MEASURING THE RECOVERY OF THE BENGUELA CURRENT LARGE MARINE ECOSYSTEM: AN APPLICATION OF THE DPSIR FRAMEWORK

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LIST OF ACRONYMS

AVHRR	Advanced Very High Resolution Radiometer
BCC	Benguela Current Commission
BCLME	Benguela Current Large Marine Ecosystem
CAS	Complex Adaptive System
CPUE	Catch per unit effort
DPSIR	Driver-Pressure-State-Impact-Response
DO	Dissolved Oxygen
EEZ	Exclusive Economic Zones
GDP	Gross Domestic Product
HAB	Harmful Algal Blooms
LME	Large marine ecosystem
MFMR	Ministry of Fisheries and Marine Resources
NLFS	National Labour Force Surveys
NOAA	National Oceanic and Atmospheric Administration
PSM	Problem Structuring Method
SST	Sea Surface Temperature
TAC	Total Allowable Catches

Abstract

Overfishing in the Benguela Current Large Marine Ecosystem (BCLME) resulted in degradation of the ecosystem. This study used the Driver-Pressure-State-Impact-Response (DPSIR) indicator framework to determine whether the ecosystem is now recovering. Indicator trends were analysed using various data sources that included government institutions and intergovernmental institutions. The results showed that the overall effect of Driver indicators was negative. This was mainly because of socio-economic pressure such as the need to create more jobs in light of rising national unemployment and the declining contribution of the fisheries sector to Gross Domestic Product (GDP). In addition to scientific advice, socio-economic factors also influenced the determination of Total Allowable Catches (TACs). The overall trend of Pressure indicators was positively influenced by the effect of TACs. The TACs reduced the quotas allocated for commercial fishing. Environmental factors did not seem to play a significant role in this study. State indicators had mixed results with the indicators assessed almost split in the middle between those showing a positive trend and those showing a negative trend. On the other hand, Impact and Response indicators showed overall positive results. Therefore, the conclusion of the study was that the degradation of the BCLME has slowed down and there are some signs of recovery.

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 *INTRODUCTION*

1.1.1 Drive-Pressure-State-Impact-Response (DPSIR) indicator framework

The European Environmental Agency (EEA) first introduced the Drive-Pressure-State-Impact-Response (DPSIR) indicator framework in 1999 as a modification of the Pressure-State-Response (PSR) framework (Martins *et al.*, 2012). The purpose of the DPSIR indicator framework was to depict an ecosystem in a broad manner that is conducive for communication between interested parties. The framework also supports decision-making (Martins *et al.*, 2012). The framework is therefore suitable for improving communication between scientists, policy makers, and ecosystem managers.

Using the DPSIR framework for assessing the state of degraded reef fisheries enabled communicating between different stakeholders including scientists and policy makers in a study in Kenya. This was after degradation of the ecosystem had occurred due to overfishing and use of inappropriate fishing gear (Mangi *et al*., 2007). Another study that used this method to assess a fisheries ecosystem was done near Samsun on the coast of Turkey (Knudsen *et al.,* 2010). This study seeks to establish an indicator framework that supports the holistic measurement of trends of the different natural and anthropogenic factors that contribute to ecosystem health in the BCLME. Better understanding of the different factors may assist stakeholders involved with the ecosystem to reduce pressures exerted by negative drivers and pressures, whilst increasing responses that mitigate the pressures.

1.1.2 Location of the BCLME

The BCLME is located between the Northern Boundary of Angola and the area near Port Elizabeth in South Africa where the Agulhas current starts. See the map in Figure 1.1. To the west, the boundary of the BCLME is at the boundary of the Exclusive Economic Zones

(EEZ) of Namibia and Angola. The western boundary also includes a part of the EEZ of South Africa. A key factor in the productivity of the BCLME is the coastal upwelling phenomenon. It involves the movement of nutrients upwards to where they are accessible

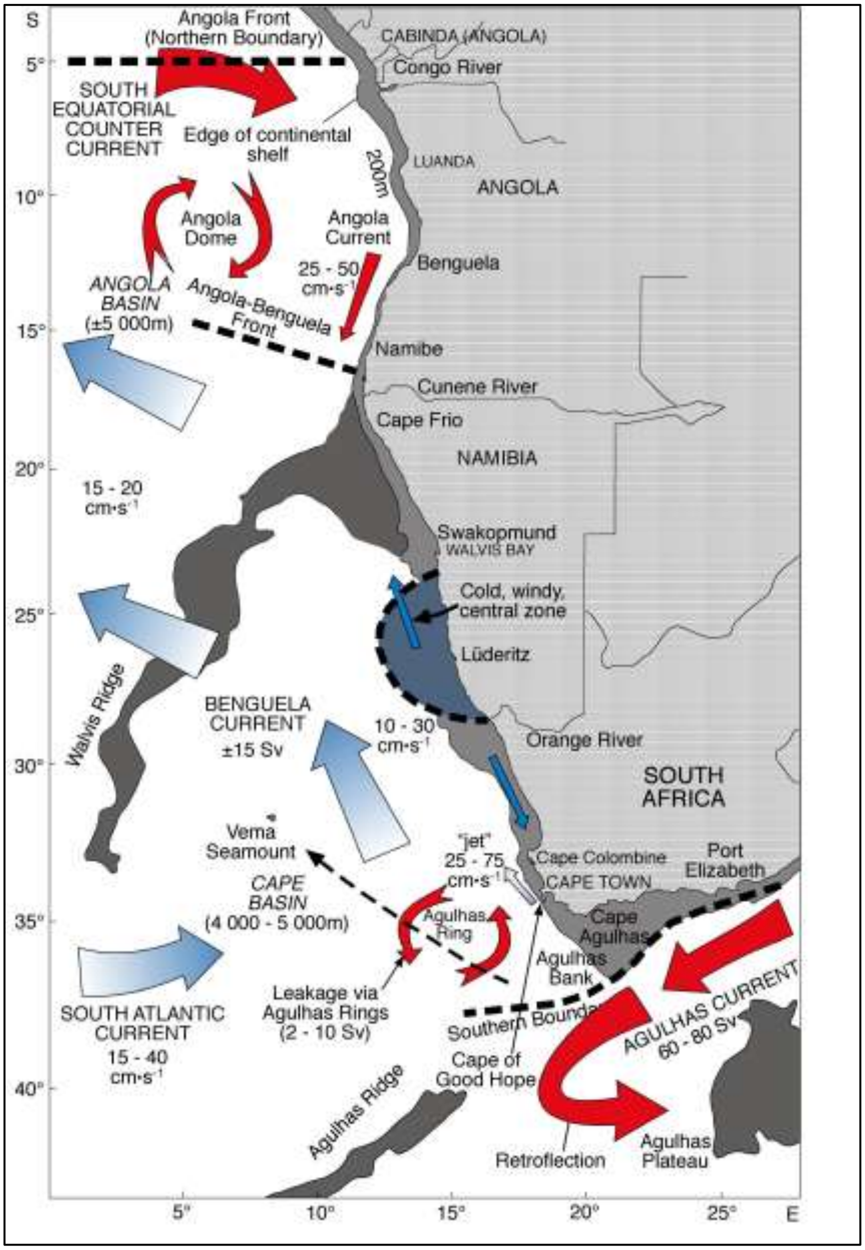


Figure 1.1 Map showing the northern and southern boundaries of the BCLME region. The study focused on the central part covered by Namibia (Source: Benguela Current Commission, 2008).

to more primary consumers. The driving force of the movement is the wind blowing towards the coast. The centre of the upwelling in the BCLME is in Lüderitz in Southern Namibia (Heile & O'Toole, 2009). Although the BCLME covers Angola, Namibia and part of South Africa, this study focussed mainly on the central part of the BCLME, which is the area covered by Namibia. See Figure 1.1 for the map of the BCLME region.

1.1.3 Degradation of the BCLME

Overfishing that occurred in the three decades spanning from 1970 to 2000 caused degradation of the BCLME. High volumes of catches occurred in the 1970's and the 1980's. However, the stress due to overfishing peaked in the 1990's resulting in reduction of biomass and of catches of most species. In addition, environmental factors also led to stress in the system (Heymans *et al*., 2004).

According to O'Toole (2009), scientists and policy makers of the BCLME reached consensus in the late 1990s regarding the major transboundary problems affecting the BCLME ecosystem. The scientists from the BCLME countries (Angola, Namibia and South Africa) agreed that problems include degradation of fisheries, productivity changes due to environmental variability and deterioration of water quality.

At around the same time, international concern for the state of overexploited marine ecosystems and loss of marine biodiversity led to international policy and conventions such as the Jakarta Mandate on Marine and Coastal Biodiversity (1995), the Reykjavik declaration (Declaration, 2001) and the Johannesburg Declaration on Sustainable Development of 2002 (World summit on sustainable development, 2003). In line with these initiatives and regional agreements, there have been efforts over the past decade by Angola, Namibia and South Africa to restore ecosystem health through cooperation and joint management of the marine ecosystem. Some of these efforts include joint management of the ecosystem through the Benguela Current Commission, implementation of a science programme for transboundary research, and training and capacity building initiatives (Hampton & Willemse, 2012; Hempel *et al.*, 2008).

1.1.4 Need to measure recovery of the BCLME

Policy makers and managers of the BCLME need information on how current policy and management interventions are performing in order for them to make the most of the policies and resources targeted at the recovery of the BCLME. This research sought to use indicators in a way that makes it easier for policy makers to put science into the context of broader issues that influence the ecosystem.

1.2 *RESEARCH PROBLEM*

The BCLME suffered from historical degradation caused by overfishing. Efforts to help the ecosystem to recover intensified in the past two decades. For these efforts to be effective, policy makers, managers and scientists need to have good understanding of the interactions between different factors influencing the ecosystem. For the BCLME, specialists in different sectors generate useful data on aspects of the ecosystem but there has been no attempt to bring together indicators and to find common understanding on what is happening in the ecosystem. A clearer understanding of the recovery of the BCLME from previous degradation that links the different sectors and their cause and effect relationships is required.

1.3 *JUSTIFICATION*

The BCLME makes a significant contribution to food, employment and GDP for the countries of the Benguela region (Hempel *et al.*, 2008). Sustaining the continued availability of the ecosystem's goods and services will therefore make a significant contribution to the people of Namibia. A suite of indicators that meets the information needs of policy makers holistically may lead to policy makers making better decisions that would result in significant improvements in the management of the ecosystem.

Traditionally, scientists have focused on narrow and specific lines of study whilst policy makers require a broader, more holistic understanding that links specific scientific study to changes in socio-economics and shifts in policy. It would be useful to bridge this gap between science and policy by use of an indicator framework such as the DPSIR framework, as it demonstrates the cause and effect relationships that affect the health of ecosystem and allows easier communication from scientists to policy makers (Mangi *et al*., 2007).

Various stakeholders are participating in efforts to help the ecosystem to recover from overexploitation that resulted in extensive degradation of marine resources including some important fish stocks (Roux & Shannon, 2004; Hutchings *et al*., 2009). Therefore, there is a need to understand the direction in which ecosystem health is going, considering changes in pressure on the ecosystem and the impact of the efforts to correct previous degradation. This study used the DPSIR framework of indicators to measure trends that give this broader picture of whether the ecosystem is recovering.

1.4 *RESEARCH GOAL*

This study assessed the recent trend in ecosystem drivers, pressures, state, impacts and responses (DPSIR) in order to determine whether the BCLME is recovering or not from previous degradation caused by overfishing.

1.4.1 Specific Objectives

The following were the specific objectives:

- To assess potential DPSIR indicators to use in the BCLME;

- To evaluate recent trends (2000-2010) in the indicators and recommend ways to improve recovery of the ecosystem;
- To demonstrate the use of the DPSIR framework as a means of measuring and communicating status and changes of a large marine ecosystem.

1.5 *RESEARCH QUESTION*

Does an assessment of the trends in DPSIR indicators for the BCLME show whether the BCLME is recovering from previous degradation?

1.6 *RESEARCH HYPOTHESIS*

The trends developed from the DPSIR indicator data for the Northern Benguela Large Marine Ecosystem can be used to holistically demonstrate whether the ecosystem is recovering from previous degradation.

1.7 *RESEARCH ASSUMPTIONS AND OPERATIONAL DEFINITIONS*

1.7.1 Assumption

The BCLME extends across three countries. Each country measures the various indicators for its territory. Hence, the authorities, systems of measurement and languages are different. However, it is assumed that trends in Namibia, which is part of the central to northern part of the LME, are representative of general trends in the LME.

1.7.2 Definition of terms

By-catch	Non-quota species that are caught together with target species (Pitcher & Cheung, 2013).
Catch-per-unit-effort	The rates at which fish or other living marine resources are caught. This rate is linked to the abundance of the stocks being targeted (Barnes and Hughes, 2009).
Fishing effort	Refers to inputs, such as time and fuel , required for a fishing vessel to catch fish (Barnes and Hughes, 2009).
Discards	Non-quota species that are discarded at sea (Pitcher & Cheung, 2013).
Landed Value	The total value of fish being taken off the fishing vessels.

1.8 *STRUCTURE OF THESIS*

Chapter 1 introduced the study and gave background information. Chapter 2 will review available literature relevant to the study. Chapter 3 presents the research design and methodology, and Chapter 4 presents the results and data analysis. A discussion of the results shall follow in chapter 5. The conclusion of the study and some recommendations derived from the study will be given in chapter 6.

CHAPTER 2: LITERATURE REVIEW

2.1 *DESCRIPTION OF DRIVER INDICATORS*

Drivers are natural and anthropogenic forces that cause changes in an ecosystem. They can act directly on the ecosystem; for example, an increase in demand for fish can be the driver that leads to pressure on the fish stocks (Burkhard & Müller, 2008). For example, the need to create employment and revenue may be a driver that results in authorities issuing more fishing quotas, resulting in increased fishing effort (De Jonge *et al.*, 2012). Environmental variability is an example of another driving force in the BCLME. Change in sea temperature and wind direction and intensity are associated with significant changes in fish catch rates (Jury, 2012). Some potential Driver indicators that can also be used are fish prices, consumption and market (Knudsen *et al.,* 2010), and variation of sea surface temperature (SST) and wind speed (Chassot *et al.,* 2011).

Heymans *et al.* (2009) use ecosystem modelling to show that maximising jobs or maximising profits in the BCLME occurs with increases in fishing efforts. This is further evidence of the increase in pressure on living marine resources driven by the need to satisfy socio-economic factors such as job creation and revenue maximisation. In Namibia, reporting of the contributions of fisheries to national employment levels and to GDP occur annually because it is part of measures of performance (Ministry of Fisheries and Marine Resources, 2011).

2.1.1 Increasing fish prices and strengthening Namibian dollar driving the need for more fishing

Increase in the price of fuel negatively affects fishing by reducing profits, as fuel purchases comprise between 30% and 40% of the total revenue of Namibian companies (Hashange, n.d.). Increase in fuel prices and adverse exchange rates between 2008 and 2009 resulted in a reduction in the contribution of fishing to GDP from 4.6% to 4.0%. This created pressure to make up for this loss of revenue. In 2011, the Minister of fisheries increased fishing quotas by giving fishing rights to 3178 new applicants (Steenkamp, 2012). Therefore, fish prices and the contribution of the fishing industry to GDP are drivers for the BCLME.

2.1.2 The need to sustain the fishing industry versus saving fish stocks from collapse

Policy makers often have to make a decision to try to balance the need for maintaining or maximising socio-economic benefits derived from exploiting living marine resources and the need to maintain the exploited ecosystem in good health. Hence, the government may put specific legislation in place aimed at encouraging socio-economic improvement whilst ensuring that living marine resources are conserved (Jarre *et al.,* 2013). In the BCLME, there were fears of possible collapse of the fishing industry, loss of export markets and loss of employment when TACs were reduced significantly in order to allow the stock levels of some species to recover (Roberts & Isaacs, 2006). In addition, stock levels could be adversely affected by the discarding of marketable catch that may occur when individual fishing quota holders reach their TAC limit for particular species (Poos *et. al.,* 2010)

2.1.3 Significance of fisheries to the Namibian economy

Between 1995 and 2007, the fishing industry contributed between 4.5% and 7.8% of the GDP of Namibia. A significant reduction of this contribution may lead to political and economic pressure on policy makers and ecosystem managers to increase exploitation of the living marine resources. In addition, the industry contributed to creating employment through offshore fishing operations and through on-land processing of catches. As Namibia already has high unemployment rates of at least 40%, employment levels in the industry can also affect social and economic pressure in the ecosystem (Christiansen, 2012).

