ECONOMIC POTENTIAL OF THE NAMIBIAN DEEP-SEA RED CRAB FISHERY

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ABSTRACT

Sustainable economic benefits of a resource rely on sustainable regulated fishery. The purpose of this study was to assess the economic potential of the Namibian deep-sea red crab (*Chaceon maritae*). It adopted a bioeconomic model to assess the ecological and economics balance of the resource, and scenario analysis technique to assess onshore development potential. The bioeconomic model estimated MSY at 3,654 tons, which is 10 tons more than current harvest of 3,644 in 2017, signifying a sustainably harvested resource, with a profitable operation. Crab species are generally sensitive, and its quality deteriorates rapidly as compared to other fish species. Therefore, any disruptions in temperature, salinity, and oxygen results in low quality products. Based on the results of onshore processing scenarios, the development of onshore processing will necessitate technical modifications to the existing onshore and offshore operations for possible future development by 2035. However, a thorough cost-benefit study is required to compliment the narrations of onshore processing analysis. Furthermore, there is need for collective effort to strengthen research, capacity building and communication gap bridge between the stakeholders (government, universities and fishing industry) to explore the potential and facilitate initiatives and innovations such as utilization of by-products for economic value.

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ACRONYMS

BE - Bioeconomic Equilibrium
BON- Bank of Namibia
GDP – Gross Domestic Products
CPUE - Catch Per Unit Effort
CSR - Corporate Social Responsibility
CW - Carapace Width
EEZ - Economic Exclusive Zone
MSY - Maximum Sustainable Yield
FAO - Food and Agriculture Organization
FOA - Fisheries Observer Agency
GDP - Gross Domestic Production
MCS - Monitoring Control and Surveillance
MEY - Maximum Economic Yield
MFMR- Ministry of Fisheries and Marine Resources
MITSMED-Ministry of Industrialisation, Trade and SME Development
MSY - Maximum Sustainable Yield
NatMIRC-National Marine Information and Research Centre
NBP- Number of Baited Pots
NDP5- 5th National Development Plan
NSA- Namibia Statistic Agency
SDG-Sustainable Development Goals
TAC - Total Allowed Catches

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1 INTRODUCTION

Namibia is a country located in the South West Africa, with an area space of 823,290 km2 and a population just over 2 million. Its coastline is characterized by the Namib desert that stretches along the coastline over 1,570km (fig. 1). The marine sector is fully industrial majorly because of the coastline geographical features, with a few small-scale fishers based on angling activities. The Namibian Economic Exclusive Zone (EEZ) of 200 nautical miles is supported by the Benguela current system, categorized as one of the highly productive upwelling systems in the world (Lange, 2003). Namibia has access to more than 20 valuable species that are commercially harvested (MFMR, 2007).

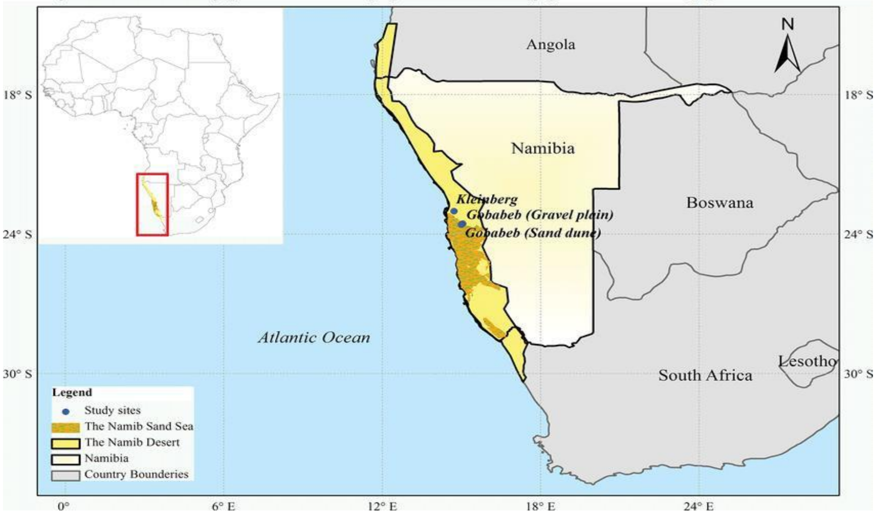

Figure 1. Namibian map illustrating the geographical feature of the Namibian coastline

Namibia’s marine resource was over exploited by foreign fleets during the open access regime before 1990. The development of the marine sector began after independence in 1990, when it gained full control over its marine resources. Subsequent to the implementation of a fisheries management system in 1991, the sector’s economic importance was acknowledged and its potential for output growth and employment creation has been expressed in several national intervention programmes and development plans (Chiripanhura & Teweldemedhin, 2016). The sector is currently the third-largest contributor to GDP after agriculture and mining, contributing an average of 4 % over the past five years and the second-largest foreign earner after mining (NSA, 2018).

Deep-sea red crab (*Chaeon maritae*) is one of the valuable commercial species exploited in the Namibian’s EEZ. It is comparatively small in terms of catches, contributing 0.7% to an overall fisheries’ catches of about 500,000 tons in 2018, with only seven right holders exploiting the resource. Although the deep-sea red crab was overexploited during the 1970s-1980s, its population stock has increased threefold from fishable biomass estimated around 10,000 tonnes in the early 1900s to 32,000 tonnes in 2019 (MFMR, 2019). Subsequently, the fishery’s catches became stable during 1996-1997 ranging between 1,000-2,000 tons and thereafter, improved to about 3,600 tons in 2018 (MFMR, 2019).

The deep-sea red crab is highly valuable, it’s landed value was estimated at US$ 12.8 million in 2017 (MFMR, 2018). Besides, the fishery employs about 148 persons and contributes towards foreign earnings as its entire production is nearly export-oriented. The export value of deep-sea red crab products has increased from US$ 1 million to over US$ 15 million over the years as shown in fig. 2 (NSA, 2019).

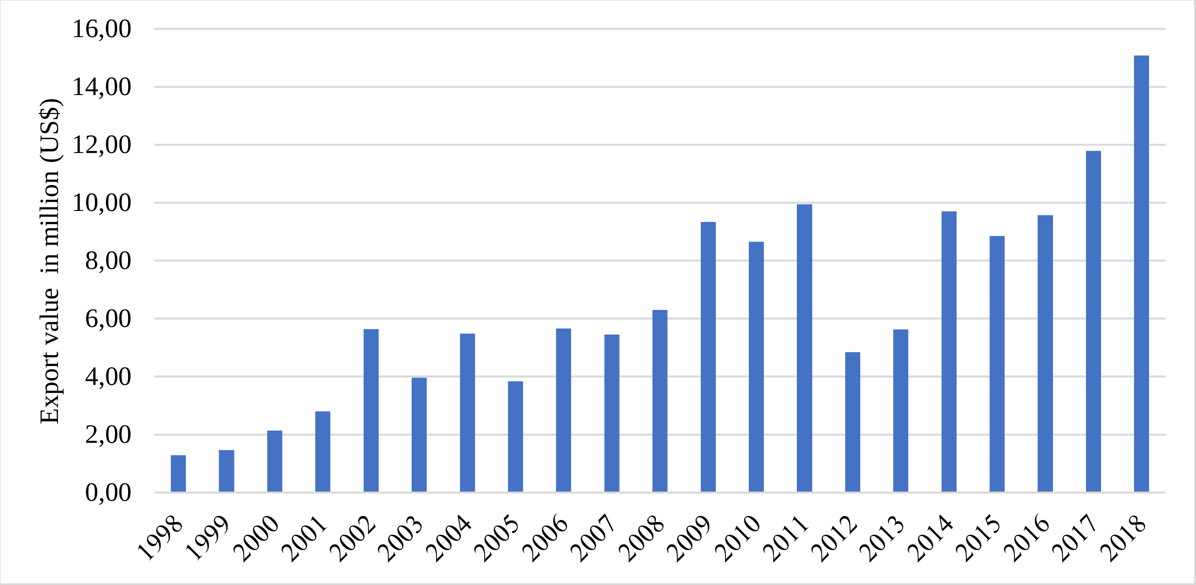

Figure 2. The export value of the Namibian deep-sea red crab 2014-2018 (NSA, 2019)

1.1 Problem statement

Despite contribution of the deep-sea red crab fishery to the economy, its entire production has been offshore based since inception in 1970s. This practice has contributed to a stagnant state of the deep-sea red crab value chain that involves; harvesting, processing and packaging of whole round crab, or butchered into traditional sections (legs and claws), with minimal production of flakes and meat (MFMR, 2018). Furthermore, about 80% of an average whole round Namibian deep-sea red crab is discarded at sea as waste (MFMR, 2013), which seems rather larger than an average crab waste of about 45%-60% (Su, et al., 2019).

Several national plans and policies such as the National Development Plan (NDP5) and “Growth at Home” strategy advocates for value addition and investments in onshore processes to increase the current value-added, maximize employment creation and develop value chains that are based on raw materials available in Namibia (MITSMED, 2013). Moreover, the Ministry of Fisheries and Marine Resource (MFMR) has developed a “Namibianisation” measure aimed at securing increased benefits for Namibians, especially in onshore and skill development.

Offshore based activities and utilization of the deep-seed red crab resource are the major contributing factors to a stagnant value chain and employment of 148 over the past 10 years. Therefore, the need to assess the full potential of the fishery through onshore development.

1.2 Research objectives

The most critical objective of fisheries management is to ensure ecological sustainability of the resource and optimal socio-economic benefits (MFMR, 2014). While that is true, fisheries environments undergo several conditions that can potentially obstruct sustainable economic benefits to fishers and communities such as entry in the fishery, change of technology, change of effort at sea etc., (Rosenberg, 2003). A bioeconomic model is therefore, adopted to evaluate the current economic sustainable yield of the deep-sea red crab fishery. Additionally, scenario analysis is undertaken to compliment the fishery's potential for growth and development.

The purpose of this study is therefore to assess the economic potential of the deep-sea red crab fishery in enhancing its general contribution to the economy. The objectives of the study are to:

- Determine the deep-sea red crab sustainable profits, at the current level of effort and catches, using the bioeconomic model.
- Assess the potential of onshore processing in the deep-sea red crab fishery.
- Suggest management measures for sustainable utilization of the crab resource.

1.3 Justification of the Study

MFMR has a regulatory framework in place, that sets conditions to responsibly manage living aquatic and resources to ensure a sound environment for fisheries. Moreover, it emphasizes on developing management measures to maximize economic benefits through value addition, enterprise development, local procurement of goods and services, and revenue to the government. Therefore, it is crucial for MFMR as a regulatory institution to employ well informed management measures, taking into account both, the ecological state of the resource and its economic value to realized optimal socio-economic benefits.

In addition, the management of fisheries to promote economic growth and social inclusion, as emphasised by the concept of blue economy, requires a whole different type of policy approach that looks beyond the existing traditional ways of doing things and recognising the potential wealth of resources

Therefore, this study will be informative to policy makers and players in the fishery, in taking proactive and innovative measures towards the social and economic development of the sector. A bioeconomic model employed this study is the first of its kind to the Namibian deep-sea red crab fishery, which will be instrumental in establishing strategies that can potentially drive the development of the fishery.

2 DESCRIPTION AND HISTORY OF THE FISHERY

2.1 Deep-sea red crab management regime

Before independence in 1990, the Namibian fishing sector operated under an open access system, which was fully controlled by foreigners. The deep-sea red crab fishery is no exception, it was overfished and controlled by Japanese fleets (De & Beyers, 1994). After independence, Namibia implemented fisheries management tools that are right based that entails TACs determinations and quota allocations.

2.1.1 *Fishing rights*

Fishing rights are issued as a means of limiting entry into the fisheries sector for sustainable operations. These rights are granted under four categories, 7, 10, 15, and 20-year terms (MFMR, 2000). Extension of fishing rights under different categories is subjected to an evaluation of the respective right holder's performance in view of the Marine Resource Act and compliance with fisheries laws, policies, and conditions attached to the right.

2.1.2 *TACs and Individual (non- transferable) quota allocations*

The determination of the deep-sea red crab TACs is set annually, in line with the fishing season that commences 1st January to 31st December. TACs are set based on scientific recommendations whilst consideration is given to socio-economic aspects such as employment, value addition, investment, etc. NatMIRC is a government research centre with a responsibility of undertaking research on various fisheries resources to provide advice on the state commercial exploited species and its environment (Oelofsen, 1999). The survey results are presented to the Marine Resource Advisory Council (MRAC), a body appointed in line with the Marine Resource Act no. 27 of 2000 to advise on marine resource-related issues. MRAC thus, put its recommendations after a deliberate discussion to the Minister for consultations, before they are submitted for cabinet approval.

Once TACs are endorsed by the cabinet, quotas are allocated to right holders on a pro-rata share basis. The pro-rata allocation is based on the assessment of individual right holders on set criteria for quota allocation such as socio-economic factors etc. as outlined in the Marine Resource Act No. 27 of 2000. This process takes roughly a month before the next fishing season commence.

The regulations relating to the exploitation of marine resources outlines how making fishing gear should be conducted, how conversation factors should be applied when deep-sea red crab is landed in sections etc., and any other regulation related to exploitation of the resource are in place and applicable to the deep-sea red crab fishery (MFMR, 2000).

