Species list for control and impact reef sites surveyed in Big Bay, Saldanha Bay.**

| Group | Scientific name | Common name |
|---|---|---|
| Actiniaria | *Bunodactis reynaudi* | Sandy anemone |
| Anomura | | Hermit crab |
| Ascidiacea | *Pyura stolonifera* | Red Bait |
| | *Ciona intestinalis* | Transparent ascidian |
| | *Styela angularis* | Angular ascidian |
| | *Botrylloides leachi* | Ladder ascidians |
| Asteroidea | *Henricia ornata* | Reticulated starfish |
| | *Marthasterias africana* | Spiny starfish |
| | *Patiria granifera* | Red starfish |
| Bivalvia | *Aulacomya ater* | Ribbed mussel |
| | *Mytilus galloprvincialis* | Black mussel |
| Brachyura | *Platydromia (Cryptodromiopsis) spongiosa* | Cryptic sponge crab |
| Bryozoan | *Alcyonidium nodosum* | Nodular Bryozoan |
| | *Cellepora cylindriformis* | Cylindrical false coral |
| | Chaperia sp | Scrolled false coral (yellow/orange) |
| | *Gigantopora polymorpha* | Staghorn false coral |
| | *laminopora bimunita* | Pore-plated false coral (purple-brown) |
| | *Alcyonidium rhomboidale* | Soft False coral |
| | *Schizoretepora tessellata* | Lacy false coral |
| Crinoidea | *Comanthus wahlbergii* | Common feather star |
| | *Tropiometra carinata* | Elegant feather star |
| Cirripedia | *Notomegabalanis* | Barnacles |
| Echinoidea | *Parechinus angulosus* | Cape urchin |
| Gastropoda | *Africofusus ocelliferus* | Long-siphoned whelk |
| | *Argobuccinum pustulosum* | Pustular Triton |
| | Burnupena sp | Whelk |
| | *Bullia annulata* | Annulated plough shell |
| | *Bullia digitalis* | Finger plough shell |
| | *Clionella sinuata* | Ribbed turrid |
| | *Nassarius* | Dogwhelk |
| Holothuriodea | *Thyone aurea* | Golden sea cucumber |
| | *Pentacta doliolum* | Mauve sea cucumber |
| Malacostraca | *Jasus lalandii* | West Coast rock lobster |
| | *Palaemon pacificus* | Sand shrimp |
| Opisthobranchia | *Polycera capensis* | Crowned Nudibranch |
| Pennatulacea | *Virglaria Schultzei* | Feathery sea pen |
| Phaeophyta | *Colpomenia sinuosa* | Oyster thief |
| Polychaeta | | Fanworm polychaete |
| | *Gunnarea capensis* | Cape reef worm |
| | | Tangle worm polychaete |
| | Spirorbis sp | Spiral fanworms |
| Porifera | Haliclona sp | Sponge (Blue grey turrets) |
| | Haplosclerida | Crusting White |
| | Leucosolenia sp | Sponge (White turrets) |
| | | Orange crusting sponge |
| | Poeciloscerida | Orange upright sponge |
| | Tetractinellida | Golf ball/hard round |
| | Homoscleromorph? | Soft tearing sponge |

| Group | Scientific name | Common name |
|---|---|---|
| | Callyspongia | Tall turret sponge |
| | Calcarea | yellow sponge |
| Scleractinia | *Allopora noblis* | Noble coral |
| Fish | | Klipvis |
| | | Pipefish |

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