2.2 *PRESSURE INDICATORS*

In the DPSIR framework, the pressures are because of the presence of drivers. Hence, the influence of socio-economic factors and environmental factors creates the conditions that force the ecosystem to improve or deteriorate. Therefore, fishing effort should change in response to the drivers discussed in the last section. Such changes can be enforced by quotas which force fishing crews to change the number of vessels and/or size of fishing gear (Burkhard & Müller, 2008; De Jonge *et al.*, 2012). Therefore, TAC and Catch Per Unit Effort (CPUE) can be used as indicators of pressure on the ecosystem (Shin *et al.,* 2010).

CPUE may have a larger influence on the fishing industry's perception of the size of fish stocks than the results of research surveys that determine the state of the fish stocks (Field *et al.,* 2013). This perception may in turn influence the amount of pressure that the industry puts on defending current quotas or asking for more quotas in order to exploit more living marine resources.

According to Edoff (2012), Namibia has a system of using TACs for managing the rate of exploitation of fisheries that is better than in many other countries. The system works by first determining the total amount of fish that may be exploited sustainably. Individual operators get quota's or fishing rights based on this total. However, government scientists who advise the Minister are not the only ones influencing the determination of Namibian TACs. Rather, there is also influence from scientists hired by interest groups and socio-economic experts that sit on the Namibian Fisheries Advisory Committee. This committee also gives its recommendations before the Minister issues TACs. Therefore, socio-economic considerations affect the allocation of TACs by the Minister (Paterson *et. al.,* 2013).

Pressure on a marine ecosystem also emanates from By-catch and discards. By-catch are non-quota species that are caught during commercial fishing activities and brought in as part of the total catch (Pitcher & Cheung, 2013). Discards refer to non-quota species that are discarded at sea. The By-catch includes fish, seabirds and mammals. Therefore, the loss of some of these species through By-catch may seriously impact the stock levels of affected species and may eventually reduce the biodiversity of the ecosystem. An overall decline in By-catch may suggest recovery of the ecosystem. However, caution is required because the reduction may also be in line with reduction in CPUE as the ecosystem further deteriorates (Pitcher & Cheung, 2013).

Environmental or climate change drivers result in changes such as increasing or decreasing the amount of food and oxygen available. This in turn changes the amount of marine living resources that can survive in the ecosystem (Chassot *et al.,* 2011). Therefore, indicators that show environmental variation such as Sea Surface Temperature (SST), Dissolved Oxygen (DO) and wind-stress may be used to show environmental pressure arising from environmental drivers.

2.2.1 Climate changes in the Benguela

Many instances of change in wind speed and direction that have an effect on the ecosystem have occurred in the BCLME. In particular, the winds have been increasing their tendency to move outwards from the shore towards the sea. This can cause increased upwelling (De Young *et al*., 2011). Upwelling is the phenomenon that makes nutrients available in water close to the surface due to wind-induced movement of nutrient-rich water from lower layers. This phenomenon results in the BCLME being one of the most productive marine ecosystems (Skogen, 2004: 11). There has also been a general increase in Sea Surface Temperature (SST) and a decrease in oxygen levels in the central region of the Benguela around Walvis Bay in Namibia. This has occurred because of the influence of warmer, low oxygen water coming into the area from the warmer Northern Benguela region off the coast of Angola. The low oxygen levels may be significantly affecting the stock levels of some living marine resources. However, changes due to the exploitation of living marine resources by human beings most likely exceeded changes due to environmental factors (De Young *et al*., 2011). In spite of the significance of human influences, warming events have been known to lead to major changes – also called regime shifts – in the ecosystem (Reid and Beaugrand, 2012).

Variation in pH brings changes in a marine ecosystem. Such changes can affect survival or modify feeding and breeding patterns. For example, changes affect intertidal isopod, *Paradella dianae* (Munguia and Alenius, 2013) and on blue mussel *Mytilus edulis* (Gazeau *et al.,* 2010). Some of the changes are caused by dissolution of carbon dioxide in seawater leading to increased acidity. Carbon dioxide in the atmosphere comes from human activities (Munguia and Alenius, 2013).

2.2.2 Pressure from pollution

Pollution in the BCLME is not a major problem. There is no widespread pollution emanating from the coast. However, there may be limited localised pollution near coastal settlements such as Lüderitz and Swakopmund. The potential for extensive Harmful Algal Blooms (HAB) is also minimal in spite of the fact that some HABs occur naturally in the ecosystem (Heile & O'Toole, 2009)

2.3 *STATE INDICATORS*

State refers to changes over time that occurs in an ecosystem. The changes can be ecological or they can be socio-economical (Martins *et al.*, 2012). Changes do not necessarily occur soon after exposure to pressures. There is the possibility that in some instances they may occur later compared to the time of exposure to the pressures. Challenges in measuring State indicators may also occur when the area covered by the ecosystem is large (Burkhard & Müller, 2008). In this study, the area was limited to the central Benguela area that is off the shores of Namibia. Although this area is still large in terms of spatial extend, it is a representative sample of the large marine ecosystem. Using Namibian indicators made it possible to avoid the complications of combining indicators from three different countries with different monitoring systems and different languages.

It is common to use catch data of fish to determine the state of marine ecosystems. The use of the catch data has been particularly effective in developed countries where there are skills and resources available to allow accurate determination of stocks. However, even in developing countries the catch data is very useful when available. Other indicators such as data collected by fishing crew and/or the community (Agnew et. al., 2013; Kleisner et. al., 2013) may support where data or skills are lacking in developing countries catch data. In this study some of the indicators analysed include available Biomass data, CPUE data, landings and By-catch data.

The variation in biomass in a marine ecosystem may be used as an indicator for changes that are happening in the ecosystem. Changes in biomass may occur after introduction of pollutants or overexploitation of living marine resources (Gómez-Canchong *et al.,* 2013). Changes in biomass may also occur due to environmental effects. For example, changes in horizontal stirring in the Benguela upwelling system resulting from changes in wind speed and direction lead to reduction of plankton biomass (Hernández-Carrasco *et al.,* 2014).

Chlorophyll-*a* may be used an indicator of productivity of a marine ecosystem. In addition, Chlorophyll-*a* studies may also be used as an indicator for water quality (Szymczak-Żyła *et al.*, 2011). Remote-sensing data for Chlorophyll-*a* analysis of plankton may present a useful solution for analysing extensive water bodies (Racault *et. al.,* 2014).

2.4 *IMPACT INDICATORS*

Changes in state described above have ecological and socio-economic impacts. Indicators that are sensitive to these impacts can be used as Impact indicators (Burkhard & Müller, 2008). Mangi *et al.* (2007) show that over-exploitation of fish resources may lead to a decline in fish catches. Lack of viable alternatives may lead to even more pressure on the reduced fisheries as people seek a source of protein and a means of livelihood. Therefore, decline or increase in fish catch and CPUE are examples of Impact indicators that can be used.

In the 1990s reduction in winds causing upwelling led to increase in SST. Some researchers suggest that the impact of these changes in state was a reduction in biomass and change in stock structure of stocks such as sardine. The length of the sardine was shown to be less at maturity. In addition, the species produced fewer offspring. These changes are illustrations of impacts that may result from changes of state in an ecosystem (Kreiner *et al.,* 2011).

Mean trophic levels of fish landings may also be used to show the ecosystem impact of changes in the BCLME (Angelini & Vaz-Velho, 2011). The increased voyage of foreign vessels into the BCLME in the past century resulted in exploitation of living marine resources including fish, seabirds and seals. This exploitation resulted in changes in the trophic structure of the ecosystem. As an example, the exploitation of top predators such as seabirds and seals resulted in lowering of the trophic levels of the ecosystem in particular periods over the past century. The effect of the absence of top predators may have been counterbalanced by the increased commercial fishing by pelagic and demersal fisheries (Watermeyer *et al.,* 2008).

2.5 *RESPONSE INDICATORS*

Response refers to how humans react to change of state and impacts in the ecosystem. These responses should ideally be directed at addressing the drivers and pressures in order to relieve the stress in the ecosystem. Responses can be proactive in addressing pressures before they cause a change of state or they can be reactive to correct the change of state and the impacts that results (Burkhard & Müller, 2008). Response indicators are referred to as process indicators since they measure progression of response measures. However, whether or not these response processes result in positive impacts on the ecosystem is measured by pressure and State indicators. Examples of responses are policy change and advocacy (Burkhard & Müller, 2008). For the BCLME, Hampton and Willemse (2012) note that marine protected areas, legislation/policy changes, training and capacity building, marine governance structures, transboundary research and skills sharing were created. These responses can be the basis of Response indicators.

As part of the response to the degradation of fish stocks in the 1960s and 1970s, studies by experts with different specialist skills were done in order to understand the BCLME. Two key studies were the Benguela Fisheries and Environment Interactions and Training (BENEFIT) and the BCLME programmes. These programmes were donor-funded (Hutchings *et al.,* 2009).

As a response to the pressures and changes of state in ecosystems due to climate change, the government of Namibia ratified the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto protocol. Therefore, Namibia is also contributing to international efforts to reduce climate change from greenhouse gas emissions. The changes brought by climate change affect both marine and terrestrial ecosystems. There have been national efforts to increase the capacity of aquaculture and mariculture which is targeted at reducing pressure on marine fisheries. There is also the need for countries in the BCLME (Angola, Namibia and South Africa) to enhance cooperation on scientific research and on joint management of transboundary stocks (De Young *et al*., 2011). This need is being satisfied by transboundary marine governance organisations such as the Benguela Current Commission (BCC).

2.6 *IMPORTANCE OF THE DPSIR INDICATOR FRAMEWORK*

2.6.1 DPSIR identifies pressures that people can control

Indicators portray some characteristics of an ecosystem. They can be used to communicate changes in the ecosystem enabling people to give simple quantitative descriptions of the changes (Hopkins, 2012). The DPSIR indicator framework is important in that it enables the identification of pressures in the ecosystem that can be managed by humans. These pressures are linked using this framework in a way that gives an idea of the cause and effect relationships that may exist between the drivers and pressures and the impacts and responses that they cause. However, the relationships between the components of the DPSIR framework are not simple and it may be very difficult to ascribe a particular impact or response to a given pressure (Hopkins, 2012).

2.6.2 DPSIR as a decision supporting tool

The DPSIR framework of indicators may be used as a tool for supporting decisions of managers and policy makers. It may also support discussion of various stakeholder issues among different stakeholders. The framework also enables cause and effect relationships to be established for effects that are influenced by human activities. These cause and effect relationships link socio-economic changes and environmental interactions to changes happening in the ecosystem (Acton, 2013: 373). The DPSIR framework is useful as a decision supporting tool in evaluating and handling environmental issues for policy intervention. It also helps as an aid for sharing the impacts of policy changes with stakeholders (Gregory *et al.*, 2013).

2.7 *DEFINING THE STUDY AREA AS AN ECOSYSTEM*

The ecosystems approach was a paradigm shift from the traditional sector-by-sector management of marine issues. Under the ecosystem approach, sectors such as marine mining, transport, tourism and fisheries are part of the same system. Therefore, management of each component is in the context of the other components. The social and economic aspects of the interaction of human beings are also part of the ecosystem and there has been integration of scientific knowledge with the social and economic aspects of managing large marine ecosystems (Sherman & Duda, 1999; Roux & Shannon, 2004; Mechling, 2005). The ecosystems approach considers the BCLME region described in section 1.1.2 as one marine ecosystem. Therefore, the socio-economic indicator data collected from the Namibian territory could be used to refer to the same ecosystem together with the scientific indicators collected over Namibian marine territory.

2.8 *USE OF THE DPSIR SYSTEM IN SIMILAR STUDIES*

As noted by Martins *et al.* (2012), only two research works have applied the DPSIR framework on a fisheries ecosystem. One study was on coral reefs in Kenya (Mangi *et al.,* 2007), whilst the other was on fisheries on the coast of Turkey (Knudsen *et al*., 2010). Therefore, more studies are needed in order to improve the understanding of the ecosystem relationships and communicating ecosystem issues to policy makers. This study gave a basis on which other large marine ecosystems can develop a holistic set of indicators to monitor major ecosystem issues from their root causes to their impacts.

The study by Knudsen *et al.* (2010) demonstrated that the marine system near Samsun in Turkey was declining and fishing pressure was increasing. Similarly, the work by Mangi *et al.* (2007) showed the relationship between increased unemployment and increased fishing, leading to declining fish stocks. They argued that the way different relationships are represented in their study makes it easier for communicating with different stakeholders.

2.9 *CRITICISM OF THE DPSIR FRAMEWORK*

Although alluding to the suitability of the DPSIR framework as a suitable means to encourage sustainability and efficient management, Martins *et al.* (2012) note that the framework does not fully capture the complexity of the cause and effect relationships it describes. They also note that there has not always been agreement on which DPSIR classification a particular indicator fits. Hence there is evidence in literature of conflicting classification. In spite of these and other criticisms, the DPSIR framework seems to be a good approach to improve communication of key issues of the ecosystem. Therefore, a large marine ecosystem like the BCLME is likely to have better control in managing the ecosystem with the application of this framework.

2.9.1 DPSIR and multiple stakeholder views

The DPSIR framework can be used as a Problem Structuring Method (PSM) (Bell, 2012; Gregory, 2013). It is useful for identifying environmental issues, contributing to development of policy and measuring impact of the policies. The framework is strong as a technical method for scientists and a tool for communicating with non-scientists (Bell, 2012). However, a weakness of the DPSIR framework may be the loose definition of the framework which may have allowed for different interpretations (Svarstad *et al*., 2008). Cooper (2013) notes this weakness and proposes to define the DPSIR framework in terms of human welfare in order to better define the framework. This is an example of some researchers who have taken a bias towards impacts on human society rather than the natural ecosystem and have used a modified DPSIR framework. They substituted impact for welfare to come up with a DPSWR framework (Gregory *et al.,* 2013). This research kept the original DPSIR framework in order to avoid having a bias towards social issues at the expense of the technical scientific issues.

2.9.2 Failure to account for natural pressures

The DPSIR framework has been criticised for failing to account for pressures resulting from non-anthropogenic causes (Gregory *et al.,* 2013). For example, climate change may affect the productivity of a marine ecosystem regardless of whether there is overexploitation of living marine resources or not. Similarly, a volcanic eruption in a marine ecosystem may result in pressures that have nothing to do with human intervention in the ecosystem (Elliott, 2011). In the BCLME, variation of climate is considered to be a major factor in the changes in productivity of the ecosystem. Variations in stock levels have been observed with changes in climatic factors such as wind speed and direction. When wind speed changes it affects the levels of oxygen and nutrients and therefore has a direct bearing on productivity. Similarly, warm and cold events result in major changes in productivity in the ecosystem affecting the whole food chain, from primary producers to predators. Examples of cold and warm events that have occurred in the BCLME are the Benguela El Niño’s and La Niñas (Heile & O’Toole, 2009). In order to ensure that environmental factors are not neglected in this study, some indicators of environmental variation covering the research area were considered.

2.10 *SOME CHALLENGES FACED BY RELATED STUDIES*

As incomplete monitoring or lack of monitoring of some parameters may result in missing data, the selection of indicators was not only be influenced by relevance but also by data availability (Alexakis *et al.,* 2012). In a study of the Namibian fisheries data collection and management system, it was noted that challenges exist in the completeness and speed with which data is made available. The fact that there are policies and structures in place to monitor certain marine parameters did not mean that all parameters were monitored in Namibia. There were issues of missing monitoring data. When monitoring had occurred, there were also challenges with delays in analysing the data and making it available (Uahengo, 2013). In line with the suggestion by Shin and Shannon (2010) this study combined scientific indicators with some non-scientific indicators in order to reduce the impact of missing data.

Another challenge faced by studies using DPSIR indicators on marine systems is the fact that the interpretation of which indicators constitutes the different DPSIR categories varies significantly within the literature. Therefore, indicators categorised in a certain way in one study may have been represented differently in other studies (Martins *et. al.,* 2012). This study used the indicators that appeared more frequently in literature for a given category of the DPSIR framework.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 *Introduction*

This chapter covers the research design and methodology. It describes the study as a quantitative research based mostly on secondary data. The sources of data are given followed by a description of how the indicators were chosen. The methods used for data analysis are also described.

3.2 *ONTOLOGICAL AND EPISTEMOLOGICAL APPROACH*

The ontological bias of the study is that the truth about the recovery or lack of recovery of the BCLME is objective. Thus, there is one truth which answers the research questions and this truth applies to all those who are involved with the ecosystem, including the public, researchers, policy makers and managers of the large marine ecosystem. Further, the epistemological bias of this study was that the researcher is independent of the ecosystem aspects being studied and cannot influence them in any way during the processes of the study. Therefore, the study is a quantitative study with principles of positivism, which is a realism approach (Creswell, 2009). Related studies have used data from trawl surveys covering the duration under investigation (Shin & Shannon, 2010). Similarly, this was an empirical study applying quantitative data analysis.