2.1.3 *Monitoring, Control, and Surveillance (MCS)*

Namibia's approach towards the protection of EEZ is performed by means of sea and air surveillance through regular at-sea inspections. The fisheries observer program allows an observer on vessels with a berth to ensure compliance and collection of scientific data (MFMR, 2000), whilst fisheries inspectors are responsible for monitoring landings at the commercial landing harbours, Walvis Bay and Lüderitz. This has proven to have worked in monitoring landings as transhipment in the high sea is not permitted, unless authorization is obtained from the Minister responsible for fisheries as stipulated in the Marine Resource Act no. 27 of 2000. Vessel monitoring devices are also installed in vessels licensed to harvest in the Namibian waters.

2.1.4 *Government rent*

Direct government revenues collected from the fisheries sector include quota fees, Marine Resource levy fund (fund research and training), by-catch levies as a penalty for landing non-targeted species (all of which must be landed) with charge rates per tonne set on a species-specific basis. License fees per trip are paid based on all vessels deployed at sea for fishing purposes.

2.2 Biological status

2.2.1 *Distribution and population dynamics of deep-sea red crab*

The deep-sea crab is a shared species between Namibia and Angola. It is widely distributed along the West African coast, from the west of Cape cross (23 ° 35' N) in Namibian waters (fig. 3) towards the north into Angolan waters (Melville-Smith,1989). It resides in a narrow bathymetric zone, with an inshore boundary between 340 m and 380 m and an offshore boundary around 1000 m (MFMR, 2014). Figure 3 shows the fishing ground of commercial vessels in 2016 fishing season.

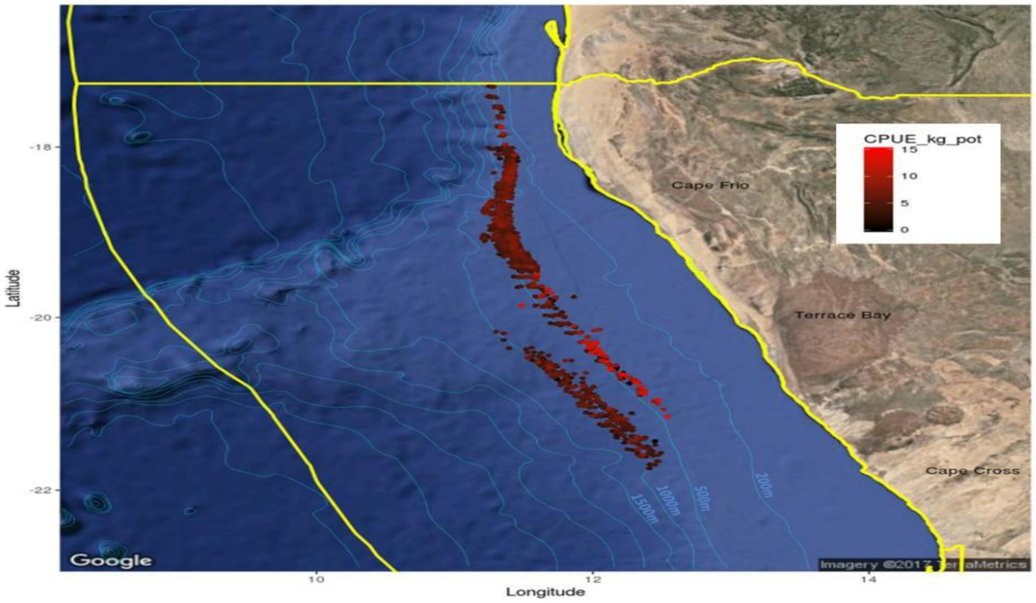

Figure 3. Commercial fishing ground for 2016 fishing season (MFMR, 2017)

The deep-sea red crab is a slow-growing species, like most deep-sea organisms. It is dominated by male crabs, making up about 95 % of the fishable biomass (MFMR, 2014). The species reaches a maximum size of about 180 mm Carapace Width (CW) and may live longer than 25 years (Simon, 2015). In terms of food intake rate, a history of low intake rate is observed, with females likely to have higher incidences of an empty stomach. The red crab consumes a large variety of prey organisms, with small molluscs and polychaete worms frequently observed in stomach contents (MFMR, 2008). Figure 4 below shows the deep-sea crab species (Chaceon Maritae) harvested in Namibia.

Figure 4. Namibian deep-sea red crab (adopted from MFMR, 2018)

Past studies showed that male crabs tend to mature at 80 mm CW and females at 62 mm CW (Melville-Smith,1988), whilst recent data shows females mature at 79-80 mm CW (MFMR, 2016). Male crab tends to live in deeper water from 500m as opposed to a female that predominantly found in shallow water (less than 500 m). In the early 1990s, commercial vessels were restricted to harvest in shallower water, less than 500 m to protect the breeding stock of female crabs (De & Beyers, 1994). However, the restriction was later lifted and reduced the mesh size to 89 mm CW to allow commercial harvesting in shallow water, at the same time, to ease female crab escape.

During the 1980s and early 1990s, tagging studies on the deep-sea red crab population indicated substantial migrations of adult female crabs to Angola (Cochrane, et al., 2009). It is, however, important to point out that the surveys have experienced lack of information on recruitment over the years and this has contributed to the problem of understanding the population dynamics of the species. The use of pod fishing surveys using small mesh sizes did not provide conclusive results (MFMR, 2018). Furthermore, the fact that the stock is shared and stock assessment between the two countries is done independently (MFMR, 2014) also plays a significant role in the proper assessment of the stock.

2.2.2 *Fishable biomass*

The Namibian deep-sea red crab fishable biomass is estimated using the modified DeLury model. As illustrated in figure 5, the fishable biomass has increased from the lowest estimate in 1991 at 10,000 tons to the highest estimate at 30,000 tons in 2017, representing an overall increase of 200%.

This is a good indication that the stock rebuilding strategy adopted as part of the fishery's management has a positive impact on the stock, after over-exploitation before 1990. Moreover, the growth trend is consistent, although at a slow rate.

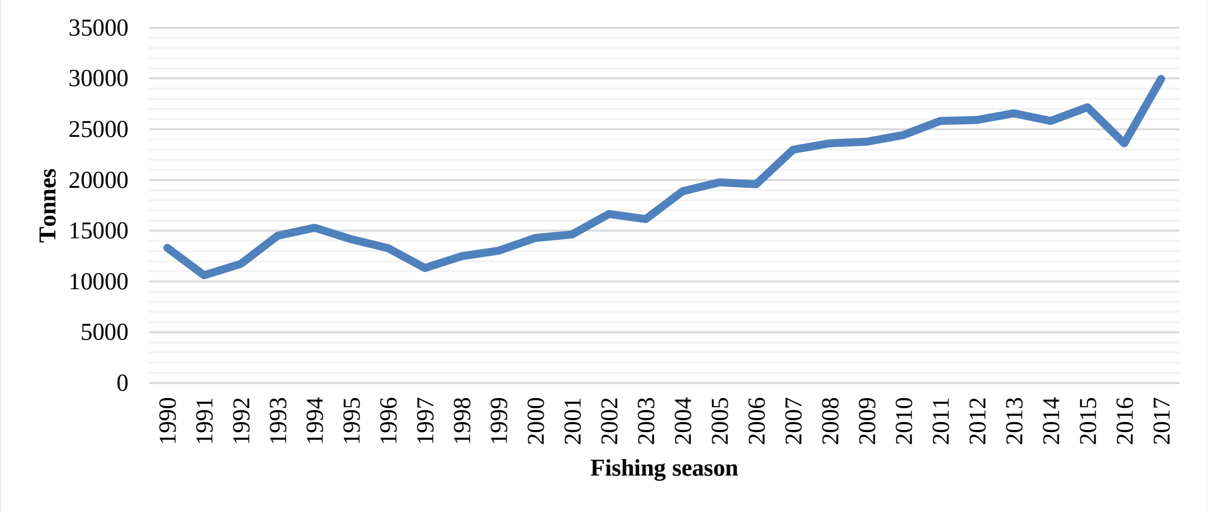

Figure 5. Fishable biomass of deep-sea red crab 1990 -2017 (MFMR, 2019)

2.2.3 *Total allowable catches and annual catches*

Since inception in the 1970s, the deep-sea red crab resource has been commercially exploited using Japanese-style beehive traps on long-lines (fig. 6). The traps are made from conical metal frames bordered by a fishing net with a trap entrance located on the upper side of the structure. The trap is long enough, about 50 cm above the ground when set up on the ground ensuring easy access of crab into the trap. Once the crab is trapped, it is kept in what is referred to as a kitchen area of the trap that ensures all crab end up in the bottom of the trap (SEAF0, 2017). The trap lines consist of about 200-1500 beehive pots, with an interval between the traps of about 18 m, and each line may cover about 30km, on the seafloor and surface (SEAF0, 2017).

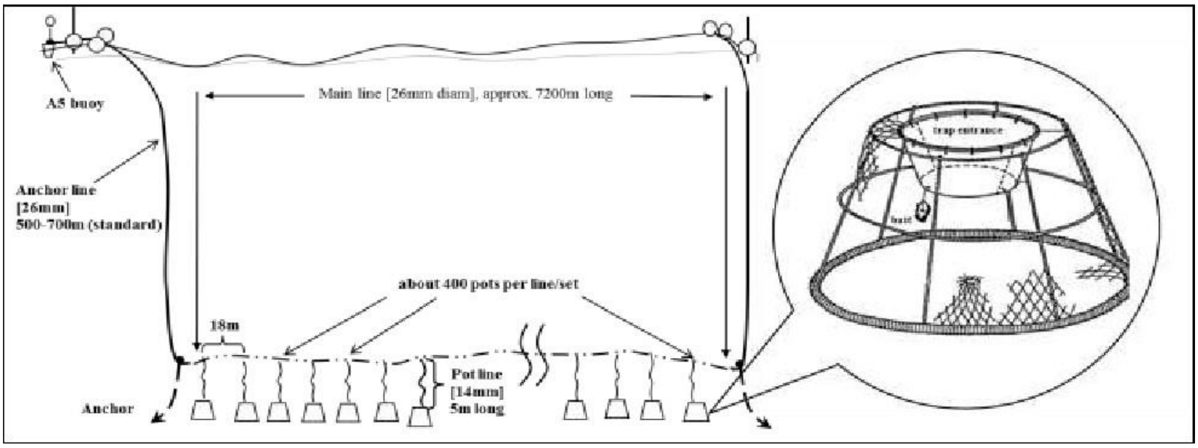

Figure 6. Deep-sea red crab fishing gear setup and illustration of a Japanese beehive pot (SEAF0, 2017)

During the open-access regime, the highest landings were observed in 1983, recorded over 10,000tons (Melville-Smith,1988) whilst average catches during the 1970s and 1980s ranged between 6,000-8,000 tons annually (MFMR, 2004). During these periods, the fishery was exploited by a maximum of five vessels annually.

After the implementation of the management system, the TAC was initially set at 6,000 tons in 1990 and reduced significantly to 2,000 tons by 1997 as shown in fig. 5, whilst landings fluctuated during the same period. The TAC and landings fluctuated from 1500 to 6000 tons between 1990- 1997 and stabilised between 2000 to about 3600 tons during 1998 to 2017 as exhibited in figure 7 below.

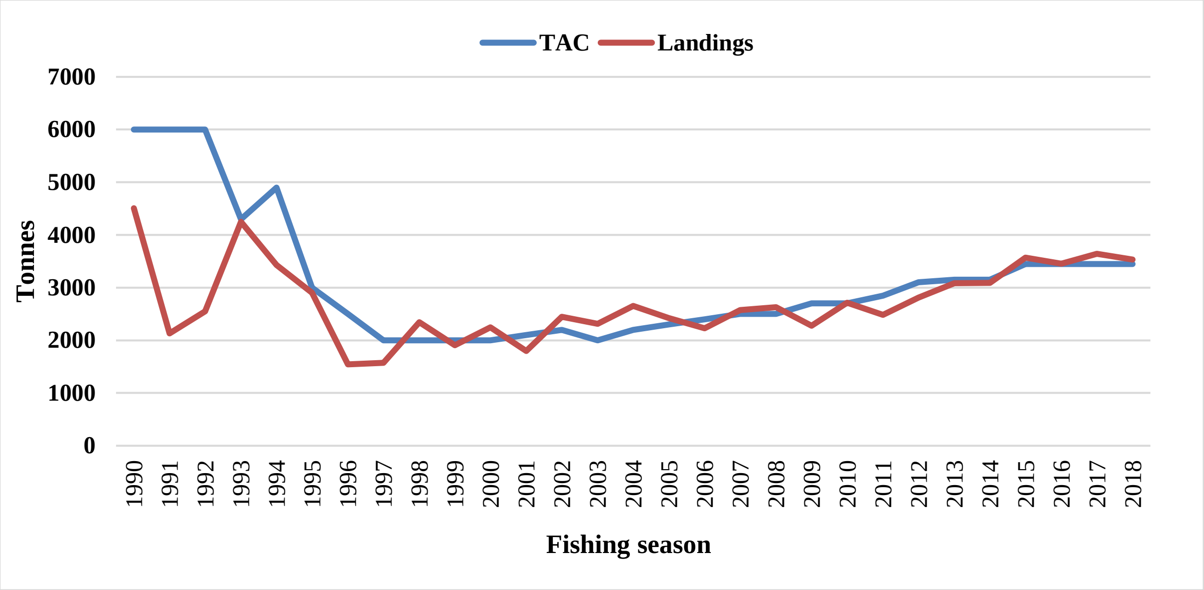

Figure 7. TACs and Landings 1990-2018 (MFMR, 2016)

2.2.4 *Total effort and CPUE*

Effort in the deep-sea red crab is measured by the Number of Baited Pots (NBP) deployed at sea, whilst Catch Per Unit effort (CPUE) is measured by the weight of crab in kilograms per pot. The total effort deployed at sea by the commercial vessels has shown a significant reduction of about 50% from 1.5 million baited pots recorded in 1990 to 500 thousand reported in 2017 (fig. 8).

