TRAWLING AND LONGLINING IN THE NAMIBIAN HAKE INDUSTRY

by

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Master of Science in International Fisheries Management.

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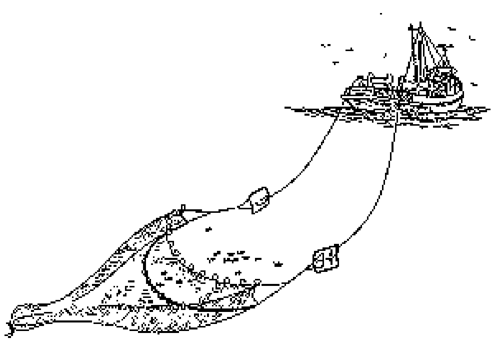

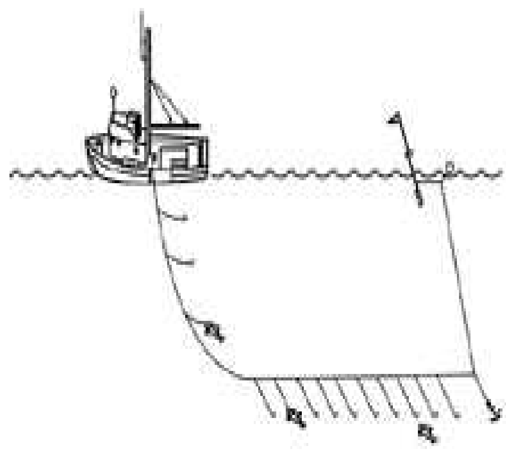

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Dedication

This work is dedicated to my parents. My father, the late Matheus Elago though time was not enough for us to know each other, I will forever wish I knew you more. To my mother, the late Hileni Elago your memories keep coming back to me and will never fade away. We will meet one day. I love you mum!

✞

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I thank the Almighty, keeping me in a positive state of mind. I pray that he will continue to lead and guide me as I continue my journey to further my career on the path that he sees fit for me.

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To all my friends, especially those who kept in contact with me via Internet and phonecalls, to those reading the paper, I wish you a blessed life, God Bless You All.

Pandu Elago

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Abstract

Two hake species are caught off the coast of Namibia. These are Merluccious capensis and Merluccius paradoxus, and they are not distinguished between in catches . Two fishing fleets harvest hake, these are trawlers and longliners. In this study, the focus has been on the biological and economic characteristics of two different fishing methods. The Pella and Tomlinson surplus production model was used, and the parameters estimated by applying time series of catch and effort data. Revenue and cost were estimated in order to do an economic assessment of the hake fishery. The results from the model analysis suggests a higher benefits (economic rent) from the longline fishery only, with high catch rates, high effort, revenue. The model indicates that the level of stock from both longlining and trawling are operating under a sustainable level of fishing effort. The maximum theoretical resource rent of the trawl and longline fisheries amounts to N$891 million and N$1,7 billion respectively. However from the current hake stock we will expect a decrease in catch in a long run (trawl fishery) with a stable or even a decreased effort from today's fishery for Namibian hake to be at the level of maximum economic yield of effort and catch. The higher rent generated by longliners is due to the high price they receive for their landings which is usually exported; and the different selection pattern from the two fishing fleets. Thus, a difference of N$802 million will accrue to longliners according to the model results.

Keywords: Namibia, Hake, Trawling, Longline, Bioeconomics.

1. Introduction

1.1 Introduction

Before Namibia became independent in 1990 there was no local hake industry to speak of. Only in 1991 did Namibia took full control of its resources for the first time. Hake stocks were exploited under no jurisdiction by distant water fleets (see Sumaila 2000a). After independence, regulations were put in place. Ironically, this industry has proved to be somewhat of a benefit to the Namibians after independence as a healthy demand for Namibian hake had been created in the European market, (see Stievenart, 1998). The future of the Namibian hake industry has looked bright since then. The hake resource is the most important commercial resource in the demersal sector of Namibia's fisheries, in terms of both landed mass and exports value (see Westhuizen 2001). The industry generates foreign exchange and provides employment. Debate on the comparative merits of longlining and trawling for hake has been going on for sometime now. The issue of the appropriate level of longlining effort for hake has arised in several areas. A move around the world toward longlining and away from trawling with recent concern about the environmental impacts of trawling has sharpened this (Namibian brief, 1998). As demand for fresh fish increases the conflict over the placing of longlines on fishing grounds needs to be addressed. One of the main issues focuses on the efficiency of longlining and the increased concern about the environmental impacts of trawling.