3.3 *JUSTIFICATION OF QUANTITATIVE APPROACH*

This study sought to gain an objective assessment of whether or not the BCLME is improving through the use of data available in formal channels that report various aspects of the ecosystems' functions. Because of the multi-disciplinary nature of the DPSIR framework and the fact that the study sought to investigate trends over time, historical data was used rather than developing new data through new observations.

Quantitative analysis is appropriate when the data collected is numerical and can be manipulated using statistical analysis. It also works well in researches where the numerical analysis will lead to the acceptance or rejection of an initial hypothesis (Teddlie and Tashakkori, 2009). Therefore, since most the indicator data that was gathered for this study was numerical, it was appropriate to use quantitative methods. Also in line with Teddlie and Tashakkori (2009), the initiation hypothesis for this study could be accepted or rejected based on regression analysis of indicator trends.

In science, results are more likely to be trusted when they are based on parameters that can be quantified and represented in numbers compared to when results are descriptive (Lakshman *et al.,* 2000). Although this study included some indicators from other disciplines, it was predominantly a scientific study of an ecosystem. Therefore, quantitative analysis was useful for making the results scientifically credible.

According to Merriam (2009), quantitative methods are used in studies looking for cause and effect relationships or for predicting or understanding the distribution of characteristics of a particular system. This study was considering trends for attributes affecting ecosystem health in the context of cause and effect relationships using the DPSIR framework. In contrast, qualitative studies would focus more on how people in a particular context would interpret data. Therefore, a qualitative approach would seek to ascribe meaning to various points of views whilst considering the background and method in order to come up with a subjective conclusion through inductive reasoning (Yilmaz, 2013).

3.4 *DATA TYPES AND SOURCES*

3.4.1 Data types

Most of the data used for this study were secondary data although some primary data were also used. The main difference between primary and secondary data comes from how the data is generated. The researcher collects primary data through methods such as experiments, observation, interviews and questionnaires. The purpose of the data would be to satisfy the researcher's specific area of interest. On the other hand, secondary data is data that the researcher does not acquire directly. Instead of carrying out observations, interviews or other activities, the researcher uses data that was obtained as primary data by another researcher (Vartanian, 2010).

The advantage of secondary data is that it saves effort, time and money. Instead of carrying out extensive observations and surveys over 10 years this study used data that had already been generated by government institutions and other researchers. Government institutions had the resources and authority to get indicator data that covered the whole extend of the Namibian territory. Such coverage would not be possible for one researcher. The processes and resources of the government institutions also ensured that data of good quality was collected (Boslaugh, 2010; Vartanian, 2010).

However, the government institutions did not cover some of the data that was required for this study. Either the missing aspects were not being monitored or the data had not been made available to stakeholders. Another challenge with the secondary data sources was that there was no information on the research methods used and how the data was analysed (Vartanian, 2010).

3.4.2 Data sources

Similar to the approach used by Alexakis *et al.* (2012) data was collected from various data sources in order to create time series data that populated the DPSIR indicator framework for the study period and the study area

Primary data was used for determining the SST and Chlorophyll-a at different places in the BCLME. See section 3.6.2 for a description of how the analysis was done. The data was sourced from MFMR. Primary data was also used to determine changes made to the legislation from 2000 to 2010. The data was obtained from the Namibian Legal Assistance Centre (LAC).

The rest of the data was secondary data. The main sources of data included government reports such as the Ministry of Fisheries and Marine Resources (MFMR) Annual reports, the Ministry of Labour's National Labour Force Surveys (NLFS), the National Statistical Agency (NSA) and documents from the Benguela Current Commission (BCC). Documents from the BCC included the State of the Fish Stocks Report and studies based on Hake surveys. Additional supporting data was obtained from various literature sources. Some of the data was also obtained from the BCLME Strategic Action Programme Implementation (SAP IMP).

Data which was provided as national averages were used as given. On the other hand, calculation of annual averages was done for data published as monthly averages. Most of the data was available in both hard copy and in soft copies published on the websites of the institutions concerned.

3.5 *INDICATOR SELECTION*

An initial pre-selection of indicators to be analysed was made based on a review of literature. The final set of indicators used was determined after considering the availability of data. Some of the data of interest was not being monitored adequately or has not been made available to allow it to be used for research. Table 3.1 shows data collected. Some of the well-tested criteria for indicator selection used by the IndiSeas Work Group and other researchers were used as described by Shin *et al.* (2010). Hence, quantitative ecological indicators were used for the pressure, state and Impact indicators. The indicators had to be significantly sensitive to the ecosystem changes they were tracking. They also had to be measurable so that they would have values at different stages in the period being measured. In addition, the indicators needed to be based on established ecological processes that could be related to factors which led to degradation of the ecosystem. The characteristic of being suitable for communicating to a broad range of stakeholders including the general public was also considered for indicator selection. Hence, similar to

Shin *et al.* (2010), this study included fish length, landings and biomass. In addition, these scientific indicators were combined with corresponding non-scientific indicators for drivers and responses to complete the DPSIR framework. Table 3.1 shows the data that was collected after looking at this criterion and considering the data that was available.

Table 3.1 Data Collected

TYPE OF INDICATOR	**DATA COLLECTED**
Driver	1. From NSA reports, Unemployment and GDP contribution of Fisheries. 2. MFMR annual reports: Fish Catch values 3. Research article: TAC allocated versus Scientific advice
Pressure	1. From SAP IMP Project and MFMR: Catch per unit effort (CPUE), By-catch, and Sea Surface Temperature (SST). 2. MFMR annual reports – Statistics of Total Allowable Catches (TACs)
State	1. From MFMR annual reports: Primary production – Chlorophyll-*a*. 2. From BCC, FAO and MFMR: Biomass, Target species landings.
Impact	1. From BCC/ SAP IMP Project and MFMR: Changes in recruitment, Mean size structure.
Response	1. From MFMR annual reports: aquaculture production and Budget for Marine resources development. 2. From Ministry of Environment: Changes in size of Marine Protected Areas. 3. From Namibia Legal Assistance centre: Changes in relevant legislation.

3.5.1 Trophic levels of species indicators used in this study

In the selection of indicators, the first consideration was whether a potential indicator fitted into the required DPSIR category. The second consideration was whether data for the chosen indicator was available for the research period. If several indicators were available, the possibility of getting as much spread as possible in trophic levels was considered. Taking indicators from different trophic levels ensured that indicator species were considered from different levels in the food chain (Van der Lingen *et. al.*, 2006). Table 3.2 shows Trophic levels of some of the species used as indicators in this study.

Table 3.2 Trophic levels of species indicators used in this study. (Source: Watermeyer et al., 2008).

	Indicator	Trophic level
1	Chlorophyll-a	1#
1	Hake (*M. capensis*)	4.45
2	Hake (*M. paradoxus*)	4.11
3	Rock lobster	*
4	Sardines	2.65
5	Seals	4.58

**Trophic level not determined. #Trophic level of organisms with Chlorophyll-a that is detected by Satellite studies was assumed to be in trophic Level 1.*

3.5.2 Generation of fisheries and marine resources data in Namibia

Fisheries and marine resources data is collected by inspectors who are aided by observers. The data is analysed and released by different departments in the MFMR. The Directorate of Resources Management collects biological data, whilst the statistics section of the

Directorate of Policy, Planning and Economics collects data about rates of exploitation of marine resources. These departments have a role in ensuring that data is reliable and accurate. The data generated is used to generate reports published by the MFMR (Uahengo, 2013). This study used data in reports published by various relevant sources including the MFMR in order to populate the DPSIR indicator data required for exploring the recent trends in the ecosystem.

The State of the Fisheries Report, published by the Benguela Current Commission (BCC), is available in soft copy from the BCC website or in Hardcopy from the BCC offices in Swakopmund, Namibia. The BCC website (http://www.benguelacc.org/) also has information on activities being done to manage transboundary marine resources between Angola, Namibia and South Africa. The MFMR annual reports from 2003 to 2012 are available from the MFMR website, and are also available in hardcopy from the MFMR library. The Legal Assistance Centre website has details of legislation introduced in Namibia over the past decade. From the database, information was deduced on the changes in legislation in support of improving ecosystem health.

3.5.3 Sample size

Long periods have the advantage of showing the trends clearly from the major decline of the 1960s and the 1970s. However, for some of the indicators, data extending beyond 10 years was difficult to obtain. Therefore, the study focused on trends between 2000 and 2010. The BCLME extends from Port Elizabeth in the South, through the whole of Namibia's marine territory to the Northern boundary of Angola. See the map on figure 1.1. The study area is located in the central part of the ecosystem. Based on the measurement of the coast line from the Northern Boundary of the BCLME to the Southern boundary, the study area is more than 35% of the ecosystem. The benefit of using Namibia as a sample is that Namibia is only influenced by the Benguela current unlike South Africa which also has the influence of the Agulhas current (see fig 1.1). Upwelling, a key phenomenon influencing the behaviour and productivity of the ecosystem in the BCLME, is centred in Lüderitz in the Namibian territory (Heile & O'Toole, 2009).

3.5.4 Partnerships for data generation

The Ministry of Fisheries and Marine Resources (MFMR) is the main custodian of data pertaining to living marine resources. This data is analysed and published as part of MFMR annual reports. Other entities that are in partnership with MFMR also collected data. These entities include the Food and Agriculture Organisation (FAO), the Benguela Current Commission (BCC) and the BCLME SAP IMP project (Under the United Nations). Websites of FAO, BCC and MFMR have electronic copies of some of the published information. The BCLME SAP IMP project and BCC employed the researcher of this study as a Monitoring and Evaluation specialist. He was granted permission to use data generated by the projects for the purposes of this study. Published reports by BCC, FAO and MFMR already have this data. However, the SAP IMP project provided access to some of the data that was used to make the MFMR reports such as the state of the fish stocks raw data.

3.6 *DATA ANALYSIS*

Trends of the suite of indicators were determined for the period 2000 to 2010. Use of a shorter temporal range would have resulted in a much lower statistical confidence due to variance. Larger ranges would have been limited by availability of data for some of the trends. Plotting of the three-year moving averages removed random fluctuations and therefore improved the determination of trend by visual inspection. The study also used Least-squares regression analysis to determine trends in the indicators so that a decision could be made on whether there is an improvement in the ecosystem or whether the ecosystem is deteriorating. The possibility of using multivariate analysis to come up with a combined trend for all the DPSIR indicators was considered (Blanchard *et al.,* 2010). However, this idea was discarded because of the differences in fields of study and types of data that was generated from the indicators. Although most of the data was quantitative, some of the data such as trends in legislative changes or declaration of marine protected areas was qualitative.

3.6.1 Recalculation of annual averages

In this study, since secondary data sources were used, most of the data was originally collected on a daily or monthly basis and presented in published reports as annual averages. No attempt was made to seek the raw data of daily measurements and recalculate the annual averages. It was assumed that, since the study sought trends rather than absolute values of the various parameters, the available published data was reliable enough to use as it was. It was assumed that the authorities or organisations producing the data were collating and assessing data in a consistent way over time.

3.6.2 Determination of SST and Chlorophyll-a

SST and Chlorophyll-*a* were deduced from NOAA AVHRR satellite image data. The satellite images that covered the geographical extend of Namibia, from about 16°S latitude to about 28°S, were obtained from the MFMR annual report (Ministry of Fisheries and Marine Resources, 2011). Values for SST and Chlorophyll-a corresponding to latitudes 18°S, 21°S, 24°S and 27°S were determined by overlaying a grid on the satellite image. The values of SST or Chlorophyll-a concentration were then taken from the intersection points on the graph (Figure 3.1). The values obtained for latitudes 18°S, 21°S, 24°S and 27°S were averaged to give a representative value of SST for each year across these latitudes.

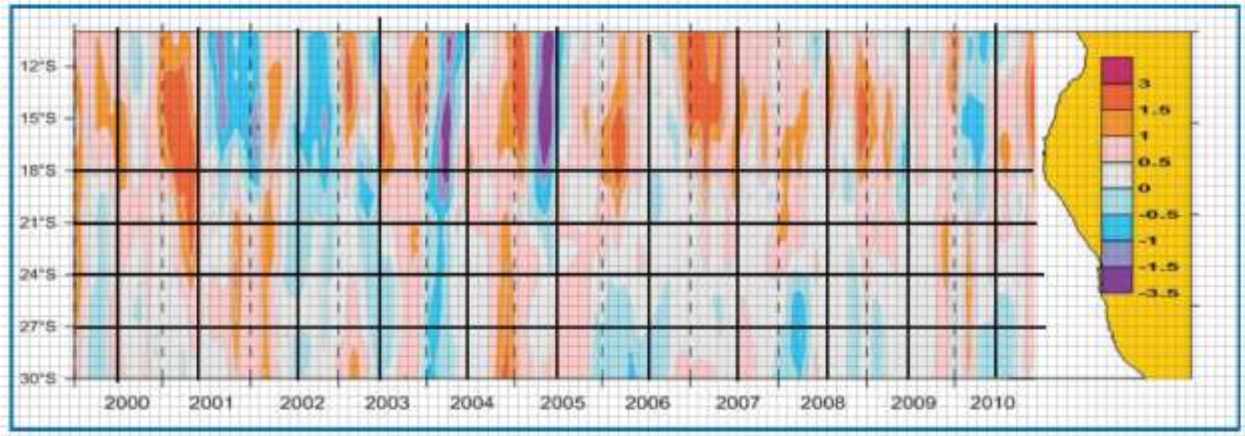


Figure 3.1 Determining average SST values from a satellite image of SST covering Namibia from 2000 to 2010 (Source: Ministry of Fisheries and Marine Resources, 2011).

3.6.3 Analysing trends in Driver indicators using regression analysis

Setting limit values that can be used to determine whether a trend is increasing, decreasing or neutral presents some challenges as noted by Eero *et al.* (2012). The challenge is increased by the fact that a key purpose of applying the DPSIR framework in this study is to be able to communicate to different stakeholders who may have different understandings of what to refer to as recovery or degradation trends. Eero *et al.* (2012) defined threshold values for transforming their indicator data into values of +1 for TRUE or “good” state and -1 for FALSE or “bad” state. The rest of the indicator values were fitted between these limiting values using a linear relationship. In this study, the same concept was used by assigning a state of recovery, continued degradation or neutral state. Determination of trends was made by assessing whether the slope of a linear plot of the indicator data was increasing or decreasing. The determination of the slope was first made by inspection of the three-year moving average trend line of the time series of interest. This moving average trend line made the curve smooth making it easier to see the direction the trend was going. Linear regression analysis was used to determine a value for the rate of increase or decrease of the slope.

Least squares regression analysis assumes a linear relationship and produces the line of best fit corresponding to equation 1:

Equation 1. Linear equation used to calculate the rate and direction of change of indicator values:

$$\boldsymbol{y} = \boldsymbol{sx} + \boldsymbol{b}$$

Where *x* is the time period (from 2000 to 2010 of the study),
y is the average value of the indicator for that year,
s is the slope and b is the intercept on the x- axis, and
R^2 measures the extent to which the data points fit into a straight line.

Therefore, in the regression analysis of indicators the value of slope *s* gave the average rate at which an indicator was changing. If *s* was negative it meant that the indicator property was decreasing and a positive value meant that the indicator property was increasing. Values with slope less than ± 1 needed more scrutiny as they had a tendency towards neutrality and could have been indicating that the ecosystem had maintained a steady state of neither increasing or decreasing in that particular parameter. Therefore, similar to Eero *et al.* (2012), regression analysis may be used to analyse the direction of changes in trends.

3.6.4 Use of a moving average trend line

The three-year moving average used in this study is useful for smoothing out the trend, making it easier to determine, by visual inspection, how a particular parameter is changing. The three-year moving average is calculated as illustrated below:

> If an indicator has values represented by the following letters a, b, c, d, e, f, g, h, I, j, and k for consecutive years the three-year moving averages would be (a+b+c)/3, (b+c+d)/3, (c+d+e)/3, (d+e+f)/3, and so on.

Therefore when these moving averages are plotted, the effect is to reduce sharp differences between adjacent values letting the analyst focus more on the overall trend. For an example of how a plot of the moving average compares with the plot of the original data set see Figures 4.3 and 4.4.

3.7 *RELIABILITY*

The Reliability of method and data based on secondary data sources could be tested by applying the basic principle of reliability testing in methods based on content analysis. The data collection is assumed to be reliable if there is a good agreement from data assessed by different researchers (Joffe, 2005: 216; Mayring, 2000). In this study sample data was compared with data collected and published by another researcher.