The CPUE has increased from about 3kg pot to 7.58 kg which shows an improvement of catches per unit effort during the period 1990-2017. This improvement in CPUE is attributed to a reduction of effort at sea as shown in figure 8. Furthermore, the growth observed in the fishable biomass has contributed to the increased CPUE over the years.

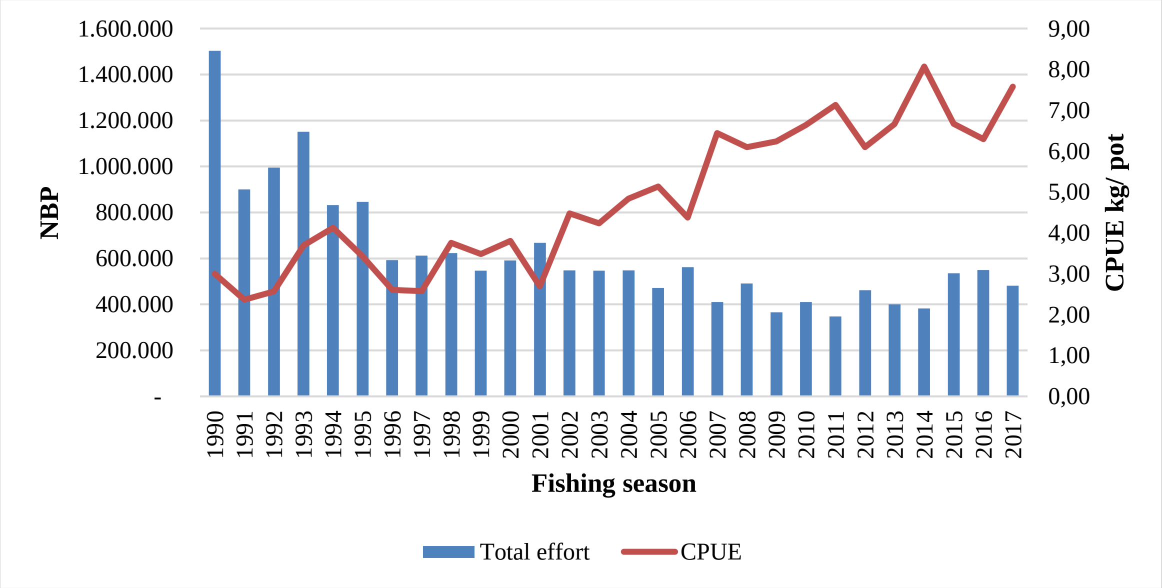

Figure 8. Total effort and CPUE, 1990-2017 (MFMR, 2019)

2.3 Description of value chain and economic performance

The concept of the value chain was best described by Michael Porter (1985) as the sum of activities of an industry that aims to realize a competitive advantage. In fisheries, value chain can be described as the full range of activities required to bring about higher quality and better fish products (Rosales, et al., 2017). Actors in the value chain aim for an effective value chain that maximizes the opportunity of adding value in the eyes of the end consumer whilst the processes of adding value are cost-efficient (Parke, 2014). Hence, value occurs at different points of the chain but mainly focuses on the factors of production and marketing.

Governance plays a crucial role in any value chain for the mere fact that value chains are highly dependent on utilization of natural and environmental resources. A broad value chain based on raw materials is generally encouraged by the Ministry of Industrialisation, Trade and SME Development (MITSMED) through its growth at home strategy that promotes Namibia's competitive advantages and opportunities. In addition, MFMR and other stakeholders in the fishery sector has contributed positively to the value chain interventions in fisheries, implemented in line with national economic programs.

2.3.1 *Handling of crab products*

Crab species are vulnerable to changes in the environment during the harvesting process that any disruptions in temperature, salinity, and oxygen contribute to the weakening of the harvests or mortality. Its quality tends to deteriorate more rapidly after death than any other fish. This is mainly due to growth and multiplication of microorganism and the action of enzymes (Kramer et. Al, n.d). Time control is a vital element in the processing of crab to avoid tarnished and chalky texture products.

The Food and Agriculture Organisation (FAO) emphasizes on the sensitivity of the species in its code of practices for fish and fishery products. Minor damages of legs and claws make the product vulnerable to infections and quality loss. It is further stressed that water holding tanks are ideal handling methods in an event of onshore processing, in which seawater is continuously pumping to extend the life span and protects crab from physical damage (Don, Heidi, & Soner, 2009). On the other hand, crabs should be butchered and portion into sections immediately upon harvesting. Sections are carefully separated and cleaned before freezing or cooling down to the temperature as close as possible to 0 °C, which should be done as rapidly as possible. Cooked crab meat is an excellent growth medium for bacteria and easily spoiled (Kramer et. al, n.d). For this reason, it must not be exposed to bacterial contamination and should be kept cold and handled as fast as possible during all steps of processing, shipping, and marketing.

2.3.2 *Namibian deep-sea red crab value chain*

The fishery is made up of two main players in the value chain, the vessel owners and or right holders. Due to the geographical location of deep-sea red crab resource fishing grounds, the entire value chain takes place in the vicinity of Walvis Bay. Hence, utilize the Walvis Bay harbour for all docking and offloading activities (MFMR, 2016).

A typical value chain of the deep-sea red crab as illustrated in figure 9, begins with harvesting of raw materials. A quota is allocated and harvested as inputs into the value chain by right holders or through catch/Joint Ventures (JV) agreements. Processing of deep-sea red crab has been strictly an onboard activity since the 1970s (Melville-Smith,1988; MFMR, 2018). After the development of an onshore processing in 2016, about 1% of annual catches is re-processed onshore (MFMR, 2018).

Namibian deep-sea red crab is processed into different product forms; whole round crab, sections (legs & claws), meat or flakes, and packed under the international standards for food safety, Hazard Analysis and Critical Control Point (HACCP). The size of crab and specifications of clients play a critical role in determining product types (MFMR, 2016). Crab sections is the most basic value-added product, from large crab above 110 mm CW. Smaller crabs are packed into different leg sections with or without shells, claw products are mainly taken from 100-110 mm CW, and flakes/meat is extracted from legs sections. The whole process is undertaken onboard the vessel and despatched to the international market immediately after landing at the Walvis Bay airport. Figure 9 shows the value chain of the deep-sea red crab fishery.

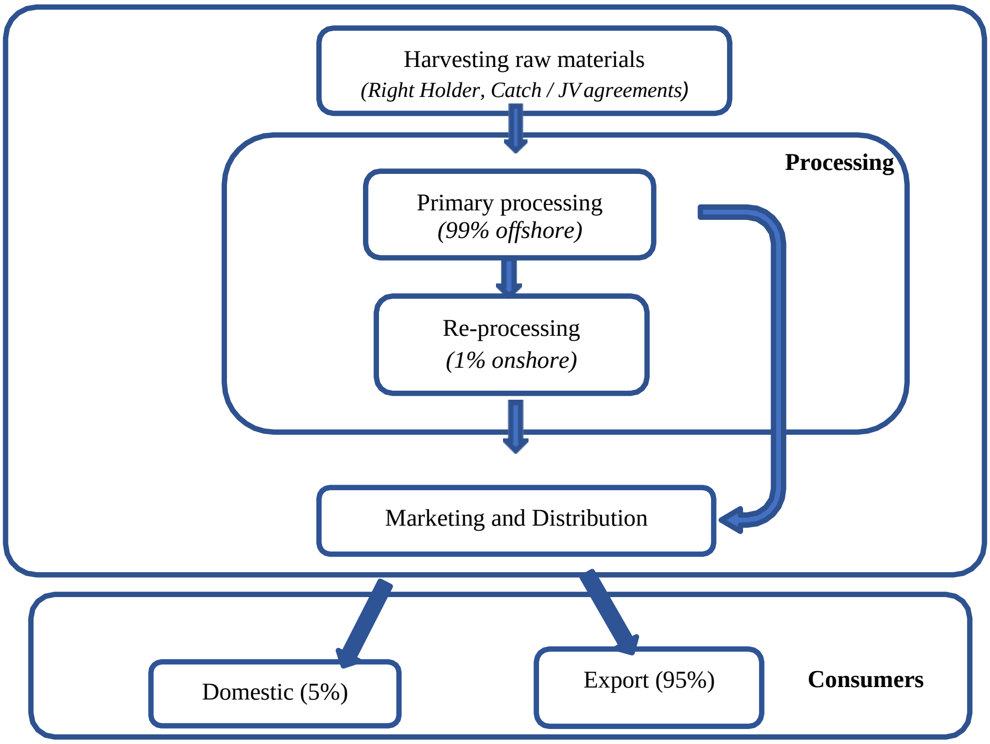

Figure 9. The current Namibian deep-sea red crab value chain, 2018

2.3.3 *Management and ownership*

It is a common practice for players in the Namibian fishing industry to coordinate in order to attain operational efficiency, this is true for the deep-sea red crab fishery. Right holders without fishing vessels and operators (vessel owners) collaborate through short and/ long-term operational arrangements to catch, process, and market & distribute the production (MFMR, 2016). Through these arrangements, companies become vertically integrated and obtain absolute control over the value chain as illustrated in fig. 9. Vertically integrated firms minimise the risk of high cost of information, as information is available from the point of harvesting to the end consumer (Szollosi, 2014). Marketing of crab products is handled on behalf of right holders by the operators through agreements between operators and subsidiary companies in respective markets.

2.3.4 *Description of the fishing fleet*

The fleet of the deep-sea red crab is made up of four industrial vessels. All of which are Namibian based, flagged and fully operate in the fishery throughout the fishing seasons (MFMR, 2019). Figure 10 shows the type of vessels used in the fishery.

Figure 10. Deep-sea red crab vessels utilized in Namibia

Fishing vessels in the fishery are either fully or partially owned by right holders. The entire fleet is 81% Namibian owned, whilst the balance of 19% belongs to foreigners; Japan, Denmark and Spain. The fishery is fully capacitated to exploit the resource at the current stock level as depicted in table 2. Although vessel's features vary, all vessels are large and fitted with processing factories on board. The characteristics of deep-sea red crab are shown below.

Table 1. Characteristics of the Namibian deep-sea red crab fleet, 2018

	Range
Namibian ownership in %	54% -100%
Catch capacity per day (tons)	5tons -8 tons/ day
Holding capacity $m3$	146m^3-635m^3
Length in meters	44m-55m
Gross Register Tonnage (GRT) (tons)	607m- 789m
Horsepower in KW	750kw-1500kw
Age of vessels	31-48 years
Number of crew	24 - 38

Source: MFMR, 2019

2.3.5 *Namibian deep-sea red crab markets and prices*

Deep-sea red crab is considered as a luxury product and thus, not commonly consumed in the local market. It is produced in different products; Live crab, frozen whole round crab, fresh/ frozen sections (legs, claws), and minimal volumes of meat and flakes. Crab products are traditionally demanded in Japan and China, for its rich texture and colour. However, new markets for Namibian deep-sea red crab products have been established in Spain and South Africa, taking up about 80% of total production, whilst less than 5% is sold in the local market (MFMR, 2018).

The Namibian deep-sea red crab fishery is a price taker in the world market. As a luxury product, crab products in the world market is very sensitive to market fluctuations mainly supply. Live crab caught the highest price during 2010-2013, ranging between US$ 25 and US$ 35 per kg (fig. 11). Live crab production was explored during 2010-2013, which caught a highest price in the world market amongst other products (MFMR, 2014). Due to lack of direct transportation to export markets and sensitivity of the specie, the project was costly and therefore, discontinued.

It is clear from fig. 11 that there has been a significant reduction from the market price of whole round crab that led to a shift from whole round crab as a main exported product to sections from 2014 to 2018. Although sections are sold fresh or cooked (frozen), there is no consistency in price differences in different markets as prices are highly unstable (MFMR, 2018). Meat and flakes were not produced during 2014-2018.