Hake is traditionally caught by large bottom trawlers, but a trend in the world market to pay higher price for line catch of hake has resulted in development of a line fishery for hake in some countries.

1.2 Objective of the study

The main aim of this paper is to look at the fish stock that is harvested by two different fishing gears and how this will impact the biology and economics of the fishery. Consideration is taken into the theoretical aspects of two fishing gears, trawling and longlining fishing hake. One interest is to undertake an economic assessment and analyse the potential of the resource in biological and economic sense. To investigate which one of the two fishing method are both biologically and economically beneficial to the hake sector. But most importantly, I would aim to provide insights that would increase the ability of Namibia to benefit economically from the resource in a sustainable manner. Even though few companies are using longlines in Namibia today, the understanding of how beneficial it is compared to trawling is yet to be studied in the Namibian context. The selectivity from the two gears is very different, with trawling catching a variety of sizes of fish and longline catching mostly older matured hake. One will question if longline fishery will bring positive or negative effects on the trawl-based fishery; and which of the two methods, trawling and longline, will provide the greatest economic benefits.

A Pella and Tomlinson (1969) surplus production model is used, with cost and revenue functions added. A short summary of the impact on the biomass of the hake stock caused by longlining and trawling will be analysed. Although detailed data are not readily available, the direction of a comparison of trawling and longlining on economic grounds seems clear.
Chapter 2 brings the reader some background information on the Namibian hake fishery. Chapter 3 presents the basics for the models used. Chapter 4 covers the data set applied, followed by the results from the model in chapter 5. The thesis results are summarised in the discussion and conclusion parts, chapter 6.

Background information was obtained from the Ministry of Fisheries and Marine Resources (MFMR) in Windhoek, as well as from the Marine and Research Institute (MRI) in Swakopmund. A bioeconomic model of Pella and Tomlinson used was adapted from Eide (1989). The economic data used were taken from a study by Hutton and Sumaila (2000). Related theoretical books were collected to give a full description of trawling and longline fishery. Fisheries biology textbooks and journals were used to guide the understanding of the model.

2. Background of the Namibian Fishery

This chapter takes us to the time when the marine resource in Namibia was identified and became one of the main sources of income for the country. It covers part of the developments before and during colonialisation time, up to the time when Namibia got its independence in 1990. It will give an overview of the fishery sector touching on the structure, commercial species in Namibia waters, the distribution and marketing of Namibian fish, employment level in the sector, and regulations that are followed in the fishery sector.

2.1 Location of the fisheries

Namibian coastline stretches about 800nm (about 1 500 km). The shelf area from the shore to 200m depth is approximately 110 000 km^2 , and to 1000m depth, approximately 230 000 km^2. The coastline extends from the Orange River in the south to the border of South Africa and Northeast in Angola. Nearly all the fishery occurs in the shelf area. The widest shelf part lies off the Cape Cross-Walvis Bay area and off the Orange River in the South. The hake fishery is located off the west coast of Angola and Namibia from latitude 15^o to 30^o south. The waters of the Namibian coast are cold, with an increase level of biological productivity, which is a result of seasonal South East winds that induce upwelling in the Benguela current at the coast, making available an abundant supply of nutrients in the upper layers. The Benguela current system is located off the South East Atlantic coast of Africa between 15^o and 35^o south. It is one of the four major eastern boundary current systems in the world, (Boyer and Hampton, 2001).