3.8 *VALIDITY*

Establishing the validity of the findings of this study was done by comparing the results of the findings with results of related research found in literature. Therefore, the results of research measuring ecosystem health of the BCLME were used to compare with results of this study.

CHAPTER 4: RESULTS

4.1 *INTRODUCTION*

Data was collected for each of the DPSIR indicator categories. The trend was determined by plotting the three-year moving average followed by linear regression analysis for the indicators. The combination of visual inspection and the gradient of the regression line were used to determine whether an aspect of the ecosystem was improving or further deteriorating.

4.2 *DRIVER INDICATORS*

4.2.1 TACs allocated compared to TACs recommended by scientists

In order to demonstrate the existence of drivers that are not based on science a comparison of TACs, allocated by the Minister of Fisheries and Marine Resources (MFMR), with TACs recommended by scientists was made. Some of the socio-economic drivers are analysed in the following sections. Data used was for hake fisheries obtained from a study by Paterson *et al.* (2013). As shown by Figure 4.1a, MFMR allocated TACs above recommended levels in 2004, 2005, 2009 and 2010. In general, MFMR has had a tendency to issue TACs above what was recommended by scientists. Figure 4.2b shows the regression analysis of the difference between the official allocated TAC's and the recommendations by scientists. The regression analyses of all the Driver indicators analysed are summarised in Table 4.2.

4.2.2 National unemployment as a driver for increasing the rate of exploitation of living marine resources

Table 4.1 shows the national unemployment Figures for Namibia which were published after national surveys done in 1997, 2000, 2004, 2008 and 2012. The surveys are done approximately every four years. The results show a small decrease in unemployment in 2004, followed by a sharp increase in unemployment in 2008.

Table 4.1 Employment Figures determined from the National Labour Force Surveys of 1997 to 2012

Year	1997	2000	2004	2008	2012
Unemployed %	34.5	33.8	36.7	51.2	27.4

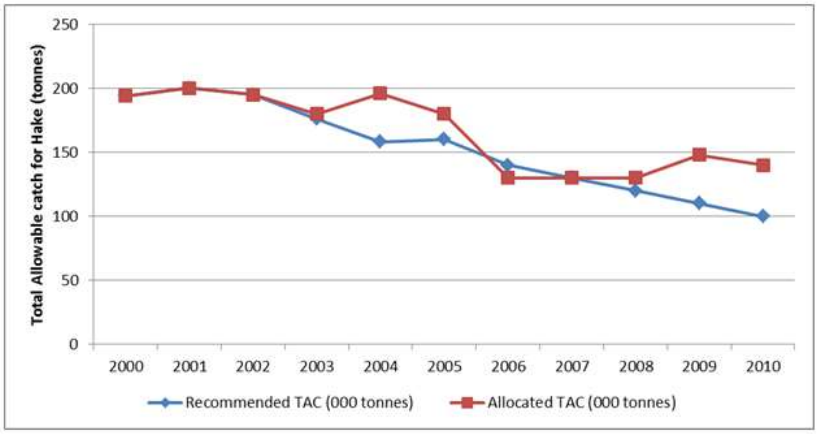
(Source: National Labour Force Surveys (NLF, 1997-2012)).

4.2.3 Catch value and contribution of fishing to GDP

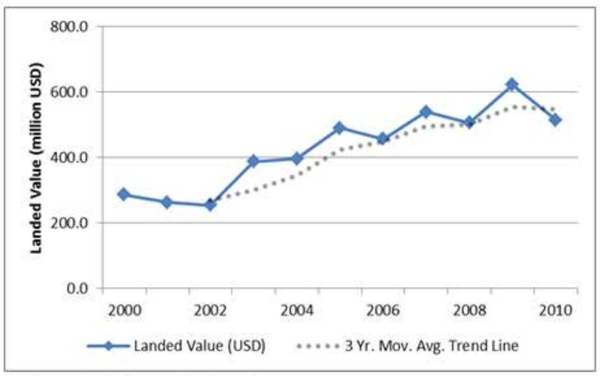
Figures 4.1b and 4.1c show that although the value of fish catches have been increasing, the net contribution to GDP has gradually decreased from values above 7% in the period just after 2000 to below 4% in 2010.

4.2.4 Analysing trends in Driver indicators using regression analysis

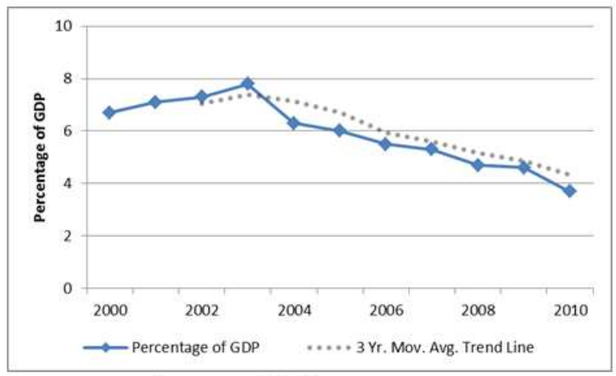
The regression analysis of Driver indicators shows that three out of the four indicators have a negative trend, meaning that the drivers analysed are leading to pressures that negatively affect the ecosystem. Figure 4.2 shows regression analysis of the indicators used. A summary of the results of regression analysis is found in Table 4.2. Therefore, the overall trend is that drivers are imposing a negative effect towards the health of the ecosystem.



a. Recommended vs allocated TAC for Hake



b. Fish landed value



c. Contribution of fisheries to GDP

Figure 4.1 Analyses of trends in Driver indicators.

4.3 *PRESSURE INDICATORS*

4.3.1 Catch per Unit Effort (CPUE)

CPUE values were analysed for hake and rock lobster. The moving average trend lines are shown in Figure 4.3 whilst the linear regression trends are shown in Figure 4.4. The CPUE for hake is generally increasing whilst the CPUE for lobster is decreasing.

4.3.2 Total Allowable Catch (TAC)

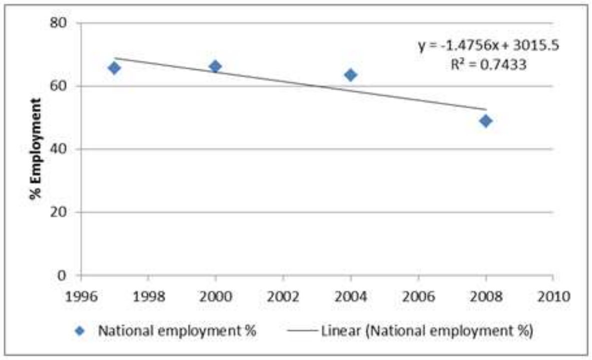
Figure 4.3c shows that the values of TACs for hake and Lobster were generally decreasing for the period of study. This means that the TACs were being used to reduce the quantities of these species that fishermen were allowed to catch. On the other hand visual inspection of the trend for Sardines in Figure 4.3 shows that the trend line is almost horizontal which means there was no significant decrease or increase. However, the regression analysis in Figure 4.4 shows a slight positive slope meaning that there is a slight overall increase in the volume of sardines that the authorities allowed fishing crews to catch over the study period. Table 4.3 shows a summary of the regression analyses of Pressure indicators used in this study.

4.3.3 Sea Surface Temperature (SST)

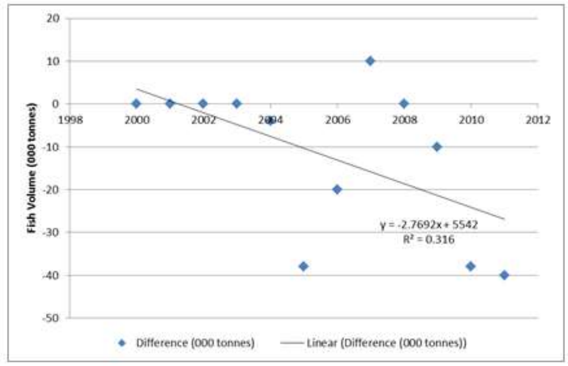
The moving average trend line and the linear regression trend line for SST show that the values of SST are fairly random on either side of the trend line. The result is that there is no overall increase or decrease in SST. The slope of the regression trend line has a value of 0.00, which confirms the fact that there is no overall increase or decrease in SST for the chosen period. See Figures 4.3e and Figure 4.5.

Table 4.2 Summary of regression analyses of Driver indicators

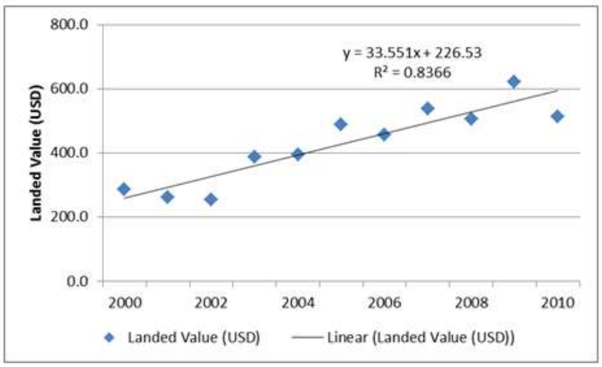
	Driver Description	**R^2**	**Slope S**	**Impact on Ecosystem**
1.	Difference between recommended and allocated TACs	0.31	-2.77	-Ve
2.	Landed value of fish	0.84	+33.55	+Ve
3.	Contribution of fisheries to GDP	0.83	-0.35	-Ve
4.	National Employment	0.74	-1.48	-Ve



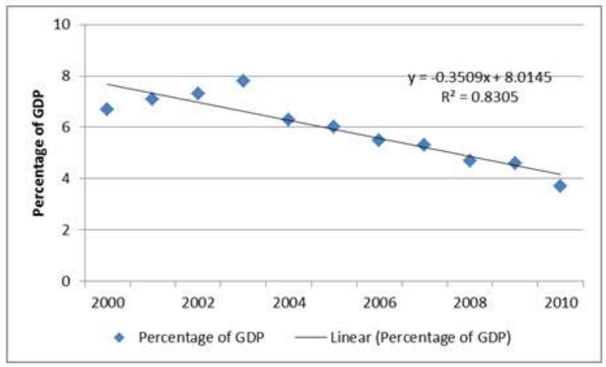
a. National employment



b. Difference: Recommended minus allocated TACs



c. Landed value/USD



d. Percentage of GDP

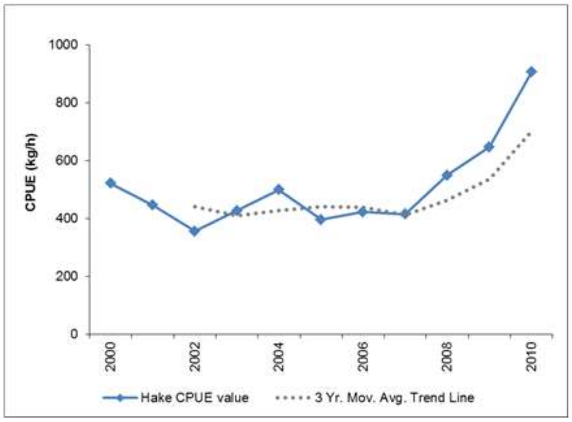
Figure 4.2 Regression analyses of Driver indicators.

4.3.4 By-catch

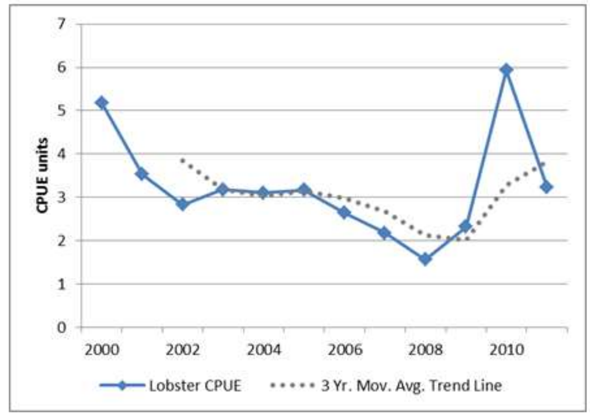
The trend line in Figure 4.3f shows that By-catch volumes were decreasing during the research period. Similarly, linear regression in Figure 4.5f shows a negative slope value. Therefore, the negative pressure on the ecosystem, emanating from the catching of non-quota species, was decreasing in the period from 2000 to 2010.

4.3.5 Overall trend in Pressure indicators

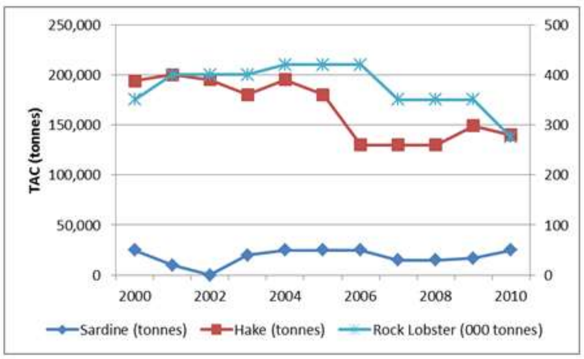
An analysis of the trends for Pressure indicators is shown in Figure 4.3, Figure 4.4 and Figure 4.5, and summarised in table 4.3. The overall trend depicted by Pressure indicators is positive since there were four positive trends, one negative trend and two neutral trends.



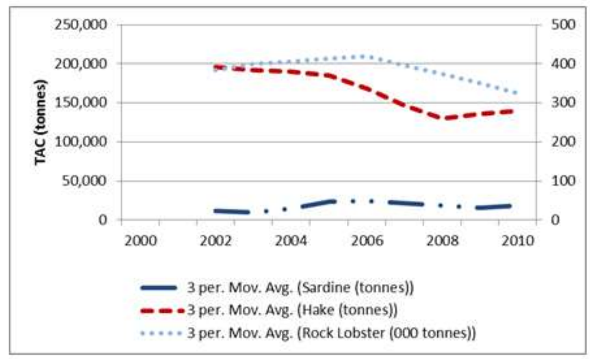
a. Hake CPUE



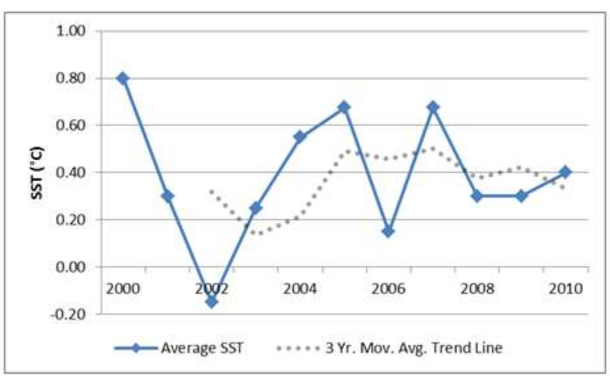
b. Lobster CPUE



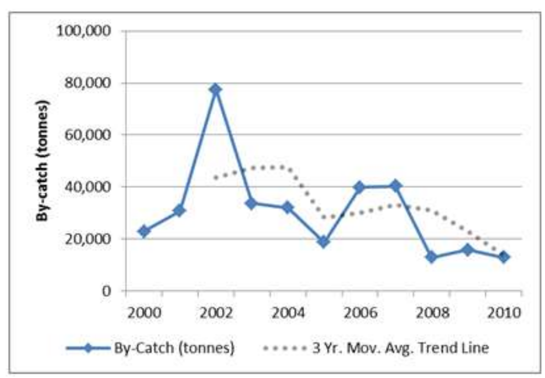
c. TACs for Hake, Sardine and Rock Lobster



d. Hake, Sardine and Rock Lobster TAC Trend lines

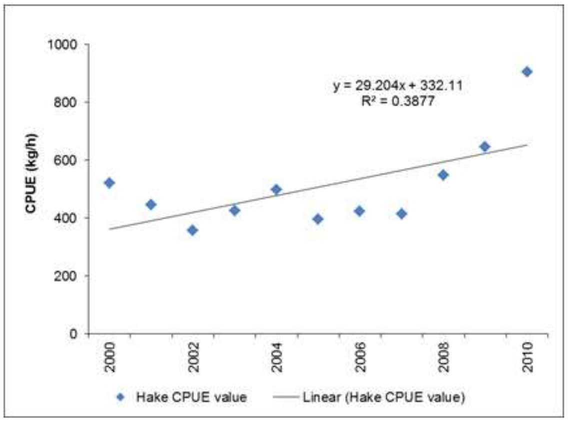


e. Average SST along 18°, 21°, 24° and 27° latitude

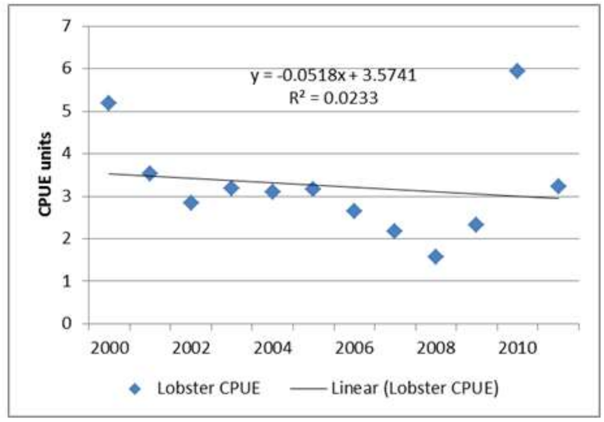


f. Trend in by-catch

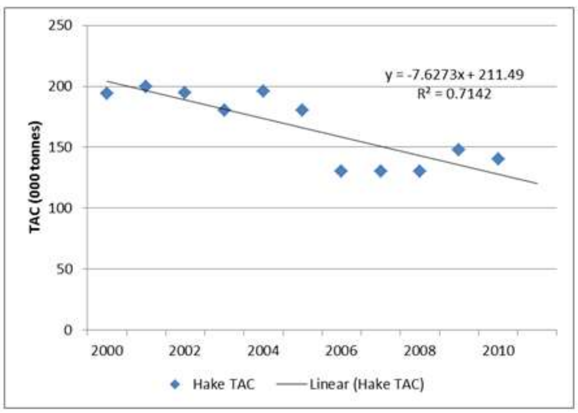
Figure 4.3 Analyses of Pressure indicators including moving average trends.