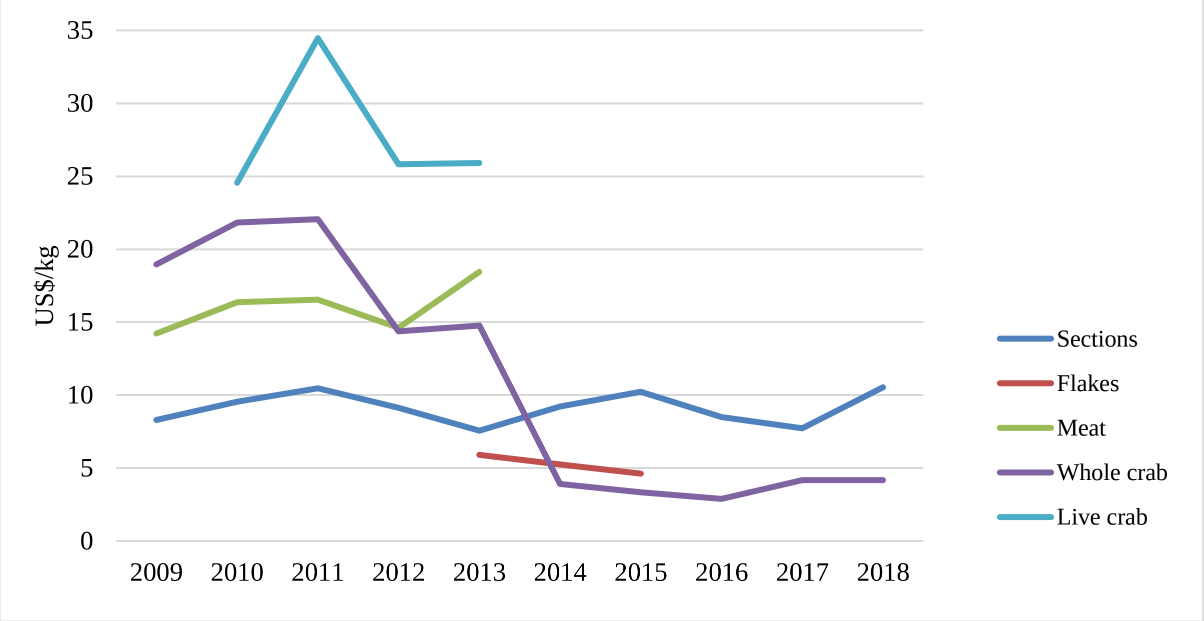

Figure 11. Average market price of deep-sea red crab products 2009-2018 (MFMR,2019)

2.4 Possible value addition in crab

2.4.1 *Value-added crab products*

Most crab species are available as either live whole crabs, fresh cooked whole crabs, or frozen cooked whole crabs, sections or single legs (Nakamura et al. n.a). Crab meat that has been picked from the shell is also a common and popular product form. In some markets such as the USA, crab products are marketed whole (live, fresh and frozen), canned crabmeat form and as speciality products i.e. cocktail claws and ‘snap n eats.’ Crab meat is available as refrigerated fresh, pasteurized, or frozen meat and is often packed in metal or plastic containers. The meat of various types of crabs harvested globally is also available as a canned product. In Japan, crab is marketed live, whole frozen, as frozen sections, and as crabmeat for the sushi market. However, there is a strong trend for frozen sections in the world market.

2.4.2 *Utilization of crab by-products*

Environmental concerns have attracted the attention of decision-makers, scientists and even laymen in fisheries and other sectors. The world has become increasingly conscious of issues such as food crisis, droughts, fodder, pollution of air and water, problems of hazardous chemicals and radiation, depletion of natural resources, extinction of wildlife and dangers to flora and fauna (Karatas, 2016). The SDG no. 14 (life below water) and the blue economy initiative strive to discourage the idea of perceiving oceans as a means of free resource extraction and waste dumping (UN, 2017). The fundamental objective is to sustainably and protect marine and coastal ecosystems from pollution and address the impacts of ocean acidification, to enhance conservation and sustainable use of ocean-based resources.

The Namibian deep-sea red crab fishery is amongst the commercially harvested species with the largest proportion that is not utilized for economic gains. At present, the fishery utilizes about 20% of whole round deep-sea crab for commercial purposes, whilst the remains of 80% made up mainly of shells is discarded as waste. Crustacean waste disposal does not only harm the ocean's environment but is an economic loss to nations partaking in disposing activities. Although little literature exists on the environmental impact of crab shells sea dumping, the importance of shell utilization has been researched because of its growing commercial interest. Hence, initiatives to increase demand, especially high in protein products through full utilization of available by-products and protect the natural environmental resources is of utmost importance.

Disposing of crustacean shells as waste has been a worldwide concern to governments, fishermen, and processors even before the 1980s. Its importance has gained interest and has been investigated by several researchers (Bakiyalakshmi, Linu, & Swarnilla, Isolation and application of chitin and chitosan from crab shell, 2016; Burrows, 2007; Ratch, n.a; Buendia, 1999). Crab shells contain about 25-30% chitin, 25% protein, 40-50% calcium carbonate (Pandharipande & Bhagat, 2016). Chitin is a common biopolymer found in crustacean’s exoskeletons and other arthropods, that is valued for its biological and physio acetylation properties i.e. biodegradability, biocompatibility and non-toxicity and its degree of acetylation and molecular mass (Arbia, Arbia, Lydia, & Amrane, 2013). Thus, chitin and its derivatives have great economic value because of their biological activities, industrial and biomedical applications. Moreover, its unique properties allow for many potential applications in different fields; agriculture, medicine, pharmaceuticals, cosmetics, food processing, textiles, environmental protection, and development of biomaterials, for instance, gels, films, nanomembranes, and polymer nanofibers.

Although the production of chitin is known to be complex with expensive procedures, recent researchers have assessed easier and faster ways of extracting chitin from crustacean shells. A recent study titled ‘conversion of crab shell to useful resources using sub-critical water treatment’ found a fast and less costly two-stage method of extracting chitin compared to the traditional method with about five processes, long time treatment and consequently, high costs (Nakamura et al. n.a). Another alternative method is assessed with the use of proteolytic enzymes or proteolytic microorganisms (Hajji, Ghorbel-Bellaaj, Younes, Jellouli, & Moncef, 2015). This method produces high quality chitin with higher molecular weights as compared to the chemically prepared shellfish chitin. Moreover, it is cheaper fermentation process is much cheaper and maintains the quality of by-products.

Chitin stimulates the growth of chitin eating bacteria in the soil by creating a hostile environment for the fungus and nematodes (Bakiyalakshmi, Linu, & Swarnilla, Isolation and application of chitin and chitosan from crab shell, 2016). It is a source of biofertilizer and supply crops with a balanced source of nitrogen, phosphorus and potassium. Unlike chemical fertilizer that is usually applied in most fertilizer, bio fertilizer made with crustaceans’ shells are organic and effective in stimulating microorganisms and significant role in the nitrogen cycle (Bakiyalakshmi, Linu, & Swarnilla, Isolation and applicationof chitin and chitosan from crab shell, 2016).

Several studies have confirmed high concentration of chitin in crab shells as compared to other crustaceans such as shrimp shells (Jagadeeswari et. al., 2016; Arbia, Arbia, Lydia, & Amrane, 2013). About 45% of non-edible remains of crab is an opportunity of organic by-products to produce renewable highly valuable and environmentally friendly products. A globally well-known company Primex specializes in the production of chitin-chitosan from imported shrimp shells in Iceland is used to produce a variety of products for different purposes in human and animal health, weight management, heart, digestive health amongst others. These products are marketed in the international products under the Chito Clear and LipoSan Ultra brands (www.primex.is).

United Kingdom is one of the biggest crabs producing nations with about 20,000 tons found in Scotland, Northern Ireland, and England. The nations operate about 75 shell processing plants specializing in crab and other shellfish (Michaela & David, 2008). As part of waste management measures, seashells discards are prohibited in the United Kingdoms and shells are either disposed as compost, incineration, landfill or used as bait or transformed into dressed crab products. Value addition initiatives of products from chitin and chitosan are explored and are potentially feasible, however, such initiatives are not put in practice for other economic reasons.

Thailand has a large and well-established chitin-chitosan industry that dedicated to the production of agriculture products (Ratch, n.a). It produces agriculture products such as vegetation spray that promotes disease resistance and increases the quality and production of orchid and other ornamental plants. It is also applied in crops such as rice, palm, corn, cassava and tropical fruits with success and has been incorporated in animal feed for fish and shrimps as feed coating as well as supplemented in the drinking water of poultry, cattle and porcine farming.

Restaurants in Europe i.e. Spain and France, enjoy a satisfying winter fare ‘soup/bisque’ made from the empty, outer shells that would otherwise be thrown away. Crab shells are perishable and odorous; therefore, kept frozen immediately. Caviar in crab shells, a yellow part that is found in the top part of the carapace, gives a thick texture to the soup. These products are common in the UK (Michaela & David, 2008). Moreover, crab shells of crab (*Cancer pagurus*) species found in northern Europe, Mediterranean and the Atlantic Ocean, are used by caterers and food industry as serving plates (Michaela & David, 2008). Cquest shells is a United Kingdom supplier of cleaned crab shells used for both hot and cold crab meat dishes in France and Belgium. Crab shells go through cleaning processes to ensure unwanted particles attached to the shells are removed and a further visual examination on their suitability for the market and meets the quality standards in size and cleanliness.

2.5 Regional development in Namibia

Fisheries in the world are exploited for subsistence, profits and recreational purposes. Namibia’s fisheries are no exception, its fisheries policies are designed to allocate resources to the private sectors to generate profits for economic development amongst other purposes.

Regional development within Namibia is assessed through, shares in the hands of Namibian citizens, investments (direct investment in fisheries and enterprise development) and socio-economic contributions such as employment creation, procurement of goods and services produced within Namibia. Corporate Social Responsibility (CSR) and the contribution of fisheries towards resource food security, in each of the 14 regions of Namibia as per the Marine Resource Act No.27 of 2000 is also important.

Namibia has four coastal regions, covering 54% of the country's land area. However, only 20% of the population lived in these regions in 2011 (NSA, 2011). These regions are highly characterized by the Namib desert that runs along the entire Namibian coastline; hence, the area is not conducive for settlements. The fishery sector has played a significant role in regional development through a wide range of activities in and outside of the coastal towns through increased participation and involvement of regional projects.

The deep-sea red crab's role in regional development is noted from shareholders participating in the fishery, acquisitions of fishing vessels and a processing plant, creating permanent jobs to an average of 146 persons in 2018 from different regions and through corporate social responsibilities (CSR). During 2012-2018, the fishery made CSR contributions valued at US$ 610 thousand through availing bursaries, sponsorships of sports events, building/upgrading schools, donation of health equipment and supporting old age homes in different regions, etc. (MFMR, 2018).

Furthermore, the fishery invested in a fish shop in a neighbouring region as its contribution to enterprise development and improve food security (MFMR, 2019). Although the development of a fish shop is seen as a small project, the spill over effect of fish shops in a region cannot be underestimated as it contributes towards the nutritional diets of residents and business activities in those areas. In addition to deep-sea red crab sold locally, right holders have an obligation and have shown a commitment to supply other fish and fish products based on the demand patterns of the country.

MFMR encouraged right holders to procure locally made goods and services from SMEs such as fruits and vegetables and other food items for crew members, and inputs in production to ensure local empowerment and SME development (Bernhard Esau, 2019).

3 BIOECONOMIC MODEL APPROACH

Fisheries management as a multidisciplinary field requires incorporation two main disciplines: biology and economics. Generally, the management of fisheries is concerned with determining optimal harvesting strategies that maximizes the present value of economic rents from the fishery overtime, at the same time it requires an understanding of biological evolution and behaviour of the resource. Bioeconomic models are known for analysing changes in natural resource management policies as they integrate economic and biological influences in the system (Andrerson & Seijo, 2010; Foley, Armstrong, Kahui, Mikkelsen, & Reithe, 2012). This model is widely used for its appealing qualities as it restricts interactions with environmental fluctuations and estimate the welfare of fisheries economics (Kragt, 2012; Knowler, 2002).

Due to the dynamic nature of fisheries systems, any change in catch level affects the population stock of that resource and eventually, affect catches. Therefore, the Gordon Schaefer model (Gordon, 1954; Schaefer, 1954) describes biomass growth following a logistic curve and a harvest rate. This model applied in this study is for a single species, harvested with similar industrial vessels.

3.1 Modelling

3.1.1 *General model*

A theoretical framework, based on Gordon & Schaefer's (1957) model, is applied to maximize long-run benefits from the Namibian deep-sea red crab fishery. More precisely, change in the crab stock is assumed approximated as:

$$\dot{x} = G\,(x) - h \qquad \text{Net Biomass growth} \qquad (1)$$

where x represents biomass, ẋ is biomass growth, and h is harvest. $G\ (x)$ is a natural biomass growth.

$$h = h(e, x) \qquad \text{Harvest Function} \qquad (2)$$

Where harvest is a function of size of the biomass, x and the fishing effort, e applied on the available stock. And for the net benefits (profits) function, expression (3).

$$\pi = ph(e, x) - c(e) \qquad \text{Profit Function} \qquad (3)$$

where $\boldsymbol{\pi}$ is profit, p represents the price of the landed fish and c is the marginal cost associated with fishing. Profit in the deep-sea red crab fishery is a function of price of harvests, the sustainable yield and the costs of operations, whilst the harvesting costs is a function of fishing effort as in expression 3.

3.1.2 *Specific Functional Forms*

For the biomass growth function G(x) in expression 1, we adopted a logistic functional form as given below:

$$G(x) = \lambda x(1 - \frac{x}{K}) \qquad (4)$$

where r is the intrinsic growth rate of the harvesting population and K is the harvested population’s natural equilibrium size or the system carrying capacity.