2.2 Development of the fishery

2.2.1 Past situation

> In pre-colonial times fish were an important source of food for the small Khoisan communities who gathered, trapped or speared their prey in the shallow coastal lagoons of the central-northern Namib Desert.
>
> Moorsom, (1984).

During the 18th century, vessels from Europe and North America came as close to the Namibian coast in search of whales and seals. Later the Germans came, settled and Namibia became a German protectorate in 1884. Under German rule, people, especially, from Europe started to move to Namibia for trading and tourism. Namibia is one of the few countries in Africa that became independent as late as 1990s. Hake resource off Namibia has a history of exploitation spanning more than 40 years.

Overexploitation of the resources was the main problem to the sector because of the late regulation that came into existence after independence. Catches are recorded since 1965 by the International Commission for the South East Atlantic fisheries (ICSEAF). Before independence, fishing for hake was divided because of political factors between the offshore fishery, which was dominated by distant water fleets of freezer trawlers, and inshore fishery that includes small freezer and wetfish trawlers. The longline fishing for hake along the Namibian coastline has been practised since 1983.

Even though the longline in Namibia was practised directly on hake, there has been a major by-catch of kingklip (*Genypterus capensis*) and monk (*Lophius Vormerinus*) from the longliners. Generally longlining has a low level of by-catch and discard compared to the by-catch that trawling takes up (Anon.,1997).

2.2.2 Present situation

From the total demersal fishery landings, around 87% is reported to be hake, with the remaining consisting of monk, sole, kingklip, snoek etc. The hake stock is one of the most important fish species in Namibia benefiting the economy from both high earnings and catches. It's estimated that hake contributed about 7.4% of Namibia's estimated export in 1994 and projected export value of N$2 900 million in 2000. The fishery (hake) contributed about N$951 million to Namibia's GDP in 1997 and generated more than

10% of GDP since 1998 (Sumaila, 2000c; Boyer and Hampton, 2001). In 2001 the TAC for hake was amounted at 200 000 tonnes comparing to 1990 when it was 60 000, showing a good progress in the industry after ten years of new management. TAC for hake has declined from 260 000 in 1999 to 194 000 in year 2000 but increased again in 2001.

The "decline" for 2000 was due to the TAC calculation procedure, called "Interim Management Procedures" or IMP introduced for the past three years. This procedure is currently being revised because both the ministry and the industry were not happy about the new invention. The main idea underlying the candidate IMPs considered is that the TAC each year be determined early in that year by adjusting the previous year's TAC up or down depending on the rate of increase or decrees in the size of the resource (Butterwoth and Geromont, 2001).