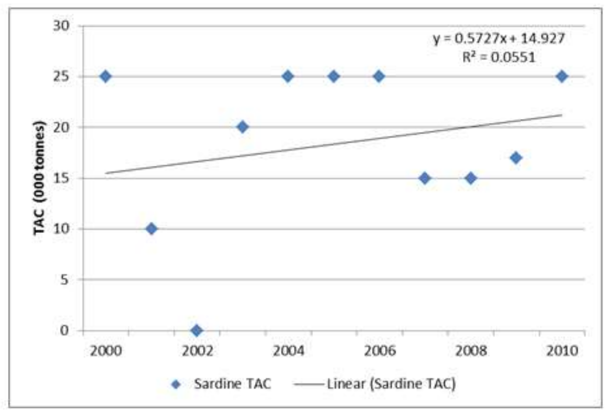
a. Hake CPUE



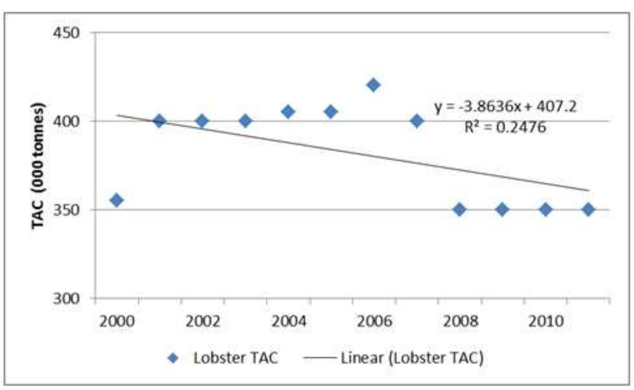
b. Lobster CPUE



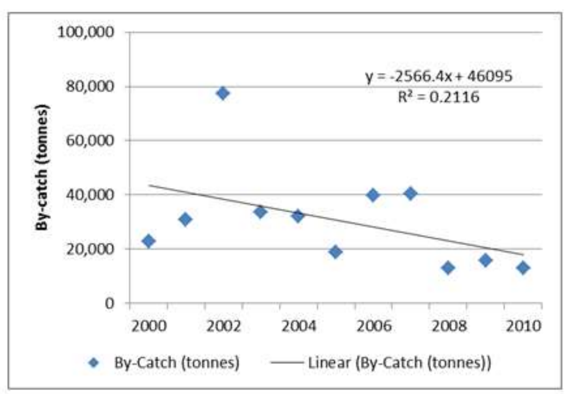
c. Hake TAC



d. Sardine TAC



e. Lobster TAC



f. By-catch

Figure 4.4 Regression analyses of Pressure indicators.

Table 4.3 Summary of regression analyses of Pressure indicators

	Pressure indicator Description	R^2	Slope S	Impact on Ecosystem
1.	Hake CPUE	0.39	+29.2	+Ve
2.	Lobster CPUE	0.02	-0.05	Neutral (slightly –Ve)
3.	Hake TAC	0.71	-7.62	+Ve*
4.	Sardine TAC	0.29	+0.57	-Ve
5.	Rock Lobster TAC	0.25	-3.86	+Ve
6.	By-catch	0.21	-2566.4	+Ve
7.	Average SST	0.00	0.00	Neutral

***Note:** Decreasing TACs have a positive impact on recovery of fish stocks as fishing crews are allocated permission to extract less fish.

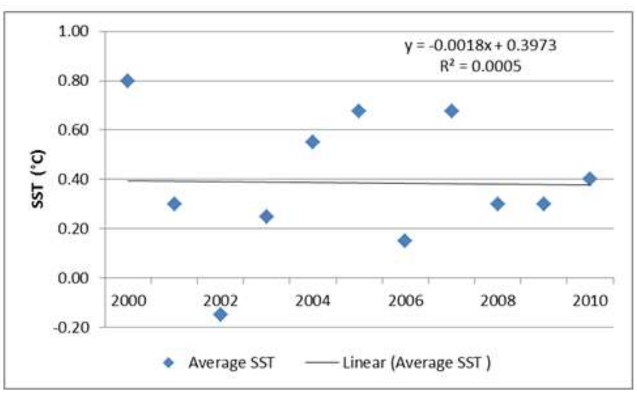


Figure 4.5 Regression analysis of Sea Surface Temperature (SST).

4.4 *STATE INDICTORS*

4.4.1 Primary production - Chlorophyll-a

Figure 4.7a shows that Chlorophyll-a has a trend that is almost horizontal, meaning that it is neither increasing nor decreasing significantly. In Figure 4.8a, the slope from the linear regression analysis is almost zero, which agrees with analysis by visual inspection. Therefore, overall there seems to be no significant shift in Chlorophyll-a concentration. However, there is a significant drop in concentration in 2002. This value is the lowest value in Chlorophyll-a concentration for the period under study.

4.4.2 Catch

4.4.2.1 Catches for hake and rock lobster

The catches for hake and rock lobster gradually decreased during the period of the study. As shown by Figures 4.7 and 4.8, the trends that show a decline in catch volumes are also confirmed by the values of the slopes on the regression analyses. When considered together with biomass (analysed in section 4.4.3) it can be seen that the decrease in catch for hake occurs at a time when biomass for hake is increasing. Therefore the stock was recovering. On the other hand, Lobster stocks were deteriorating since lobster biomass and catches were showing a decline.

4.4.2.2 Catch for sardines

Sardine catches had significantly low values in 2002 and 2006. However, the rest of the Figures seem to have a slight increasing trend. Figure 4.7c shows the trend in the moving average of the sardine catch volume. Similarly, Figure 4.8c shows the regression analysis of sardine catch volumes. The slope of the regression analysis is 0.22 which means there is a very slight increase.

4.4.2.3 Seals Harvested

The overall trend for seals harvested shows that the numbers of seals harvested is increasing. The moving average trend line is shown in Figure 4.7e and the regression analysis is shown in Figure 4.8e. When considered together with the fact that the population of seal pups at weaning is increasing, as shown in section 4.5.1, the increasing harvests may be viewed as an indication of recovery and growth of seals and possibly other tertiary consumers.

4.4.3 Biomass

The biomass of rock lobster has a decreasing trend whilst that of hake has an increasing trend. The decreasing trend in rock lobster shows further degradation of some species whilst the increasing trend for hake suggests recovery of hake and other species. Figure 4.6 and Figure 4.7f show the moving average trends for biomass of lobster and hake respectively. Figure 4.8f and Figure 4.9 show the trend analysis.

4.4.4 Summary of Regression analysis

Seals harvested and hake biomass show clear positive trends indicating that some species may be recovering from previous degradation. Chlorophyll-a and sardine catch are almost neutral with slope values of less than 0.5. However, hake catch, lobster catch and lobster biomass show negative trends that support the supposition that the ecosystem is further deteriorating. Moving average analyses of the State indicators are shown in Figure 4.6 and

Figure 4.7. Regression analyses are shown in Figure 4.8 and Figure 4.9 and a summary of the regression analysis of the State indicators is shown in table 4.4. The overall trend for State indicators is almost neutral.

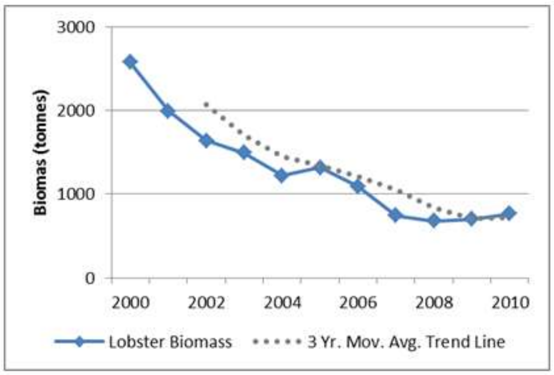


Figure 4.6 Moving average trend line for rock lobster.

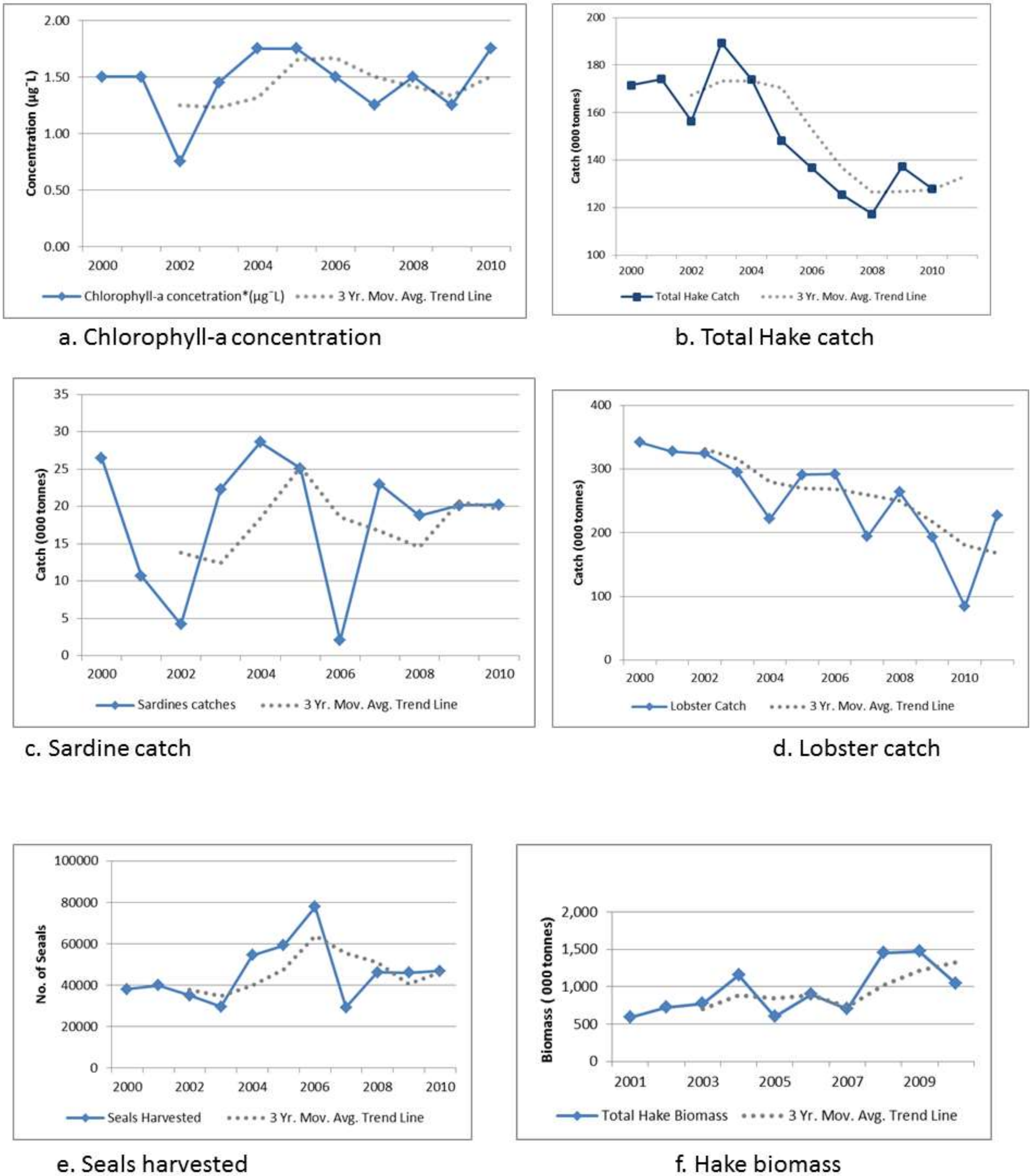
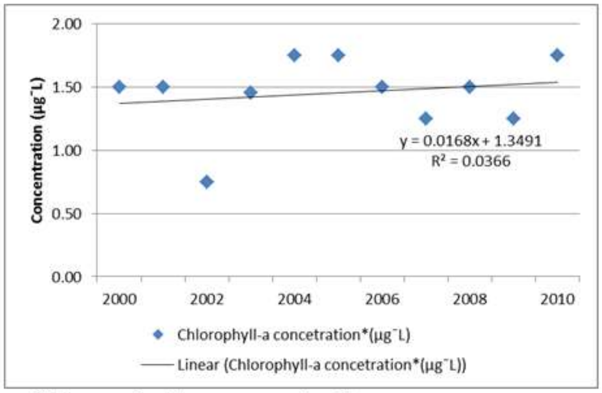
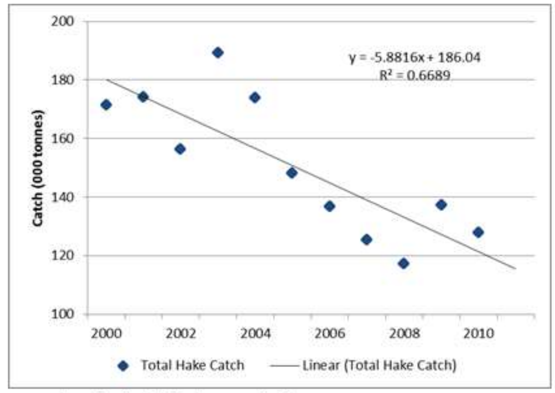


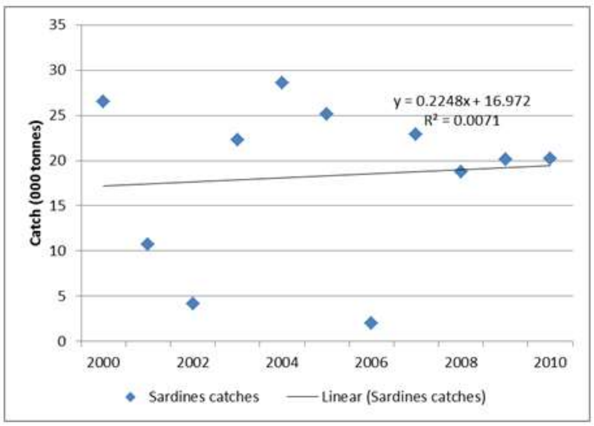
Figure 4.7 Moving average trend line analyses for State indicators.