The periodic change in stock size with harvest can be described as:

$$x_{t+1} = x_t + G(x) - h \qquad (5)$$

This means biomass (stock) size next year is equal to biomass size this year plus biomass growth this year minus harvest this year. The stock will reach sustainable state, in this case, where $G\ (xt) = ht$. For the harvesting function, a generalization of Schaefer (1954) is assumed and define as:

$$h = \delta ex \qquad (6)$$

where δ is the catchability coefficient that measures the efficiency of the vessels. Since, catch per unit effort is directly proportional to the stock biomass, from expression 5, this suggests that CPUE may be expressed as:

$CPUE = \frac{h}{e} = \delta x$ or $\delta = \frac{CPUE}{x}$ and $x = \frac{CPUE}{\delta}$

Applying a more realistic model under sustainable levels, equilibrium in the ecosystem is assumed at a sustained yield, when a change in biomass is equivalent to harvests in a specific year. Thus, change in the growth of the stock is zero as it is compensated by natural harvesting

Therefore, $\frac{dx}{dt} = \lambda x_t(1 - \frac{x_t}{K}) - h = 0$ (7)

The biomass when the ecosystem is in equilibrium is:

$$x = (1 - \frac{\delta e}{\lambda})K \qquad (8)$$

Substituting expression 8 into expression 6 expresses a long-term production expression of the deep-sea red crab fishery, which represents a sustainable harvest growth function is defined as:

h $=\delta Ke(1 - \frac{\delta e}{\lambda})$, Simplified as:

$h = \alpha * e - \beta * e^2$ (Where $\alpha = \delta K\ and\ \beta = \frac{K\delta^2}{\lambda}$) (9)

The total revenue expression is defined as:

$$\mathrm{TR} = \mathrm{p}h$$

$$\mathrm{TR} = \mathrm{p}\ (\alpha * e - \beta * e^2) \qquad (10)$$

And the total cost expression is defined as:

$$TC = \gamma * e \qquad (11)$$

where γ is the marginal cost per effort employed. Therefore, the profit expression of the crab fishery is defined as follow:

$$\pi = \mathrm{p}(\alpha * e - \beta * e^2) - \gamma * e \qquad (12)$$

where p is the price of crab products

3.2 Fishery management reference points and optimization

Following Schaefer (1954), Anderson and Seijo (2010) and Foley et al (2012), the biological components of these reference points are estimated. Imposing steady-state conditions allows the identification of three reference points. Firstly, the maximum sustainable yield (MSY), which gives the maximum catches that can be harvested indefinitely, without hurting the stock. Introducing economic parameters allows for economic analysis of the efficiency of the fishing activity and thus derives the maximum economic yield (MEY) as management targets and bioeconomic equilibrium (BE) as a limit to be avoided under the open access regime. Therefore, the three alternation reference points are explained as follow:

3.2.1 *Maximum Sustainable Yield*

$$\boldsymbol{e_{msy}} = \frac{\lambda}{2\delta} \qquad (12)$$

$$\boldsymbol{h_{msy}} = \lambda e_{msy} - \beta {e^2}_{msy} \quad \text{or} \quad \frac{K\lambda}{4} \qquad (13)$$

$$\boldsymbol{x_{msy}} = \frac{K}{2} \qquad (14)$$

3.2.2 *Maximum Economic Yield*

$$\boldsymbol{e_{mey}} = \frac{\lambda}{2\delta}\left(1 - \frac{\gamma}{p\delta K}\right) \qquad (15)$$

$$\boldsymbol{h_{mey}} = \frac{\lambda}{4}\left(K - \frac{\gamma^2}{p^2\delta^2 K}\right) \quad \text{or} \quad \delta x_{mey} e_{mey} \qquad (16)$$

$$\boldsymbol{x_{mey}} = \frac{K}{2}\left(1 + \frac{\gamma}{p\delta K}\right) \qquad (17)$$

3.2.3 *Bioeconomic equilibrium yield*

$$\boldsymbol{x_{Be}}=\left(\frac{\gamma}{p\delta}\right) \tag{18}$$

$$\boldsymbol{h_{Be}}=\frac{\lambda\gamma}{p\delta}\left(1-\frac{\gamma}{Kp\delta}\right) \tag{19}$$

$$\boldsymbol{e_{Be}}=\quad\frac{h_{Be}}{\delta x_{Be}} \tag{20}$$

3.3 Data source and description

The bioeconomic analysis employs time series data of secondary nature (1990-2017). Data used was obtained from MFMR collected annually.

3.3.1 *Biological data*

Biological data used to estimate the r, δ and K parameters are for the period (1990-2017), obtained from annual stock assessments carried out by the marine scientists and data collection undertaken by MFMR and Fisheries Observer Agency (FOA). Data includes fishable biomass of the deep-sea red crab above 89 mm CL as a proxy for stock levels, estimated by the DeLury model. Harvests and effort data were used to compute CPUE measured in terms of weight of deep-sea red crab in kilograms per baited trap. CPUE and the fishable biomass data were used to determine the catchability coefficient for the period 1990-2017. The table below shows a summary of description statistic results included in the model.

3.3.2 *Economic data*

Economic data used in the study is comprised of the landed value of deep-sea red crab, income, and expenditures and exchange rates were obtained from the rights holders for a period of four years (2014-2017).

The average landed value of whole round crab as determined by the sector is used to compute revenue for the period under review, whilst costs data used were obtained from an income and expenditure survey submitted to MFMR by right holders on an annual basis. Although costs data used is collected from two operators, the result is expected to give a true reflection of the industry for the simple fact that the deep-sea red crab fishery is fully industrialized, and its fleet is made up of large vessels with similar features such size, gross tons, engine, etc. Monetary values used in this analysis were converted to US$ with exchange rates data obtained from the Bank of Namibia (BON) website for respective years.

The total cost data of the fishery is divided into variable costs and fixed costs as shown in table 2. Variable costs are defined as the cost directly incurred as a result of deploying a fishing vessel to sea for harvesting purposes, whilst fixed cost is considered as the cost incurred by fishing associated with fishing activities, but constant over the fishing season.

Table 2 below shows the main variable and fixed costs during the period 2014-2017, as per the income and expenditure survey of two operators.

Table 2. Variable and Fixed costs (2014-2017)

Variable costs	Fixed cost
• Salaries & Emoluments Bait • Detergents & Cleaning Materials Packaging Material • Vessel Repairs & Maintenance Fuel & Lubrication • Food & Rations/Crew Provisions Unloading fees and Transhipment expenses	• Vessels Insurance • Rent Equipment on Vessels Depreciation • Fishing Gear Storage & Freight Payments on loans Bank Charges • Fishery Fees & Levies, Harbour fees Employee Contr. To Social Welfare Communication and Technical assistance

Source: MFMR, 2019

4 RESULTS

4.1 Estimating the biological Parameters

Biological data of biomass and harvest for the Namibian deep-sea red crab were estimated using the Ordinary Least Square method for the period 1990-2017. The results of the surplus model are as follow:

$$G = 0.34x\left(1 - \frac{x}{43{,}214}\right)$$

Growth (G) is measured in tons per year and biomass (x) in tons.

The coefficient of determination of the model, R-squared suggests that 99% of the variations in the surplus model are explained by the fishable biomass and level of catches. Hence, the model is best fit as only 1% of the variations are explained by other factors, not estimated in the model.

The rate of growth for the Namibian deep-sea red crab was estimated at 0.34, thus, the stock level can utmost increase by 34% annually, holding other factors constant. The estimated environment capacity without applying a single fishing effort is estimated at 43,214 tons, with a highly uncertain with a wide confidence interval of 12,064-58,259 tons. The estimated catchability coefficient of 0.000000252 as a measure of fleet efficiency suggests a trivial relationship between effort and harvests.

4.2 Estimation of economic parameters

The total cost function of the deep-sea red crab was estimated based on the cost associated with the fleet, as a function of effort. The coefficient of determination shows that 96% of the variations in the total cost is explained by effort. Therefore, the cost of deploying a unit of effort (baited pot) is estimated and assumed to be constant over time at US$ 17.21.

$$TC = 17.21e$$

Similarly, products prices generally fluctuate as a result of market forces of supply and demand. However, the average landed value for the period 2014-2017 is used as a proxy. The average landed value was determined at US$ 4110 per ton. The revenue function of the fishery was estimated as follows:

$$TR = p0.34x\left(1 - \frac{x}{43{,}214}\right)$$

4.3 Deep sea-red crab sustainable yield function

Given biological parameters as estimated above, the sustainable yield function of the deep-sea red crab fishery is presented in figure 12 below.

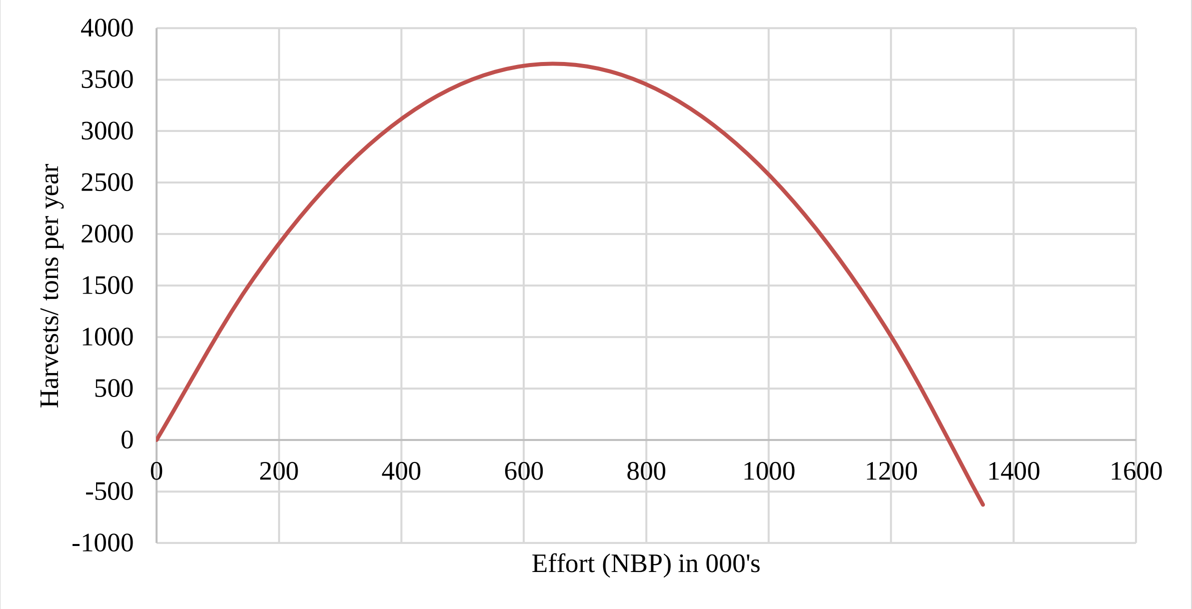

Figure 12. Sustainable yield function of the Namibian deep-sea red crab fishery

Figure 13 below shows the deep-sea red crab fishery sustainable yield, cost and profit functions and respective equilibriums points (MEY, MSY and BE) along the sustainable yield function.

The sustainable yield curve increases with effort until it reaches its peak, MSY and eventually falls as effort continues to increase. If the fishery operates at MSY, it can sustainably harvest 3,654 tons to maximize its revenue of US$ 15 million. While the highest revenue is achieved at MSY, harvesting at that level is not necessarily an ideal condition for a profit-oriented industry seeking to maximize economic rent.

By introducing cost as a function of effort, it is possible to determine the most efficient state of the fishery (MEY) and the cut-off point or breakeven point (BE), where total revenue and total costs are equal to zero. The cost function of the fishery is linear to effort (NBT) as shown in figure 13.

Economic rent is maximised at the sustainable harvest of 3,114 tons with the corresponding effort of 413 thousand baited pots.

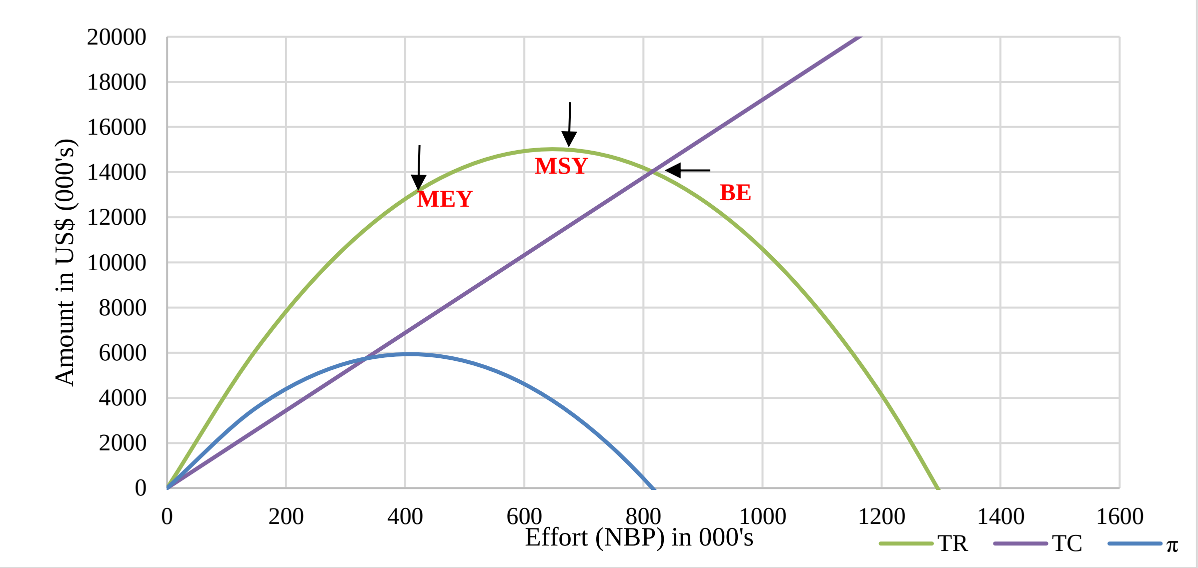

Figure 13. Equilibrium for the Namibian deep-sea red crab fishery, 2014-2017

Using 2017 as a reference year, the fishery is operating within a sustainable yield curve as exhibited in figure 12a. It harvested 3,644 tons, 10 tons higher than estimated MSY catches and exerted 480 thousand baited pots, about 60 thousand higher than effort at MEY.