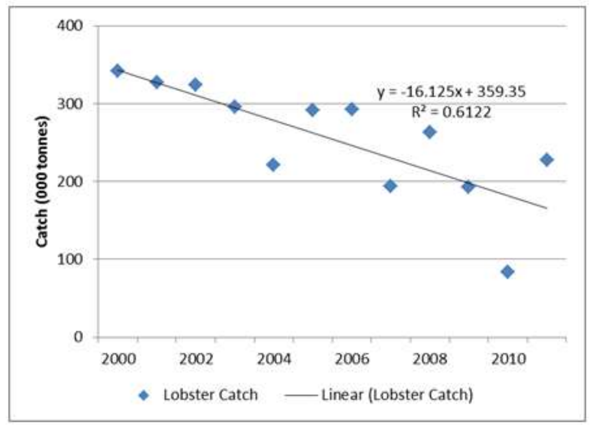
a. Chlorophyll-a concentration



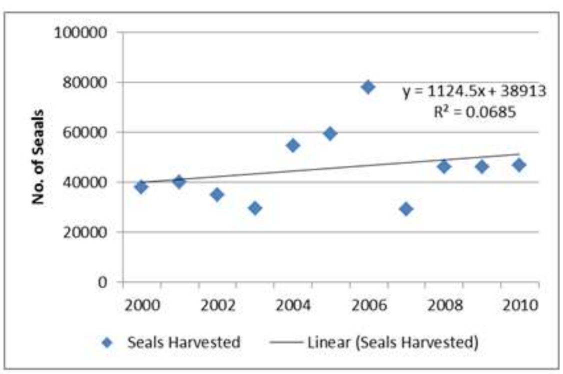
b. Total Hake catch



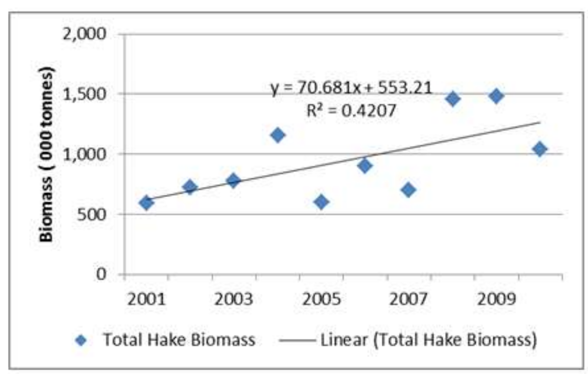
c. Sardine catch



d. Lobster catch



e. Seals harvested



f. Hake biomass

Figure 4.8 Regression analyses of State indicators.

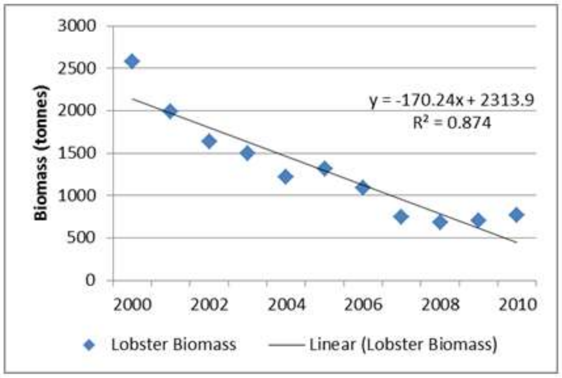


Figure 4.9 Regression analysis of Lobster biomass.

Table 4.4 Summary of regression analyses of State indicators

	State indicator Description	R^2	Slope S	Impact on Ecosystem
1.	Chlorophyll-a concentration	0.04	+ 0.02	Neutral (slight positive)
2.	Total Hake Catch	0.67	-5.88	-Ve
3.	Seals Harvested	0.07	+1124.5	+Ve
4.	Lobster Catch	0.10	-16.13	-Ve
5.	Sardine Catch	0.01	+0.22	Neutral (slight positive)
6.	Hake Biomass	0.42	+70.68	+Ve
7.	Lobster Biomass	0.87	-170.24	-Ve

4.5 *IMPACT INDICATORS*

4.5.1 Seal pups at weaning

The number of seal pups at weaning gradually increased in the period being studied. Figure 4.10a shows that although the population of pups was increasing, the increase was characterised by peaks and dips. The regression analysis in Figure 4.11a produced a linear regression line with a positive gradient (+1515.4).

4.5.2 Spawning biomass of sardines

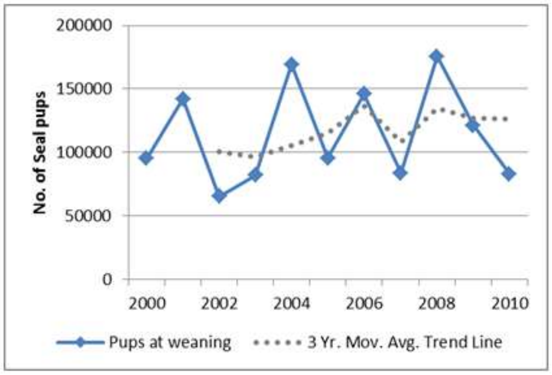
The spawning biomass of sardines showed a decreasing trend. See Figures 4.10b and 4.11b. This means less and less sardines reached the reproductive stage over the research period.

4.5.3 Average length of *M. capensis* and *M. paradoxus* (hake) species

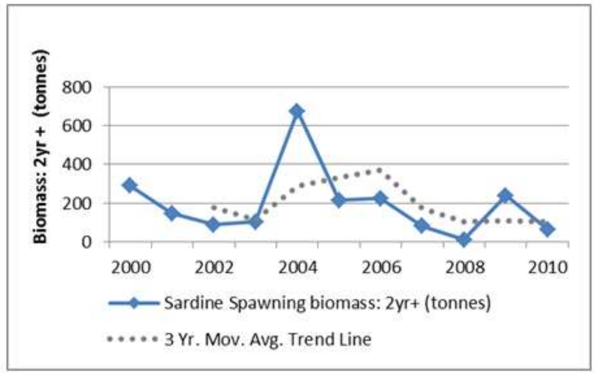
Figures 4.10c shows the trend in average length of the two hake species. The two species showed an increasing average length. Although the average length moved from 22 cm to 26 cm for *M. capensis* and from 24 cm to 33 cm for *M. paradoxus*, the slopes of the regression analysis were only slightly positive. See Figure 4.11c.

4.5.4 Overall trend of Impact indicators

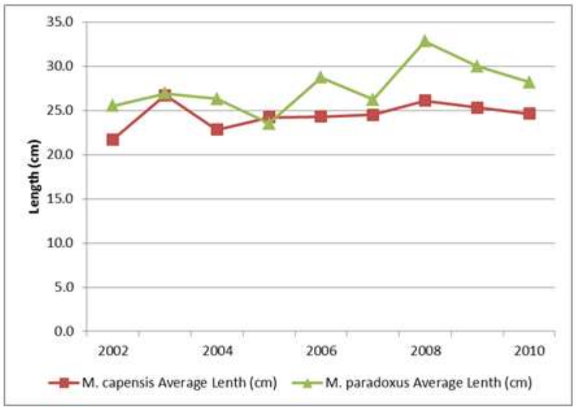
The overall trend seem to be leaning towards some improvement in the ecosystem health with two of the indicators showing positive trends and another one close to neutral showing a slight positive trend. The fourth indicator shows a negative trend. Therefore the overall trend on Impact indicators is positive. Table 4.5 shows a summary of the regression analysis. Figure 4.10 and Figure 4.11 show the trends for Impact indicators.



a. Seal pups at weaning



b. Spawning biomass of Sardines

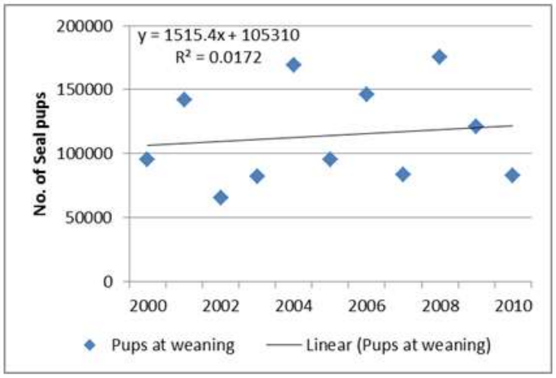


c. Average size of Hake species

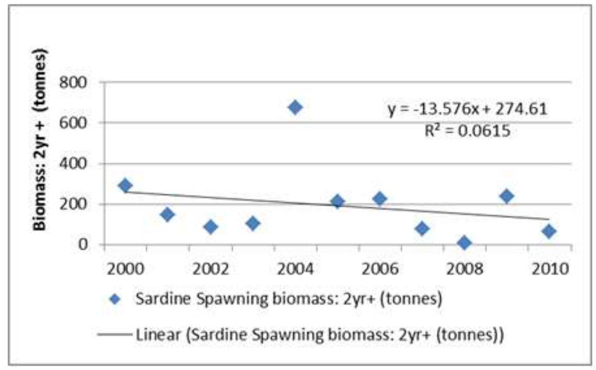
Figure 4.10 Analyses of trends in Impact indicators using moving averages.

Table 4.5 Summary of regression analyses of State indicators

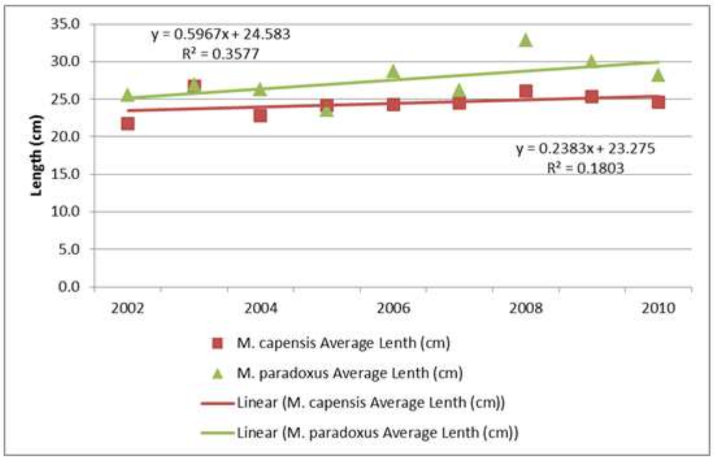
	Impact indicator Description	**R^2**	**Slope S**	**Impact on Ecosystem**
1.	Seal pups at weaning	0.02	1515.4	+Ve
2.	Spawning biomass of Sardine	0.06	-13.58	-Ve
3.	Average length of *M. capensis* (Hake) species	0.18	+0.24	Neutral (slight +Ve)
4.	Average length of *M. paradoxus* (Hake) species	0.36	+0.60	+Ve



a. Seal pups at weaning



b. Spawning biomass of Sardines



c. Hake average size

Figure 4.11 Regression analyses of Impact indicators.

4.6 RESPONSE INDICATORS

4.6.1 MFMR Operations and Development budgets

Figures 4.12a shows that the MFMR development budget and the operations budget were increasing between 2000 and 2010. This gradual increase in budgets pointed to increasing magnitude of responses that addressed the challenges faced by ecosystem health. Similarly, Figure 4.12c shows positive trends in the linear regression analysis of the budgets.

4.6.2 Number of fishing vessels inspected

The number of fishing vessels inspected decreased during the period assessed. The inspections decreased from over 300 per year to just above 100 per year between 2000 and 2010. This shows that the response to the state of the ecosystem was decreasing. Figure 4.12b and Figure 4.12d show analyses of fishing vessels inspected.

4.6.3 Marine Protected Areas

The restriction of certain activities in order to protect particular species or habitats may be an effective way of allowing the ecosystem to recover. In the period 2000 to 2010 a significant occurrence for the BCLME in Namibia was the gazetting of the Namibian Islands Marine Protected Area (NIMPA) in 2009. The Marine Protected Area (MPA) covers approximately 400 km in length along the Namibian coast and about 30km in width. The MPA covers breeding grounds and habitats of sea birds, rock lobster and some fish species (Ministry of Fisheries and Marine Resources, 2009). The areas covered by MPAs could not be given as a trend as the first MPA was introduced in 2009 and there are no other MPAs declared in the research period.

4.6.4 Legislative changes that support the recovery of the marine ecosystem

Table 4.6 shows laws that were enacted in Namibia which support the recovery of the ecosystem. The laws included creating the legislative environment for aquaculture, protecting the ecosystem from pollution and creating marine protected areas to protect some sensitive marine habitats.

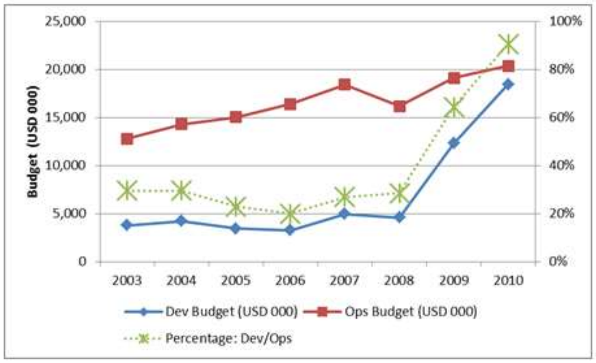
4.6.5 Summary of Response indicators

Table 4.7 shows a summary of the impact of the ecosystem responses analysed. The overall trend is positive. Three of the indicators show a positive response.

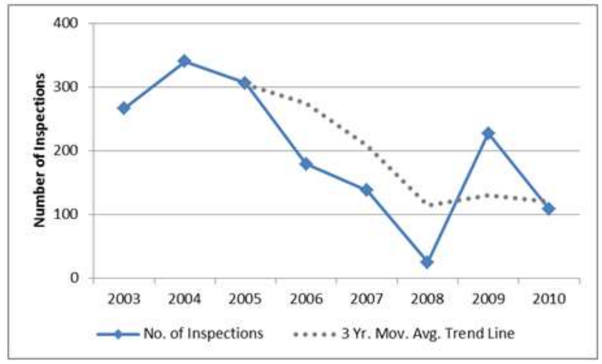
Table 4.6 Legislation which supports the recovery of the ecosystem

YEAR	Legislation or policy	Title/ Reference	Comment
2010	-	-	
2009	Namibian Islands' Marine Protected Area (NIMPA)	Government Gazette notice no. 4210 of 16 February 2009)	Protects sensitive habitats of living marine resources
2008	-	-	
2007	Environmental Management Act	No. 7 of 2007	Protection of the environment including requirement for environmental assessments and planning
2006	-	-	
2005	-	-	
2004	Water Resources Management Act	No. 24 of 2004	Protection of water resources from pollution
2003	Inland Fisheries Resources Act	No. 1 of 2003	Promotes development of inland fisheries
2002	Aquaculture Act	Act no.18 of 2002	Promotes the development of aquaculture
2001	-	-	
2000	Marine Resources Act	No. 27 of 2000	Regulates the exploitation of marine resources

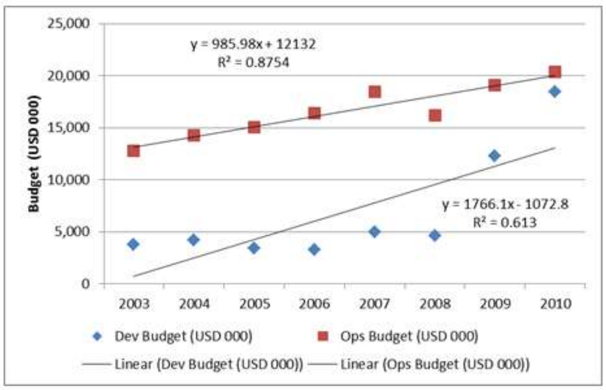
(Source: Legal Assistance Centre, 2014)



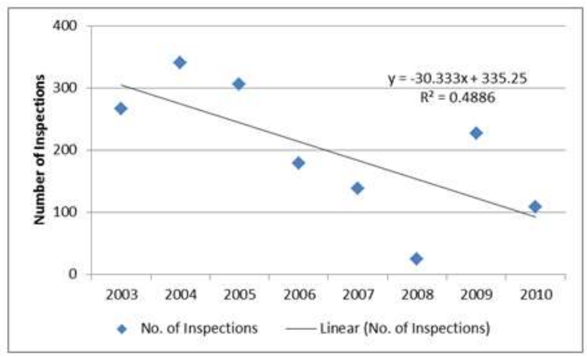
a. MFMR Budget



b. Number of fishing vessels inspected



a. MFMR Budget



b. Fishing vessels inspected

Figure 4.12 Analyses of Response indicators.

Table 4.7 Summary of analyses of Response indicators

	Response indicator Description	R^2	Slope S	Impact on Ecosystem
1.	MFMR Development Budget	0.61	+1766.1	+Ve
2.	MFMR Operations Budget	0.88	+985.98	+Ve
3.	No. of fishing vessel inspections	0.49	-30.33	-Ve
4	Legislation which supports the recovery of the ecosystem	*	*	+Ve

*Regression analysis not done because the data is not quantitative but impact is seen as positive.

Table 4.8 Summary of trends of the indicators in the different DPSIR categories

	Driver Description	Slope S	Impact on Ecosystem	Overall trend
1	Difference between recommended and allocated TACs	-2.77	-Ve	-Ve
2	Landed value of fish	33.55	+Ve	
3	Contribution of fisheries to GDP	-0.35	-Ve	
4	National Employment	-1.48	-Ve	
	Pressure Indicator Description	**Slope S**	**Impact on Ecosystem**	**Overall trend**
1	Hake CPUE	29.2	+Ve	+Ve
2	Lobster CPUE	-0.05	-Ve	
3	Hake TAC	-7.26	+Ve	
4	Sardine TAC	0.57	-Ve	
5	Rock Lobster TAC	-3.86	+Ve	
6	By-catch	-2566.4	+Ve	
7	Average SST	0	Neutral	
	State Indicator Description	**Slope S**	**Impact on Ecosystem**	**Overall trend**
1	Chlorophyll A concentration	0.02	Neutral (slight positive)	Mixed
2	Total Hake Catch	-5.88	-Ve	
3	Seals Harvested	1124.5	+Ve	
4	Lobster Catch	-16.13	-Ve	
5	Sardine Catch	0.22	Neutral (slight positive)	
6	Hake Biomass	70.68	+Ve	
7	Rock Lobster Biomass	-170.24	-Ve	
	Impact Indicator Description	**Slope S**	**Impact on Ecosystem**	**Overall trend**
1	Seal pups at weaning	1515.4	+Ve	+Ve
2	Spawning biomass of Sardine	-13.58	-Ve	
3	Average size of *M. capensi* s (Hake) species	0.24	Neutral (slight +Ve)	
4	Average size of *M. paradoxu* s (Hake) species	0.6	+Ve	
	Response Indicator Description	**Slope S**	**Impact on Ecosystem**	**Overall trend**
1	MFMR Development Budget	1766.1	+Ve	+Ve
2	MFMR Operations Budget	985.98	+Ve	
3	No. of fishing vessel inspections	-30.33	-Ve	
4	Legislation which supports the recovery	*	+Ve	

*Regression analysis was not done because the data was not quantitative but impact was seen as positive.

4.7 *OVERALL TRENDS*

Table 4.8 is a summary of all trends of the indicators analysed in this study. It can be seen that pressure, impact and Response indicators are showing positive results suggesting that the ecosystem health is recovering. On the other hand, drivers are showing that there are factors exerting a negative influence on the ecosystem. Thirdly, State indicators have an almost balanced representation from positive and negative trends.

CHAPTER 5: DISCUSSION

5.1 *DRIVER INDICATORS*

The analysis that compares the TACs allocated by MFMR with what the government scientists had recommended demonstrates that the Minister was not only influenced by scientific knowledge when allocating TAC's. The results showed a pattern in which the Minister allocated larger quotas than recommended (Paterson *et al.,* 2013). Some of the socio-economic factors that may have been considered are discussed below. This analysis confirms the suggestion by Shin and Shannon (2010) that some of the pressure on the ecosystem comes from socio-economic factors therefore there is a need to combine scientific indicators with socio-economic indicators.

5.1.1 Unemployment figures and the determining of TACs

The analysis of TACs showed that the determination of fishing quotas by MFMR was not based on scientific advice on the status of the fish stocks only, but that other non-science based factors influenced how closely the fisheries authority stuck to scientific advice. In Figure 4.1, the TACs recommended by scientists for hake are compared to TACs that were eventually authorised by the Minister of Fisheries (Paterson *et al.*, 2013). One of the key factors driving the TACs up to levels above what was recommended by scientists could have been the pressure from rising unemployment. Unemployment data in Namibia has been published approximately once every four years in National Labour Force Surveys (NLFS, 2012) (See Table 4.1). The NLFS report of 2000 showed that unemployment was decreasing, but in 2004 the NLFS report showed that unemployment had increased from 33.8% to 36.4%. Hake TACs for 2004 and 2005 were issued at 40 000 tonnes and 20 000 tonnes above the recommended TAC respectively. In 2006 and 2007 the TACs were following the recommendations of the scientists. However, after the labour survey of 2008 that showed that unemployment had risen from 36.4% in 2004 to 51.2 % in 2008, there were issues of TACs in 2009, 2010 and 2011 that were significantly above recommended

TACs. The TACs for these three years were each approximately 40 000 tonnes above scientific recommendations, which on average, is almost 40% above recommendations. This analysis seems to be in line with study by De Jonge *et al.*(2012) who suggested that drivers could arise because of the need to create employment.

The 2008 unemployment figure was higher than it ought to have been because of inadequacies of the Namibian Labour Force Survey (NLFS, 2008). A key shortcoming was the failure to include some categories of employment in agriculture, thus leading to the number of employed people being understated (Mwinga, 2008). The NLFS of 2012 improved on the methodology that was used in 2008 and included unemployment categories that had been omitted. The unemployment figure of 2012 was therefore about half the figure found in 2008 (NLFS, 2012). The overstating of the unemployment level figure is likely to have given additional pressure to policy makers to try and create more jobs. This assumption is in line with the significantly higher TACs allocated in 2009 and 2010 compared to what was recommended by scientists.

Paterson *et al.* (2013) also noted that pressure to increase TACs above what was recommended is also exerted by the representatives of the fishing industry. The fishing industry has commercial interests which include maximising profit from fishing and maintaining or improving labour conditions.

5.1.2 Contribution of Namibian fisheries to the economy

De Jonge *et al.* (2012) noted that the need to increase revenue from fishing leads to increase in fishing quotas. The trend in the contribution that fishing made to GDP in Namibia shows that fishing contributed less and less over the period under review (See Figure 4.1c). It is possible that the need to increase fishing may have also been driven by the declining contribution of fishing to the GDP of Namibia.

The significant increase in landed value was a driver that reduces pressure on the ecosystem (Figure 4.1b). How much catch value reduces pressure on individual fishing operators also depends on the corresponding increase in operating costs of the operators.

However, the inflation rate during the period averaged above 6%, which may also have reduced the effect of the rise in catch value (See Figure 5.1 for the trend in Namibia's inflation). In general, the economic factors of average inflation above 6% and a decreasing contribution to GDP negated the increase in nominal value of landed catch.

Figure 5.1 Changes in inflation for Namibia from 2000 to 2010. (Source: Bank of Namibia. Retrieved March 18, 2014 from http://www.tradingeconomics.com/namibia/)

5.1.3 Regression analysis of Driver indicators

In the regression analysis, a slope of positive (+ve) gradient for positive changes meant that the ecosystem is improving and a slope of negative (–ve) gradient meant the ecosystem is worsening. A horizontal line, gradient zero, meant that there was no change. R^2 values showed how well the data points fitted onto the regression analysis straight line. The best fit corresponded to a value of 1 and the worst fit corresponded to a value of 0. The use of regression analysis to determine trend in indicators was similar to the study by Sydeman (2014).

5.1.4 A majority of indicators showing similar trend

Three of the four indicators analysed showed that driving forces were exerting negative pressures that may lead to further degradation of the large marine ecosystems. The exception is landed value of fish which had a positive trend.

Since the majority of the indicators have negative values, the overall trend in the Driver indicators was negative. Because of competing trends from different indicators, it may be necessary to come up with a more complicated system of combining the indicators to improve the DPSIR framework (Gregory *et al.*, 2013).

5.2 *DISCUSSION OF PRESSURE INDICATORS*

5.2.1 CPUE

The fact that CPUE for hake was increasing whilst that of rock lobster was reducing may be because pressure varies on different species. Rock lobster was experiencing increasing pressure whilst hake was experiencing less pressure. The increasing CPUE for hake may have encouraged the fishing industry to lobby for higher quotas of hake (Field *et al.*, 2013). This may be because the realisation of more fish being caught compared to similar effort in previous years suggested that the stocks were increasing even though the biomass of the stock may not have improved significantly (see Figure 4.7f). Data was not available for testing the trends in CPUE for more species. It would be useful in future studies to get CPUE values of many species so that the overall trend may be deduced with increased level of certainty. For the purpose of this study the trend in CPUE was adjudged to be neutral because of the opposite trends in the two indicators analysed.

5.2.2 TACs

The analyses of the TACs for hake, sardine and rock lobster showed that there is a reduction in pressure on the ecosystem due to reductions in TACs. However, this needs to be put in the context of the discussion in Section 5.1.1 above, with regard to the difference between the TACs suggested by scientists and the TACs which were allocated. Although the trends of TACs were decreasing, the TACs issued were generally above what scientists deemed to be optimal for the recovery of the ecosystem. Therefore, there were lower TAC volumes in spite of pressure from socio-economic factors. Therefore, the trend in TACs contributes to improvement of the ecosystem.

Table 5.1 Comparison of catches with TACs

Hake

Year	**Catch (t)**	**TAC (t)**
2000	171	194
2001	174	200
2002	156	195
2003	189	180
2004	174	196
2005	148	180
2006	137	130
2007	126	130
2008	117	130
2009	137	148
2010	128	140

Rock Lobster

YEAR	**Catch (t)**	**TAC (t)**
2000	342	355
2001	327	400
2002	324	400
2003	295	400
2004	222	405
2005	291	405
2006	292	420
2007	194	400
2008	264	350
2009	193	350
2010	84	350

(Sources: Ministry of Fisheries and Marine Resources, 2006; Ministry of Fisheries and Marine Resources, 2011)

The TAC values were consistently above the catch values in the period analysed. This means that although authority was given to extract fish resources, the fisheries industry did not manage to reach the limit of their allocations (See Table 5.1). On average, the actual catches were within 1% of what was recommended by scientists. Hence, allocation of TACs reduced pressure on the ecosystem, and this may have encouraged recovery of the ecosystem. This conclusion is in line with the observation by Edoff (2012) that Namibia has a good system of managing the level of fishing through using TACs.

5.2.3 Sardine

Sardine resources were highly reduced over time. As a result, the TACs were very low (below 25 000 tonnes per year) for the period between 2000 and 2010. In 2002 the TAC for sardines zero tonnes. Given the severity of how the sardines were affected with overfishing in previous years, it may possibly have been better for the authorities to continue with a TAC of zero beyond 2002. However, as indicated in the section on drivers, there were other socio-economic pressures that create the need to keep a certain level of exploitation of fish resources. The MFMR annual reports refered to the importance of maintaining various export markets for sardine (Ministry of Fisheries and Marine Resources, 2011). Associated with this need to maintain the export markets would be the need to maintain the infrastructure and skills required for processing the sardines into the preferred products for the different markets.

5.2.4 SST

The trends for SST showed that there was no overall increasing or decreasing trend in SST for the period analysed. This trend seems to downplay the environmental effects related to warming events. However, literature suggests that significant amounts of the variations in the BCLME were due to environmental effects. In particular, SST and wind stress influence upwelling and the resultant changes in productivity and behaviour of stocks (Kreiner *et al.,* 2011). The method used to quantify changes in SST in this study averaged the SST values across four locations from latitudes 18°S, 21°S, 24°S and 27°S. It is possible that significant localised changes in SST may have been averaged out. The observation by De young *et* *al.*(2011) that there has been a general increase in SST near Walvis Bay in Namibia supports this possibility.

5.2.5 Sub-zero SST trough in 2002

Having noted the lack of major warming or cooling events in the study period, it may be of interest to further investigate the temperature variation from one year to the next. For example, the SST changed from 0.8°C to -0.15°C between 2000 and 2002. The high value of SST in 2000 may have been linked to a warming event that may have affected primary production and therefore the overall production of the ecosystem.

The sub-zero SST value in 2002 had the lowest SST value. It was the only SST value below zero. It corresponded with the lowest values for Chlorophyll-a, hake catch and sardine catch. It also corresponded to the lowest number of seal pups harvested (and the highest By-catch figures). A possible explanation could be environmental effects resulted in a lowering of temperature and lower productivity throughout the ecosystem.

5.2.6 By-catch

The trends in By-catch showed that there was decreasing pressure on the ecosystem since less non-quota species were being caught. However, Pitcher & Cheung (2013) give a word of warning on the interpretation of By-catch. There is possibility that the reduction of By-catch might be a reflection of the general reduction of catch volumes of the major commercial species. An analysis of total fish catch under State indicators confirms that the total fish catch came down from about 600 000 tonnes in 2000 to just over 350 000 tonnes by 2010. However, an analysis of the proportion of By-catch to the total fish harvested in Figure 5.2 shows that By-catch as a proportion of total catch was decreasing even though it started by increasing significantly before 2003. Therefore, the decrease in By-catch was an indication of practices that led to the recovery of the ecosystem.

Similar to suggestions by Kleisner *et. al.,* (2013), further research could also ascertain the biomass of the species from which the By-catch is obtained to determine whether the biomass is increasing. If the biomass is increasing it means that the reduction in By-catch is reflecting an improvement in ecosystem health.

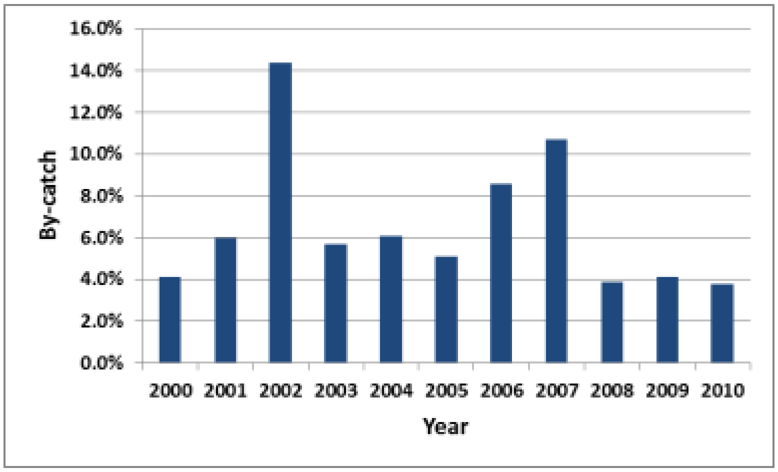


Figure 5.2 Proportion of By-catch to total fish harvest. (Sources: Ministry of Fisheries and Marine Resources, 2006; Ministry of Fisheries and Marine Resources, 2011).

5.2.7 Overall trend in Pressure indicators

The overall trends in Pressure indicators seemed to be exerting a positive influence on the ecosystem in spite of the overall negative influence of drivers which was discussed in the last section. It is of interest to note that overall negative drivers did not necessarily mean that the overall pressures on the system were negative. A reason of the mismatch between overall trends in drivers compared to pressure could be the fact that drivers were mitigated by responses. As an example, the pressures resulting from the demand for more fish may have been mitigated by policies, legislation and the monitoring efforts that were put in place as part of Namibia's governance of its marine resources. Therefore, as stated by Martins *et* *al.* (2012), the relationships between the different classes of indicators in the DPSIR framework are complex but the framework does not fully capture this complexity.

5.3 *DISCUSSION OF STATE INDICATORS*

5.3.1 Chlorophyll-a

The analysis of Chlorophyll-a concentration, does not indicate significant increase or decrease. Thus Chlorophyll-a concentration is unchanged. Since chlorophyll-a is used to indicate changes in productivity, it is likely that there was no significant overall change in the productivity of the BCLME. In addition, chlorophyll-a may also be used to show the changes in water quality. Therefore, the overall indication may be that there was no change in productivity and in water quality in the BCLME for the period that was studied (Szymczak-Żyła *et al.*, 2011). Similarities in the Chlorophyll-a concentration and SST graphs were of interest. They both had significant dips in 2002 and 2006/7. It is likely that Chlorophyll-a concentration is directly proportional to SST, as increased availability of sunlight is likely to lead to increased SST and increased Chlorophyll-a concentration.

5.3.2 Catch for hake, rock lobster and sardine

The landings for hake and rock lobster had a gradually decreasing trend during the study period. This may be an indication that the available fish resources were decreasing and therefore the ecosystem was deteriorating. Alternatively, it may be an indication that the TAC system was being effectively used to bring down the rate of exploitation of fisheries. Because of the recognised effectiveness of the Namibian system of using TAC from other studies (Edoff, 2012), it is likely that the decrease in catch volumes was an indication of effective TACs. Catch volumes are generally seen as effective indictors of the status of the ecosystem (Agnew *et. al.,* 2013; Kleisner *et. al.,* 2013).

The catch volumes for sardine remained quite low in comparison to other species, with volumes below 25 000 tonnes whilst other species were well above 100 000 tonnes. The years 2002 and 2006 had catch values of 4 000 tonnes and 2 000 respectively. Therefore, the trend for sardine catches showed that ecosystem health was not improving. Because of the very low catch volumes experienced it may be a possibility that the sardine stock may not recover to historical stock levels.

5.3.3 Seals harvested

The trend for seals harvested showed an overall increasing trend. This increase corresponded to the gradually increasing population of seal pups at weaning (see section 5.4.1). This seemed to suggest that the ecosystem is improving. Since seals are top predators, their numbers are likely to be reduced when the fish stocks they feed on decline (Watermeyer *et al.,* 2008). Therefore, when top predators are stable or increase in numbers, it is likely that fish in the lower levels of the seal's food chain are no longer declining.

5.3.4 Biomass

Changes in biomass are likely to occur after overexploitation of species in a marine ecosystem (Gómez-Canchong *et al.,* 2013). Therefore the decrease in Lobster biomass as catches were decreasing would suggest that the ecosystem is still being overexploited. However, biomass of hake increased although the catch volumes were decreasing. This may be suggesting that the hake stocks were starting to recover.