The current operations of the fishery show significant profits of US$ 6.5 million, higher than it could realise at MEY and MSY respectively, whilst profit per unit in 2017 is US$ 1,788, lower than US$ 1,826 expected at MEY level. Although the level of effort exerted in 2017 demonstrates some level of efficiency in the overall operations, the profits are increasing at a decreasing rate.

If effort is increased beyond 826 thousand baited pots at the current level of harvest, the deep-sea red crab stock will be exposed to fishing pressure and as a result, a reduction in the sustainable harvests to 3,459 and profits to zero. This becomes the sustainable point of a resource under the open access regime, where the fishery operates at break-even point.

In brief, the model estimates suggest an economically viable business and profits at the current level of harvest and effort is about 43% of total revenue, as compared to 38% at MEY and 23% at MSY as shown in table 3.

Table 3. Sustainable equilibrium and current reference point of the Namibian deep-sea red crab

Fishing Season	harvest (tonnes)	Effort (NBP)	TR (US$)	TC (US$)	Profit (US$)
2017	3,644	480,897	14,978,672	8,463,787	6,514,885
MEY	3,114	413,070	12,797,720	7,109,090	5,688,630
MSY	3,654	671,177	15,018,780	11,551,210	3,467,570
BE	3,459	826,140	14,218,180	14,218,180	0

4.4 Sensitivity of reference points to price and cost changes

The prices of crab products and costs of productions are generally prone to variations arising from several factors such as demand, supply amongst others. As expected, the prices of crab products and costs of effort per baited pot varied during the period 2014-2017.

Table 4 shows variations of prices and costs, whilst figure 13 illustrates the associated impact on fisheries reference points respectively.

Table 4. Landed value per ton and cost per baited pot in US$ (2014-2017)

Fishing season	Landed value	Cost
2014	4,832	25.46
2015	4,110	15.81
2016	3,563	14.23
2017	3,936	17.60

The relative positions of MEY and BE along the sustainable yield function depends on the economic parameters, prices and costs.

As can be deduced from figure 14, the higher the costs of harvesting per baited pot, the steeper the cost function. Similarly, a higher landed value shifts the sustainable yield curve outwards.

The cost function for 2014 is much steeper than that of 2015, 2016 and 2017, which consequently drives effort to lower levels at MEY and BE. On the other hand, the fishery experienced the highest landed value in 2014 and 2015 and consequently, higher sustainable yield curves as compared to 2016 and 2017.

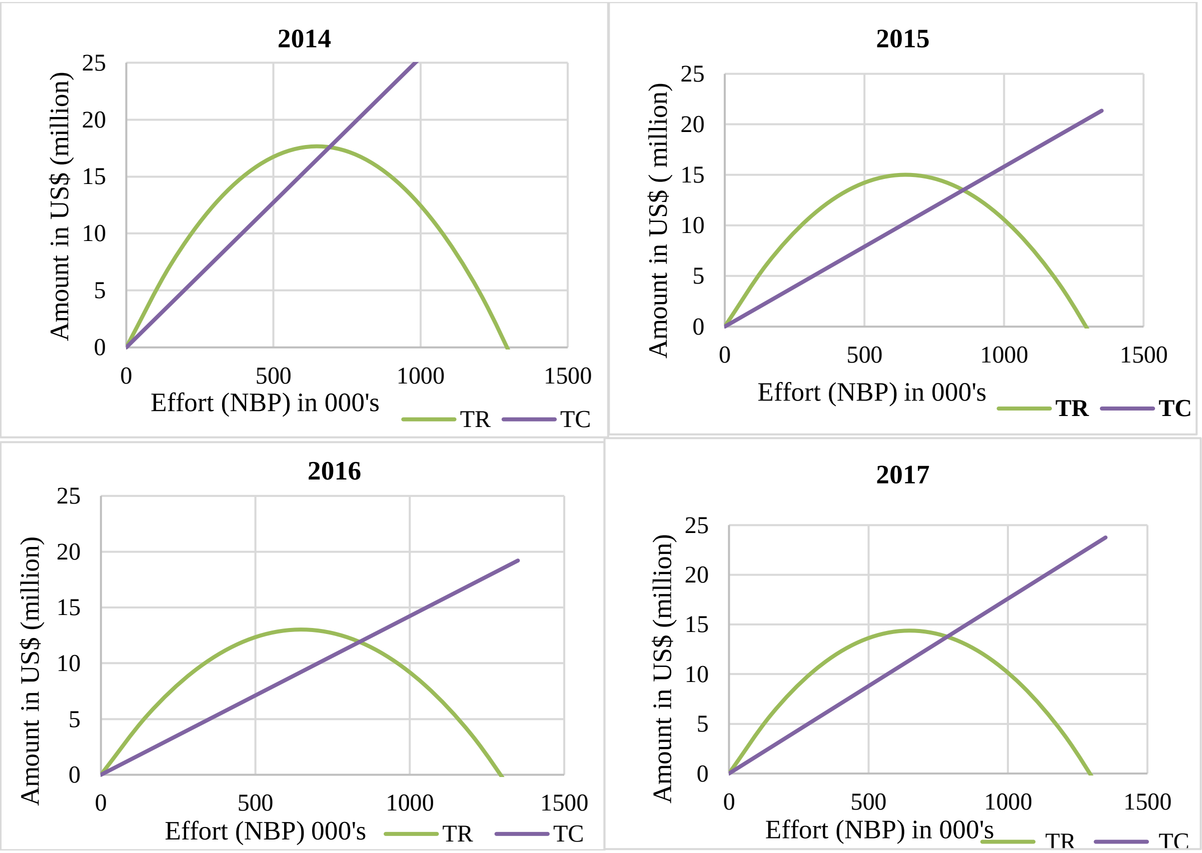

Figure 14. Sensitivity of optimal reference conditions to economic parameters

Economic parameters play a substantial role in determining the level of MEY and BE. From table 5, it is clear that price and costs variations explain the disparity between harvest and effort at MEY and BE, holding MSY level constant.

Using 2015 as a base year, a price increase from 4,110 to 4,832 in 2014 widened the harvest level gap between MEY and BE. This implies that the fishery maximises economic rent on a few catches whilst requires higher catches to break even. The opposite is true for a reduction in price per ton as illustrated in 2016. With regards to effort, an increase in cost from US$ 15.81 in 2015 to US$ 25.46 in 2014 led a narrow gap of effort levels between MEY and BE. As such, less effort was required to maximise economic rent and to break even in 2016 as compared to 2015.

It is important to highlight that the impact of the price and cost variations on reference points depends on the magnitude of the said variations and the profit margin per unit harvested. Thus, an increase and decrease in prices and cost does not necessarily lead to an increase/decrease in the harvest and effort at MEY and BE.

Table 5. Reference points for the Namibian deep-sea red crab (2014-2017)

	2014	**2015**	**2016**	**2017**
hMEY	2,798	3,198	3,163	3,038
hBE	3,650	3,340	3,395	3,537
xMEY	11,151	13,970	13,683	12,734
xBE	20,912	15,274	15,848	17,746
eMEY	346,384	433,958	425,043	395,563
eBE	692,769	867,916	850,087	791,127

5 SCENARIO ANALYSIS AND METHODOLOGY

Scenarios are generally defined as hypothetical constructs meant to draw attention to the key factors that will drive future developments (Goncalo Lobo, 2005). The use of scenario analysis as a method is important and useful in understanding the strategic implications and opportunities of an industry (TFCD, 2016). The importance of scenario analysis is recognized in providing clarity to stakeholders or policymakers of how an industry can position itself considering risks and opportunities. In addition, it provides forward-looking information to investors, lenders and insurance sponsors.

Developing scenarios is comprised of two crucial components. A clear understanding of the system structure is vital in assessing the relationship between different parts of the system and its boundaries that govern the system's development (Borjeson L. , Hojer, Dreborg, Ekvall, & Finnveden, 2006). The second aspect is concerned with drivers of change that are likely to influence the development of an industry. Drivers of change are classified into internal and external influences (Postma & Bood, 1998). Thus, the current state of the industry is an integral part of this evaluation, as it shapes the future.

Presently, about 99% of the deep-sea red crab fishery’s harvest is processed offshore, whilst the remaining 1% (about 21 tons) is handled and packed onshore since 2016. Hence, the existing processing plant, with a capacity of 4 tons per day is underutilized.

Four strategic scenarios were developed, to shed light on possible paths for future development, for the next 15 years and how they are likely to impact right holders and the processing town (Walvis Bay). The first scenario follows a business as usual path, two scenarios present how the future of onshore development, given onshore processing conditions of 25% and 50% respectively, and the fourth scenario presents a full utilization, promoting zero waste.

- Scenario 1: Business as usual
- Scenario 2: 25% onshore processing
- Scenario 3: 50% onshore processing
- Scenario 4: Full utilization of the crab resource

The strategic scenario analysis will help in addressing the following questions:

- What are the possible pathways for the future development of the deep-sea red crab within the context of key driving forces as identified?

- Does this benefit right holders and the general society? How does it affect the processing region?

5.1 Collection of data

Scenarios of explorative nature use different generating and data collecting techniques, workshops are considered for their effectiveness in collecting ideas, knowledge, and views (Borjeson L., Hojer, Dreborg, Ekvall, & Finnveden, 2006). An open-ended questionnaire was developed to capture crucial information from stakeholders related to the potential of onshore development, opportunities, and threats in the fishery.

The sampling design was based on the judgment of the researcher, founded on who will provide the best information to succeed for the objectives of the study, rather than underlying theories or a set number of participants (Etikan & Bala, 2017). Although the fishery is made up of seven right holders and four operators, the survey targeted four operators who are regarded instrumental, with relevant information to the scenarios. However, only three out of four operators responded to the questionnaire.

Due to lack of relevant data, such as market prices and associated costs of onshore development, to assess the impact of scenarios on the profitability, the narrations of scenarios are not supported by quantitative analysis and therefore, the assessment covered in this section is of descriptive nature that outlines how the deep-sea crab fishery sector is likely to unfold in 15 years.

5.2 SWOT analysis of the deep-sea red crab fishery

The analysis of scenarios in respect of the potential of the deep-sea red crab fishery requires an in-depth look at understanding the internal factors of the fisheries. These are strengths and opportunities and subsequently acknowledge weaknesses and threats in its dynamic environment (Oreski, 2012). Table 6 below summarises the SWOT analysis of the deep-sea red crab fishery

Table 6. SWOT analysis of the Namibian deep-sea red crab fishery

Strengths	Weakness
• Fisheries management system – stock is sustainably managed. • Harvesting and onshore processing capacity. • The international market for deep-sea red crab products exists. • Operational efficiency and cost-saving strategies (consolidation of quotas). • Communication across stakeholders (Crab Association of Namibia). • Technical know-how onboard processing in the sector. • Valuable species and products. • Underutilised onshore processing capacity. • International airport in Walvisbay (opportunity to export live crab).	• Little focus on research and development. • Limited resource. • Limited local expertise to produce specialised products i.e. biotech products. • Perishable products. • Old fleet.
Opportunities	**Threats**
• Opportunity for increased onshore development. • Potential for full utilization of deep-sea red crab. • Research and development on product development and general operating environment. • Live crab harvesting. • Establish cluster development strategy. • Potential for utilization of by-products. • Potential to invest in more economical and fuel-efficient vessels.	• High operation and maintenance cost as a result of long-distance fishing trips • Price taker. • Relatively small volumes of production. • Climate change and acidification of the ocean have a negative impact on crustaceans.

5.3 Drivers of change

The role of economics in fisheries management systems and its capacity to change behaviour of actors in fisheries has been acknowledged by many fishing nations. The policy environment of a fisheries industry is crucial in moulding the fishery sector into a well-developed industry, with socio-economic developments through a set of incentives (Pascoe, 2006). Although a series of fisheries policies have been established, environmental, political, socio-economic, biological and technological circumstances play a role in governing fishing activities. It is argued that uncertainty in fisheries management mainly results from the unpredictability in fish dynamics, inaccurate stock size estimates, and inaccurate implementation of harvest quotas (Gautam, Christopher, Anthony, Michael, & Larry, 2004).

Despite uncertainties in the fisheries environment, they cannot be a reason for inaction to development. Factors considered as drivers of change in this assessment are selected based on the judgement of the author, based on evidence of past trends on the associated impact they might have on the onshore development initiatives or on the likelihood to shift from its current position. The drivers of change to the development of the fishery includes: 1) Fisheries regulatory framework, 2) Fuel prices, 3) Fishable stock levels, 4) Technology and 5) Profitability.

5.3.1 *Fisheries regulatory framework*

Governance and systems controlling fisheries are key determinants in shaping the sector's growth and development. Fisheries regulatory framework creates a conducive environment for the industry to invest in onshore activities and transform raw materials into value-added products. Therefore, fisheries policies are an important driving tool in transforming existing challenges into opportunities by influencing the fisher's behaviours.

In the past, MFMR as a governing institution has implemented proactive management measures to encourage innovations and product development since 1990. For instance, the implementation of a 70: 30 policy in the hake fishery increased land-based processing to 70%. This policy is beneficial in discouraging the export of raw materials and simultaneously creates much-needed employment in the sector. A recent management condition introduced to promote onshore value addition initiatives in the horse mackerel fishery, in response to a National Development Programme Goal (NDP5) to reach a target of 70% by 2021/22. Such management measures are instrumental in driving development and exploring opportunities in the fishery.

5.3.2 *Fuel prices*

Rising fuel prices is a global phenomenon that is crucial in sectors such as fisheries. The deep-sea red crab fishery is highly fuel dependant as on-board processing factories are run on fuel. The cost of fuel contributes about 30-38% of variable expenditures (MFMR, 2018). In addition to market fluctuations of fuel prices, the vessels in the fishery are old (31 and 48 years) and expected to be fuel inefficient. Long distances to the fishing ground of about 300 to 690 km as well as intensive harvesting methods contributes to high fuel consumption. Figure 14 shows the fluctuation of diesel prices (N$/ liter) over a period of eight years, 2011-2019.

Although it is impossible to project the future trend of fuel prices for the next 15 years, observing the past trend as illustrated in figure 15, there is absolutely no reason to believe that fuel prices will decrease in the next 15 years. However, the impact of fuel expenditure will be relatively low for fuel efficient vessels. If fuel prices continue to increase, it will have a significant impact on the operations of future onshore development of the fishery.

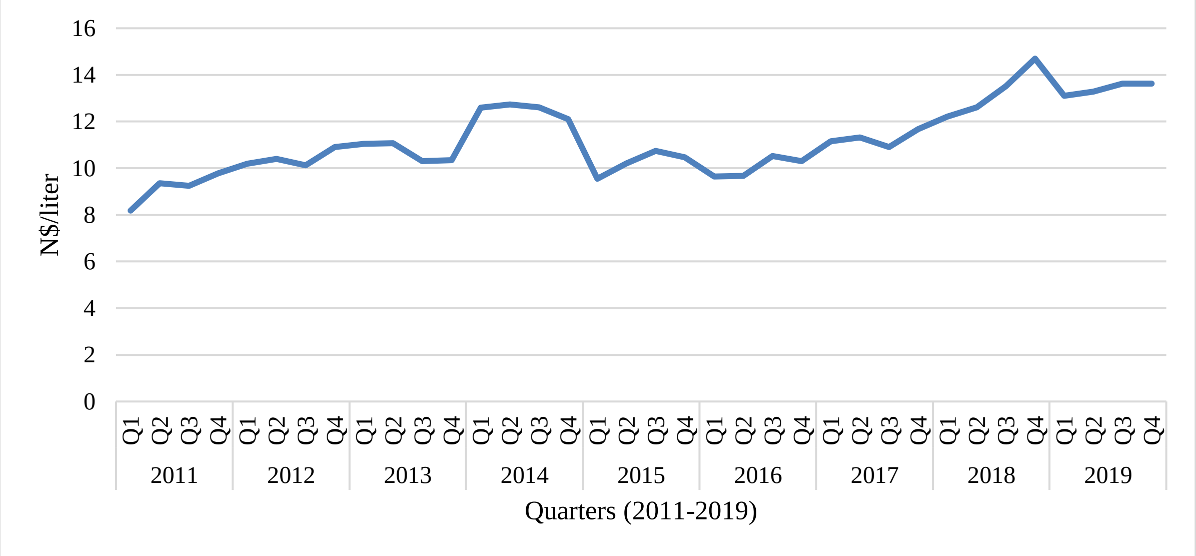

Figure 15. Diesel prices for the period of 2011-2019 (Ministry of Mines and Energy)

5.3.3 *Fishable stock levels and acidification*

Resource variability and uncertainty will remain a fundamental and possibly growing limitation in fisheries. Although the sector finds current levels of TACs as a challenge for onshore processing, its growth trends show a sustainable resource (MFMR, 2018) as confirmed by the bioeconomic results presented earlier in this paper. Therefore, it is assumed that the stock level remains relatively stable as illustrated in section 2, fig. 5.

Moreover, fisheries resources are prone to changes in the environment and can either cause a decline or increase in the general stock level species. It is important to acknowledge environmental challenges observed worldwide i.e. climate change and acidification of the ocean.

According to the Biscayne bay sea watch, an average PH level for seawater is about 8.2 but can range between 7.5-8.5 depending on the conditions in respective areas. On the other hand, the world PH levels of surface water is 8.1, a reduction by 30% (Malakoff, 2012). A study on acidification in the Atlantic Ocean found a PH of 8.05 in the South Atlantic central, 7.9 in the North Atlantic central, and the lowest PH levels in Antarctic Intermediate Water below 7.5, that gives an average of 7.00-7.76 (Ríosa, et al., 2015).

As the concentration of carbon dioxide continues to rise, it reduces the ocean PH levels and turns ocean water more acidic. This reduces the amount of calcium carbonate required during the moulting process of crabs that allows them to shed off unnecessary chemicals and grow (Chang & Michael, 2015). A reduction of calcium carbonate causes physical distress to crab and eventually poor growth, survival, reproduction, and behaviour (Harrould-Kolieb, Matthew, & Virginia, 2010). A reduction in the fishable biomass in the future implies a negative impact on profits for right holders and overall impact on socio-economic development of the fishery (i.e. investment, employment). Although acidification is a potential future threat to the fishery, it's impact in the next 15 years is less likely to affect to resource.

5.3.4 *Technology*

Technology plays an important role in harvesting and processing of fish and fish products. Technology in the production of the Namibian deep-sea red crab products can be key to maximizing product quality, increased throughput, and efficiency of onshore operations and better utilization of the parts of crab that is not utilised today. Whilst automation is seen as 'loss of jobs,' it has the potential to maximise value per unit and utilisation of by-products, which consequently creates employment opportunities from the by-products operations.

5.3.5 *Profitability*

The profitability of the fishery is an important factor in determining the capacity to invest in existing opportunities. Accounting profit is an important indicator as it measures the interactions of the balance sheet and debts (Gunnlaugsson & Saevaldsson, 2016). Although economic rent is important in economic analysis, the profit applied in this section is one that accrues to the deep-sea red crab fishery after all expenditures incurred in the process of harvesting, processing, and marketing are deducted. Because the fishery's fleet is old, ranging between 31 years and 48 years, it is reasonable to assume that the fishery is likely to be debt-free.

Earnings Before Interest and Tax (EBIT) reaped by the deep-sea red crab fishery ranged between 35% and 42% of the fishery's revenue, over the past five years (MFMR, 2018). Moreover, the bioeconomic model in section 3, confirmed that the fishery is economically viable, with sustainable profits during the review period 2014-2017. Based on how the four drivers explained above unfold, they will have a direct impact on the profitability of the deep-sea red crab fishery.

5.4 Scenarios for the future onshore processing development

In forecasting future development with respect to onshore processing in the deep-sea red crab fishery, pre-determined scenarios are assessed outlining how drives of changes described above might unfold over the next fifteen years. Since its difficult to predict profitability of scenarios and how fisheries regulatory framework is likely to unfold in the next 15 years, the analysis only considered fuel prices, fishable biomass and technology. Table 7 below shows the summary of how drivers of change are likely to unfold in each scenario.

Table 7. Summary of the role of key drivers in each scenario

Scenarios **Drivers of Change**	**Business as usual**	**25% onshore Processing**	**50% onshore processing**	**Full Utilization**	
				100% onshore	**Business as usual & onshore processing (by products)**
Fuel Prices	Increase	high	Very high	Excessively high	Reasonably high
Fishable biomass	Stable	Stable	Stable	Stable	Stable
Technology	No technological progress	Little technological progress	Moderate technology	Advanced technology	

5.4.1 *Business as usual scenario*

> **Definition**: Business as usual simply refers to the same way of doing things. Thus, it gives full responsibility to the right holders to utilize catches as viewed most beneficial to the business.

The production of deep-sea red crab in Namibia is an offshore based activity that encompasses the whole value chain from harvesting, processing and packaging export ready products. The fishery is flooded with offshore capacity, estimated at about 9,000 tons per fishing season. Onshore processing capacity is about four tons per day, equivalent to 960 tons per fishing season, if the plant is fully utilized four out of seven days per week. Hence, the existing onshore and offshore capacity is underutilized.

The average fishing trip ranges between 30 to 45 days at sea and harvests up to 200 tons in whole weight mass can be expected per trip, depending on the size and capacity of the vessel. Thus, it is reasonable to conclude that the fishery takes about 18 trips to fully land a TAC of 3,446 tons. Given four vessels in the fishery, it is assumed that each vessel harvests and process about 862 tons of the TAC per fishing season, which translates into five fishing trips per fishing season (equivalent to 7.5 months). This implies that each vessel spends about 4.5 months of the fishing season mooring at the harbour incurring costs such as harbour fees, salaries, maintenance, and repairs.

The Namibian deep-sea red crab stock is fished on the continental slope off the Namibian coast from the west of Cape Cross to the Angolan border (Melville-Smith,1989). The main fishing ground is approximately between 300 and 690 km from the Walvis Bay harbour. Moreover, deep-sea red crab is harvested in deep waters, mainly between 400-1000 meters, hence, the cost of fuel and vessel repair & maintenance are most crucial as crab vessels are fully equipped with processing plants onboard (MFMR, 2018).

By 2035, the industry's production is likely to remain offshore, with stagnant socio-economic benefits. In the absence of policy interventions regarding onshore processing, the fishery is not driven to explore the fishery's potential and invest in research & development. Therefore, opportunities are inadequate to expand the value chains. There will be little or no technological advancement and innovation. Considering a stable stock level, the industry is likely to be more efficient if its profits are re-invested in a new and more efficient fishing fleet.

5.4.2 *25% Onshore processing of deep-sea red crab scenario*

> **Definition**: This scenario refers to onshore processing that involves a landing obligation of 25% for onshore processing. Onshore landing obligation could either mean landing frozen or live crab. The choice of onshore processing relies on the preferences of the right holders to maximize quality and valuable products.

At a TAC of 3,446 tons (2017), a 25% onshore landing obligation of the deep-sea red crab is about 862 tons. Given the existing onshore processing capacity of about 960 tons annually, a 25% onshore obligation will result in full utilization of onshore processing capacity.

Since crab products are inclined to contract melanosis when poorly frozen, or frozen and defrosted for re-processing (Alex & Adriene, 2016), live crab harvesting capacity to preserve the quality products is ultimate. As such, it is necessary to transform one of the existing vessels by fitting live crab handling equipment with oxygenated system and chilling technology. Alternatively, the fishery may opt to invest in a new vessel fitted for live crab operations. This decision may consider several factors such as the existing harvesting capacity, the efficiency of operations, etc.

Due to the nature of live harvesting and handling processes, a reduction in harvesting days is expected from 30-45 days to approximately 10-15 days per trip, leading to an increase in the number of fishing trips. Consequently, a reduction in catches per trip based on the catchability rate of the fleet and tanks' holding capacity.

By 2035, onshore processing obligation of 25% would result in full utilization of the existing onshore processing capacity. In order to maximize economic returns from the onshore obligation, the industry is likely to explore high value products and secure lucrative markets. Furthermore, it is likely to utilize its by-products, even for low valued products such as crab flavoured soup in restaurants or as a source of fertilizer as has been practiced in other countries. Crab shells were, for example, dumped in Canadian fields in the 1980s and served as a source of good yields (Buendia, 1999) as they are rich in calcium and organic (Burrows, 2007). Although 25% may seem insignificant, it can potentially benefit local small and medium sized enterprises (SMEs) and consequently, regional development.

The 25% onshore processing is also associated with a significant increase in fuel consumption from the increased frequency of fishing trips. In terms of technology, the fishery would experience slow technological progress as it strives to fully utilize its onshore obligation. Since volumes are insignificant to invest heavily in technology, the fishery is better off increasing its onshore workforce for effective production of its onshore output.

5.4.3 *50% onshore processing of deep-sea red crab scenario*

> **Definition**: This scenario refers to onshore processing that involves an onshore landing obligation of 50%. Hence, equal distribution of onshore and offshore activities.