5.3.5 Overall trend of State indicators

Three of the indicators showed that the ecosystem continued to deteriorate whilst two indicators showed that the ecosystem was recovering. Two of the indicators were neutral, with the slope of the linear regression analysis very close to zero. The number of indicators showing degradation represented more than 40% of the indicators, whilst those showing that the ecosystem was recovering comprised less than 30%. The overall trend was therefore mixed although there was some slight overall tendency towards degradation. From the mixed trend we can deduce that the ecosystem was close to a dynamic equilibrium where the overall trend was neither deteriorating nor improving as they were almost an equal number of trends in either direction. As suggested by Gregory *et al.* (2013), combining these competing sets of indicators may require a means of enhancing the DPSIR framework to allow for combing different sets of information.

5.4 *DISCUSSION OF IMPACT INDICATORS*

5.4.1 Seal pups at weaning

Timoshenko (1995) demonstrated the use of the number of seal pups at weaning as an indicator of the impact of changes in a marine ecosystem. The number of pups was reduced after the degradation of the marine ecosystem through overfishing and other human activities. In this study, the number of seal pups at weaning was shown to be increasing over the study period. This may be an indication that the ecosystem was recovering from previous overfishing. The seal pups may have been growing to adult age because of the absence of pollution and the presence of adequate food.

5.4.2 Spawning biomass of sardines

The trend of decrease in biomass of sardines at spawning stage showed that the stock of sardines was still declining after the collapse of the stock in previous years. Fewer sardines were available at reproduction stage. Perhaps the low TACs for sardine allocated during the research period were still putting pressure on the recovery of the sardines. The sardine TACs were very low in comparison to other commercial stocks. For example, the TAC for sardine was 25 000 tonnes in 2010, compared to 140 000 tonnes for hake in the same year (Ministry of Fisheries and Marine Resources, 2011). Even at such low TACs compared to other stocks, the spawning biomass of sardine continued to decline. Therefore, this may be indication that the ecosystem continues to deteriorate.

The study by Kreiner *et al.* (2011), showed that the pressure on the sardine fish stocks in the northern Benguela was due to environmental changes. The upwelling in the Northern Benguela system deteriorated in the 1980s, leading to an increase in SST which is related to a decrease in dissolved oxygen. This change of physical conditions and increasing pressures from predators and fishing activities may have forced the sardines to migrate southwards in search of new spawning areas. In addition, Kreiner *et al.* (2011) suggest that pressure was particularly increased because the sardine population gradually decreased in size for different maturity stages including the peak reproductive age.

5.4.3 Average length of hake species

Kreiner *et al.* (2011) showed that when stocks of sardine were declining the average length at maturity got shorter. In contrast, the average lengths of the two hake species investigated in this study increased over the period of the study. The average length moved from 22 cm to 26 cm for *M. capensis* and from 24 cm to 33 cm for *M. paradoxis*. Although the regression analysis showed small rates of change the absolute numbers indicate a definite improvement since the whole population had an average increase in length of about 4 cm in a ten year period. If this trend in length is looked at together with the observed increase in biomass and CPUE, it can be seen than the hake stock is showing definite signs of recovery. In addition, the fall in total catch may also be demonstrating the effectiveness of TACs that were applied to the stock.

5.4.4 Overall trend of Impact indicators

The overall trend with Impact indicators was that impacts were starting to show signs of a recovering ecosystem as seen in three of the four indicators considered. The spawning biomass of sardines was the indicator showing a negative trend. There are some suggestions in literature that the sardine stocks may fail to recover due to, among other reasons, long-term changes in the upwelling system in the Northern Benguela (Kreiner *et al.,* 2011).

5.5 *DISCUSSION OF RESPONSE INDICATORS*

5.5.1 MFMR operations and development budgets

Response indicators reflect progress in processes that are directed at relieving stress in the ecosystem (Burkhard & Müller, 2008). Annual reports showed that the development budget for MFMR was used for developing infrastructure for aquaculture and mariculture. The budget was also used for training and capacity development in the fishing and marine resources industry. On the other hand, the operations budget was used for monitoring the industry, which covers activities such as enforcing fishing quotas and stopping illegal fishing. The operations budget also covered resources required for day-to-day administration functions (Ministry of Fisheries and Marine Resources, 2011). This study showed that the budgets for these activities increased over the period that was analysed. Therefore, the magnitude of the response to stress in the ecosystem increased.

5.5.2 Number of fishing vessels inspected

The degradation of the BCLME was caused by foreign vessels coming into the territory to exploit fish, seals and other living marine resources (Watermeyer *et al.,* 2008). Therefore, the monitoring of vessels in the BCLME is an important control for stopping illegal fishing. Monitoring of fishing vessels showed a gradual decrease as seen by the decrease in vessel inspections carried out per year. Thus the magnitude of response to the state of the ecosystem decreased, which suggests that there was a reduced push for removing the ecosystem health challenges of the past as compared to previous years.

It is possible that reduction in inspections could have been because of the deterrent effect of the earlier regime of inspections. When fishing vessels know that inspections are going to be done frequently, they are less likely to commit violations such as straying into prohibited territory, using inappropriate fishing gear or exceeding allocated fishing quotas.

5.5.3 Marine protected areas

The declaration of Namibia's first Marine Protected Area (MPA) was aimed at protecting sensitive habitats and was aimed at allowing depleted stocks to recover (Ministry of Fisheries and Marine Resources, 2009). The enactment of the legislation for the MPA was a big step that should be supported by effective enforcement.

5.5.4 Legislative changes

The data on legislative changes that support the recovery of the ecosystem was qualitative and therefore could not be trended and analysed for rate of increase or decrease in the same way as the other indicators. However, it can be seen in Table 4.6 that during the period of the research laws were enacted that encouraged the recovery of the BCLME through the development of aquaculture, protecting the ecosystem from pollution and creating marine protected areas to protect some sensitive marine habitats. Therefore, the enactment of laws was a significant contribution to the response to the previous degradation of the BCLME. Therefore legislation in Namibia reflected the efforts to reduce stress on the ecosystem in a similar way to what was described by (Burkhard & Müller, 2008). Some legislation, such as the Environmental Management Act and the Water Act, encompassed the Marine ecosystem but were not only targeted at the marine ecosystem.

It is also important to note that the enactment of legislation does not guarantee its enforcement. Therefore, further research may be required to see to what extend the enactment of legislation has contributed to stopping the degradation of the marine ecosystem.

5.5.5 Summary and overall trend for Response indicators

Three of the four indicators analysed were having a positive effect and therefore the overall status of Response indicators were adjudged to be positive.

5.6 *SUMMARY OF OVERALL TRENDS FOR THE DPSIR CATEGORIES*

The summary of trends showed that the drivers were exerting a negative influence on the recovery of the ecosystem. It would have been expected that the Pressure indicators would also be negative since the drivers were negative. However, the overall trend with the Pressure indicators was positive. However, the positive trends in pressure could be because of the positive influence of the responses coupled with the consistent, effective application of fishing quotas (Edoff, 2012). The State indicators showed mixed trends, with almost equal representation of negative and positive trends. On the other hand both impact and Response indicators showed positive trends. Therefore, there were still some negative trends and influences but the ecosystem was starting to show some signs of recovery.

The analysis of State indicators seems to suggest that ecosystem health may have been in a dynamic equilibrium in which some significant positive trends were counteracted by some significant negative trends. However, the trends shown by the rest of the DPSIR categories (drivers, pressure, impact and response) suggested that this equilibrium was shifting towards recovery of the ecosystem from years of previous degradation.

5.7 *INTEGRATING INDICATORS*

In this study the DPSIR framework was used to bring together a wide variety of indicators that were painting a picture of the trends in ecosystem health of the BCLME. Similar to what Blanchard *et al.* (2010) observed, some indicators showed negative trends whilst others showed positive trends. The study did not attempt to combine the indicators into a single value that shows progress in ecosystem health. It was realised that the data sets were so different and coming from different disciplines that making them into a single computed value was complicated. Instead, the overall trend in ecosystem health was assessed by using the rates of change of the different parameters rather than the actual change. Using the rates of change, it was possible to determine the overall direction of trends in the different categories of indicators by determining whether positive or negative trends were the majority. Therefore, if rates of change are used the DPSIR framework can be used to monitor how ecosystem health is changing in a large marine ecosystem.

The DPSIR approach in this study addressed the need for indicators to cover ecological, social and economic aspects. This is important because indicators covering these sectors should be considered together in order to give a holistic picture. If scientists do not come up with this holistic set of monitoring tools, the policy makers are left to rely on ineffective guidance and poor information resources (De Jonge *et al*., 2012).

Kenny *et al.* (2009) note that there is a challenge combining data being generated by different sectors in a country. However, integrating indicators using the rates of change as shown in this study may lead to collaboration between the different disciplines since the framework helps people in different disciplines understand the relationships between the various ecosystem issues.

The prospect of analysing a wide diversity of issues in order to come up with a holistic picture of what is happening in the ecosystem may seem overwhelming. However, choosing some indicators under each DPSIR category reduced the number of parameters that had to be measured, since a few indicators represented the possible parameters that could be measured for that particular DPSIR category. The few indicators make it easier to communicate the various aspects of the ecosystem (Alexakis *et al.,* 2012).

5.8 *RELIABILITY*

In order to assess the reliability of the data collected in this study, the data was compared against data published by Paterson *et al.* (2013). Paterson *et al.* (2013) collected and assessed data on hake TACs for Namibia. It was found that the data was similar with minor variations due to the number of decimal places used and the rounding off to reduce the numbers to less decimal places. Since the methodology used the trend rather than the absolute numbers slight variation due to presentation of the decimal fraction part of the numbers was not deemed significant. It was assumed that the official government reports, such as the annual reports of a Ministry would have consistent methods of assessing the indicator data given in the documents. Hence any similar deduction of trend of a given indicator for the period of the research should yield a similar trend.

5.9 *VALIDITY*

In this study, validity was tested by comparing the deduction made from this study with conclusions reached by other similar studies. Blanchard *et. al.* (2010) studied 19 large marine ecosystems that included the BCLME. They used a combination of different indicators. Their results identified a combination of positive and negative trends. Similar, this study found such positive and negative trends. In addition, this study added more insight into the reasons for these trends by following how pressures arise from drivers and how impacts and responses also give an indication of where ecosystem health is going. Pitcher and Cheung (2013) also suggest fisheries have not fully recovered from previous degradation and that the suggested recovery by some researchers is based on developed countries fisheries.

The findings of this study that Responses to previous degradation are making a positive contribution to the recovery of the BCLME and the fact that TACs are contributing significantly to the reduction of pressure on the ecosystem are in line with the findings of Edoff (2012).

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

6.1.1 Is the ecosystem recovering or deteriorating further?

This study has shown the importance of taking a broad view of the ecosystem by tracking whether or not the ecosystem has recovered using the DPSIR framework. After considering all the different factors showing recovery or continued degradation, it was concluded that the degradation of the BCLME has slowed down and some recovery trends have started appearing. This is because after considering overall effects, three of the five DPSIR categories are showing positive trends whilst one is showing negative effects and the fifth one is neither positive nor negative. Therefore, the DPSIR categories have 60% positive trends, 20% negative trends and 20% neutral trends. Hence, this study has shown that the BCLME is starting to show signs of recovery. It is now important for scientists, policy makers and ecosystem managers to put more effort into ensuring that the ecosystem fully recovers.

6.1.2 Can the study contribute to a more holistic understanding of the ecosystem?

The study demonstrated how the use of the DPSIR framework enables aspects that are of interest to different players in the ecosystem to be analysed and linked. Hence socio-economic parameters such as employment levels and contribution to GDP may have an impact on the setting of TACs and the setting of TACs may in turn affect the fishing effort. If the response is to offer alternative sources of production such as aquaculture and to increase monitoring in order to stop illegal fishing, then there will be reduced pressure on the stocks. Hence, if information is represented in this way those policy makers that are responsible for the National budgets may see a clear need to restore future viability of the fishing industry through putting more resources to support MFMR development and operations. In addition aquaculture could create more jobs and reduce the pressure for marine fishing to increase employment. Therefore, from this example, it can be seen that the DPSIR indicator framework allows the integration of aspects from many disciplines including science. This will allow the different disciplines to share understanding and combine efforts.

6.2 RECOMMENDATIONS

6.2.1 Recommendations for mitigating negative drivers

This study has shown that significant driving forces on the ecosystem emanate from socio-economic factors such as the levels of employment and the contribution of the ecosystem to the economy. It will be difficult for managers and policy makers to sustain any recovery of the BCLME without ensuring that the ecosystem contributes positively to these issues. One way of increasing the contribution of the ecosystem to socio-economic issues would be to increase the production from mariculture and aquaculture beyond the current levels (Olivier, 2012). It could also be beneficial to consider diversifying into other aquaculture products that are currently not being carried out in Namibia, such as aquaculture of seahorses. This would also lead to job creation through downstream industries (Koldewey, 2010). Similar to how extensive aquaculture production is achieved in some parts of the world, Namibia could benefit from aggressively developing capacity by smallholder aquaculture farmers and putting in place the necessary resources and policies to support these farmers (Rimmer, 2013). Since the goal of reaching the Maximum Sustainable Yield (MSY) for BCLME fisheries is affected by socio-economic factors, it is important to have appropriate mitigation through political and economic decision making. However, there may be sacrifices that will have to be made in the short term exploitation of the resources in order for long-term benefits to be realised (Ye *et al.,* 2012). In the long term a recovered BCLME will make even greater contributions to the economies of the countries in the BCLME region.

6.2.2 Addressing different indicators that are showing different trends

There may be a need to apply different approaches for different stocks. For example, Sardine populations were almost completely wiped out. It might be a good idea to stop issuing TACs for Sardines to let the species recover. The other species like hake seem to be recovering well, however, it might also be worthwhile to issue TACs conservatively to allow the species to recover. In addition, ecosystem managers may also consider developing the currently non-commercial species into commercial fisheries so as to reduce pressure on the heavily exploited species. Ecosystem managers must also take into account knowledge from research in climate change and environmental variation and use this knowledge to enhance the processes they are using for the determination of TACs, marine protected area and other issues.

6.2.3 Availability of data

The efficient contribution of all stakeholders to the recovery of the ecosystem is being compromised by poor availability of data. The relevant authorities should ensure that accurate data is quickly made available after the different processes that are used to generate the data. Not all the data that this research could have benefited from was available. Uahengo (2013), notes that there is a serious challenge with availability of fisheries data in Namibia.

6.2.4 Use of the DPSIR frame work for marine ecosystems

This study recommends that large marine ecosystems use the DPSIR system or another framework which also combines scientific data and socio-economic data in order to better understand all the forces at play in the recovery of previously overexploited marine ecosystems. Scientists may be uncomfortable in entertaining indicators that are unscientific. However, demonstrating that they understand the interplay of the non-scientific factors with scientific factors in shaping the recovery of the ecosystem helps to give policy makers and other stakeholders confidence in the scientific advice received from scientists.

6.2.5 Extending the monitoring to the other countries

This study focused on the part of the large marine ecosystem that covers Namibia. This made it easier to relate to socio-economic indicators that are directly linked to the Namibian economy such as GDP and employment figures. However, the BCLME is one ecosystem consisting of Angolan, Namibian and part of South African marine environment so it would be desirable to test the status of the ecosystem as a whole. This may be difficult using DPSIR indicators because of the differences in the three countries of the BCLME. Some of these differences include differences in policies and differences in the contribution of the ecosystem to employment and the national economies. However, in spite of these differences and the difficulties they present, the presence of transboundary stocks and transboundary ecosystem management issues make it important for future indicators to be able to tell the whole story about trends in the ecosystem. It is recommended that the governments of these three countries ensure that a whole set of trends, such as those in this study, is continuously monitored by all three countries.

6.3 RECOMMENDATIONS FOR FURTHER STUDIES

The influence of different indicators does not appear to be the same. Future studies may explore the possibility of applying weighting on the indicators in order to make them more comparable so that their rates of change can be combined to give an overall trend. One way of doing this may be to conduct a survey which requests experts to rate the relative influence of the issues represented by each indicator. The average ratings produced may be used to put weightings onto regression slope data. Future studies could try and find a way of combining the indicators for Namibia with those of Angola and South Africa to come up with DPSIR indicator data for the whole BCLME region.

There seems to be a correlation between the value of the sub-zero SST in 2002 and the values of Chlorophyll-a, hake catch and sardine catch, number of seal pups harvested and the By-catch figures for 2002. Further research using other periods with similar anomalies could lead to the interpretation of a relationship between pressure from environmental factors such as SST and wind stress, and other DPSIR factors.

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