A 50% onshore landing obligation is 1,723 tons of 3,446 tons (2017 TAC). If 50% is landed as an onshore landing obligation, the fishery will double the existing onshore capacity of 960 tons annually to fully process its landings. In addition, at most two vessels should ideally be fitted with live crab holding capacity and equipment. Because this scenario is associated with sizeable volumes of by-products, additional onshore capacity may be required.

As half of the fishing fleet requires restructuring to accommodate live crab harvesting and handling processes, fishing trips will be shorter, from 30-45 to 10-15 days. Consequently, increase the frequency of fishing trips as well as in the cost of production resulting mainly from fuel consumption and maintenance of the fleet. Even though this scenario does not require full utilizations of raw material, utilization of by-products will be in the interest of the industry to create more value. Therefore, the fishery will invest in research and development for the development of value-added products based on by-product, depending on the viability of the projects.

By 2035, this scenario is associated with onshore and offshore investment, research & development and expansion of value chains. The fishery has access to 50% of possible by-products, which is likely to encourage value addition initiatives associated with by-products, and result in broader value chains. The industry will explore possible lucrative markets that can offer high premiums for its products. Additionally, onshore development will be characterized by moderate technological progress to ensure efficient and quality by-products.

5.4.4 *Full utilization of the deep-sea red crab scenario*

> **Definition**: Full utilization scenario entails full use of the total harvests (raw materials), from the traditional products to by-products that is currently discarded at sea as waste. In contrast to the onshore processing scenarios, the proportion of onshore production in the full utilization scenario is entirely dependent on the operator’s capacity and strategy. The concept of full utilization has never been practiced in the Namibian deep-sea red crab fishery.

Full utilization scenario is assessed in two outlooks, as it can be implemented by either 100% onshore processing or merging business as usual and onshore processing. by-products should be processed for economic value into either low or high valued products. Both options are associated with maximum utilization of by-products and thus, development of a new operation which requires significant investment in machinery and equipment onshore.

<u>Option 1</u>: *100% of onshore processing of existing products and by-products*

A 100% onshore processing option presents a scenario in which operators land entire harvests in its raw form for onshore processing. Hence, onshore production is made up of the traditional products and its by-products. This option requires full transformation of the operations including restructuring the fishing fleet from freezer to live crab handling, fitted with oxygenated tanks and chilling technology. An additional onshore capacity, to process about

2,486 tons is required for onshore processing of its traditional products. Additionally, there is need for onshore processing capacity for by-products from by-products, which depends on the intended type of production.

Full transformation of the operations is associated with shorter fishing days from 30-45 days to 10-15 days and a significant increase in the number of fishing trips. Consequently, an increase in the cost of fuel to ensure full utilization of quota and quality landings. This operation requires considerable capital outlay to develop both offshore and onshore operations.

Option 2: *Business as usual and onshore processing of by-products*

This option maintains ‘business as usual’ which involves offshore processing of traditional deep-sea red crab products and onshore processing of by-products. The industry may continue with its offshore processing of its traditional products, but the complexity of processes in processing by-products will drive the industry to onshore operations. The existing onshore processing plant in the fishery is an advantage for this option, nevertheless, the fishery might require an increase in offshore freezing capacity in vessels to ensure quality landings of by-products.

The implementation of full utilization scenario may be the beginning of a biotech industry to produce chitin and chitosan from deep-sea red crab shells that is currently discarded at sea as waste. Biotechnology industries are intensive to develop and are associated with risky processes that are costly and time consuming to develop, yet, they can be profitable in the long run (John et al, 2002). The development of a biotechnology industry to produce chitin and chitosan in Namibia will not only attract high skilled jobs and improve productivity but also, impart knowledge to the residents of Walvis Bay and beyond.

However, this initiative will require collaborative effort through ‘clusters’ to take advantage of available skills, limited resources amongst others. Michael Porter described the concept of clusters as an array of linked industries and other entities important to competition, which may include companies in industries related to skills, technologies, or common inputs, governmental and other institutions such as universities that can provide specialized training, education, information, research, and technical support (Porter, 1998).

Chitin production from crustacean shells is practiced and competitive in some nations such as Asia. Although it was assessed feasible in the UK around the 2000s, it was found to involve economic processes that do not justify investment in a chitin manufacturing plant (Archer & Russel, 2008). UK’s annual production of crab was about 20,000 tons, at the time of the assessment.

By 2035, the deep-sea red crab fishery will be fully onshore based, with a well-developed and possibly broader value chain from utilizing by-products. Technological advancement will encourage the industry to explore value addition opportunities and access new markets for high valued products i.e. live crab and consumer ready products to maximize earnings.

6 DISCUSSION

6.1 Bioeconomic model

Using 2017 as a reference year, harvests of 3,644 tons reported in 2017 is below, but very close to MSY levels (3,654 tons), whereas effort of 480 thousand deployed during the same year is closer to effort at MEY (413 thousand).

The model estimated the deep-sea red crab fishery to be economically viable and its current profits have the potential to serve as incentives to invest at the current level of harvest and effort. The fishery secures about 43% of total revenue, as compared to 38% and 23% at MEY and MSY respectively. MSY level at 3,654 tons in 2017, is 6% higher than a TAC of 3,446 tons set during the same fishing season. On the other hand, MEY is estimated at 3,114 tons. Since, MEY is globally accepted as a fishery management tool to manage the resource sustainably (Kar & Chakraborty, 2011), the results confirm a sustainably managed stock. Even though economic rent is not fully maximized, the effort exerted is evidently somewhat efficient and its profits are higher than the fishery would have made at MEY.

On average, the fishery operated between MEY and MSY during 2014-2017. Furthermore, the prices and costs change as assessed on the impact on reference points during of the period 2014-2017 were highly variant but the fishery remained profitable. There is no doubt the right based management system implemented in the deep-sea red crab fishery has contributed to a stable profitability state of the fishery. Based on the results, steady state is most profitable and sustainable as it harvests within MSY levels.

6.2 Scenario analysis

It is rather clear that offshore-based production has proven to be an ideal situation to the industry for over 40 years as it provides the best incentives for the industry because of its minimal cost of production, less technical processes and simplicity procedures in handling and processing of the main demanded product (sections), which basically involves butchering and sectioning using crustacean hand scissors. It is also evident that onshore processing potential exists in the Namibian deep-sea red crab fishery, which can potentially lead to new value added products such as crab meat, crab sticks, live crab and utilization of crab by-products, thereby increasing the economic value of the resource.

Live crab is highly demanded in China, Republic of Korea and United states (FAO, 2019). During 2010-2013, the Namibian live crab was exported to the Middle East, Malaysia, Singapore, USA, and South Africa in 2010 (MFMR, 2011). However, the live crab project was discontinued majorly due to lack of direct flights to export markets at the time. Although crab shells have never been utilized for economic value in Namibia, crustacean shells are utilized for several purposes in the agriculture and health industries worldwide (Burrows, 2007; Buendia, 1999; Ratch, n.a)

Onshore processing presents three main options available to the fishery regarding shell waste; disposing of shells as waste, development of value-added products or supply by-products to possible customers. The fishery can dispose crab waste as it is, by contracting a waste management and disposal company. Disposal of crab waste onshore must be handled in accordance with the Namibian Environmental Impact Assessment regulation of 2011, which inevitably imposes a disposal cost to the fishery. A study conducted on the cost of disposing of shell waste in UK revealed that crustacean waste disposal is uneconomical (Archer & Russel, 2008). Alternatively, operators can explore other means of creating economic value, by either developing value-added products (low or high valued) or securing a market for by-products in their raw form. Developing of value added and supplying by-products to possible consumers options requires immediate treatment and storage to maintain the quality of the shells as illustrated in fig. 15.

Unlike onshore processing scenarios, option 1 (fig. 15) is not applicable in full utilization scenario. Based on the appropriate and convenient utilization strategy that fits the business, the industry can opt to restructure the entire operation for full onshore processing or combine 'business as usual' and 'onshore utilization of by-products'. Although several studies confirmed high chitin content in crab shells as compared to other crustaceans (Arbia et al. 2013; Andrade at al. 2012), this study is relevant in determining the viability of Namibian deep-sea red crab. It is worth pointing out that onshore operation, specifically in for the utilization of by products (i.e chitin and chitosan) may require expensive foreign technical expertise. Figure 16 below shows the options available to the fishery in an onshore processing.

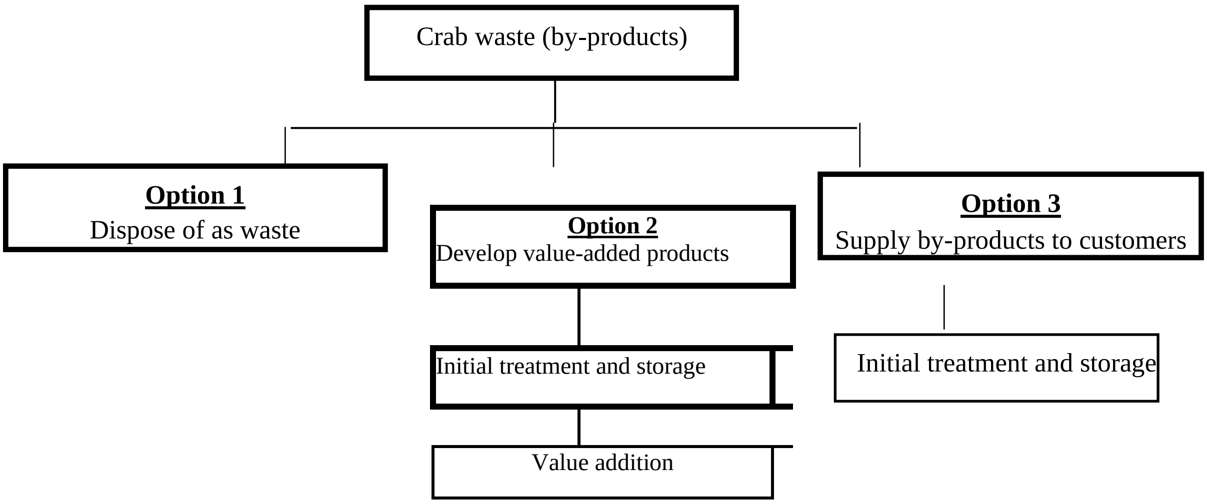

Figure 16. Main options available to the fishery for handling crab waste

The nature of onshore operations would, however, increase environmental negative externalities with a fuel inefficient old fishing fleet accompanied by frequent fishing trips. It is expected to increase carbon dioxide emissions (Greer et al, 2018). This is contrary to the UN sustainable Development Goal no. 14 and the blue economy objectives that seek to sustainably protect marine and coastal ecosystems from pollution and address the impacts of ocean acidification.

6.3 Limitation of the study

The study was subjected to several challenges that unfolded during the progress of the research. The most important challenges are highlighted as follows:

- The bioeconomic model only utilised available economic data obtained from two out of four operators, for a period of four years.

- Data collected from the Namibian deep-sea red crab fishery (stakeholders) was insufficient and lacked quantitative data to support scenario analysis. Moreover, only three out of four operators responded to the questionnaire.

- Finally, there is limited literature on utilization of by crab products for the chitin and chitosan derivatives productions.

These limitations, however, did not have a significant impact on the analysis provided in this paper, as information used is representative enough with the bioeconomic model and scenario analysis. On the other hand, limited information on by-products utilization does not provide a full picture regarding its potential in the Namibian deep-sea crab fishery.

7 CONCLUSION

The purpose of the study was to assess the economic potential for the Namibian deep-sea red crab fishery by establishing the optimal economic position, in view of the ecological characteristics of the deep-sea red crab stock. It further assessed the potential of onshore development by means of scenario analysis technique to predict how the future of the fishery is likely to be in 2035 under drivers of changes and seek to suggest management measures.

Firstly, the bioeconomic models confirms a sustainable and profitable fishery at the current level of effort and harvests. Therefore, it is recommended to maintain status quo as the industry appears to be in a good position, given a sustainable resource.

Secondly, onshore processing potential existing in the fishery, though, it requires a comprehensive cost-benefit analysis to assess the feasibility of the scenarios. This assessment should encompass technical modifications associated with transforming the fleet to handle live crab. Market analysis of potential products from by-products as well as high valued products such as live crab. The assessment should further consider possible environmental, social and economic implications.

It is important for MFMR to consider a relatively low proportion (i.e. 25%) of annual catches for onshore processing obligation. Without disregarding the need for cost benefit analysis, a smaller proportion is likely to be associated with low risk as it can gradually introduce the fishery to onshore processing. In addition, the industry would be more flexible to explore possible adaptation options whilst maintaining business as usual on 75% of the harvests. This intervention makes provision for the fishery to make effective choices regarding its operations such as investing in a more fuel-efficient vessel with less carbon dioxide emission.

Considering TAC levels, the implementation of such intervention may have high regards of cluster development strategies (Porter, 1990; Porter, 1998a; Porter, 1998b) to ascertain competitive advantage and share associated risks. Therefore, coordination between stakeholders; MFMR, right holders, and operators in order to continue running a profitable and efficient operation is of outmost importance. This includes coordination of long-term business arrangement for consistency in supply of raw materials to operators.

Lastly, there is need for collective effort to strengthen research, capacity building and communication gap bridge between the stakeholders (government, universities and fishing industry). This might improve conditions to explore the potential of the crab industry and facilitate initiatives and innovations such as utilization of by-products of for economic value.

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