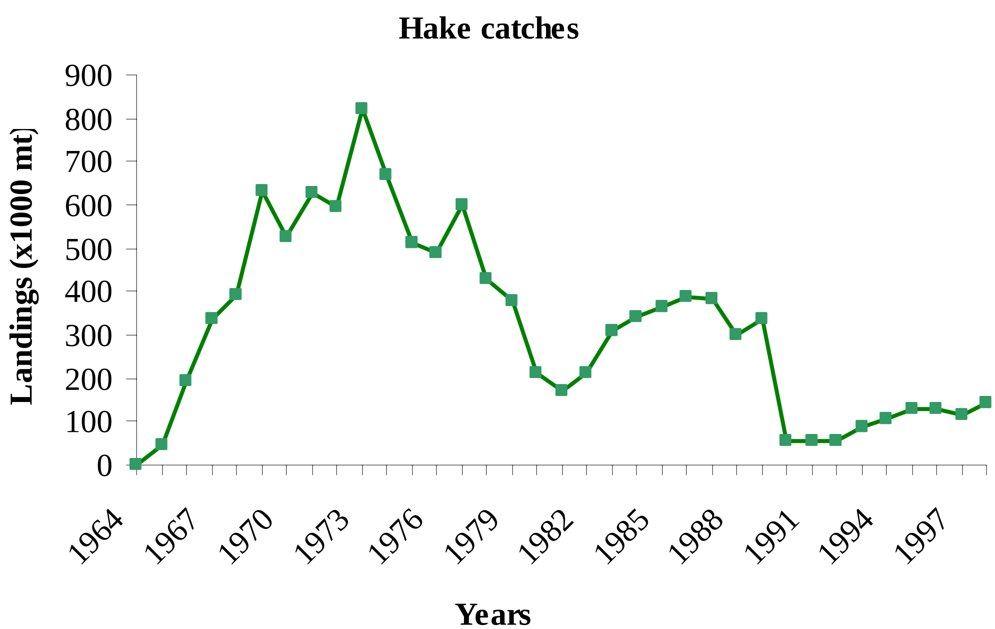
2.3 Species composition

Over 20 commercially exploited fish species are landed from Namibian waters. The commercially exploited species are found in three major resource groups comprising of the epipelagic shoaling species, the semi-pelagic fisheries and the demersal fisheries. In the later years, the deep-sea fishery was introduced and added to the group composition. Landings in volume for the demersal fishery are lesser than the pelagic fishery but it is still the most valuable fishery for Namibia than the pelagic group. The cape hake (*Merluccious capensis*) are found in shallow water occurring at 200 meter isobath, and the deep-water hake (*Merluccius paradoxus*) occurring in deeper water at 350 meter isobath to the south. However it is reported in Crawford, *et. al* (1987) that stock separation is not well understood in regard to hake species, but, from consideration of trends in catch and effort and geographical patterns of deployment of effort, four stocks of Cape hakes have been recognised by ICSEAF for assessment purposes.

Over the years, the fishable biomass of Cape hake and deep-water hake has been reasonably high. Hake grows to more than 1m length and live up to 12 years or over, spawning throughout the year. During the day they stay deeper in the sea and rise to mid-water during the night. They are unselective predators feeding on demersal and semipelagic fishes.

From 1964 to early 1970's there has been a rapid build-up of fishing effort on the stock, with catches reaching a maximum of over 800 000 tonnes in 1972. It is believed by many that the catch was considerably higher, (Sumaila and Vasconcellos, 2000a). This hake fishery started in 1964 (Figure 2.1 below). During this period there was a high increase in the number of deep-sea stern trawlers that have led to a rapid and uncontrolled increase in fishing pressure on the resource. Hake was the main target of distant water fleets at that time. According to the FAO statistics, the world catch of hake has been increasing during that period of the 1960s. The effort remained at a high level toward the end of the 1970s but with declining catches and catch rates. In 1975, an increase in mesh size was introduced with an increase to 110mm, and by 1977 the TAC's exceeded the actual catches by more than 100 000 tonnes for the year up to 1980. During this period the fishing effort was doubled.

Figure 2.1 Total hake landings since 1964 –1998.



Source: Crawford *et. al* . (1987), Anon., (1998).

Toward the years of 1980, the effort in hake fisheries declined and highly rich year classes in 1982-83 were recorded. This high period attracted an increase in effort at the time. The conditions have been stable at around 300- 400 000 tonnes for most of the eighties. It is reported that up until 1985, 99% of hake catch was landed by distant water fleets, (in Sumaila and Vasconcellos, 2000a). During the year of high catches, its known to have been because of a large proportion of young fish between the ages 2-3 years old, accounting to the low catches in later years, (Hamukuaya, 1994). The global introduction of the EEZ off the coastal states in the mid 1970s necessitated the search for new fishing areas.

Demand for fresh and frozen white fish for human consumption has always been minute in Namibia and limited in South Africa (Moorsom, 1984).

Table 2.1 Total Allowable catches and landings of hake in Namibia, 1990-2000.

Year	**TAC**	**Landings (in mt)**
1990	60 000	55 047
1991	60 000	56 135
1992	90 000	87 588
1993	120 000	108 102
1994	150 000	112 228
1995	150 000	130 374
1996	170 000	136 052
1997	120 000	117 622
1998	165 000	150 695
1999	260 000	166561
2000	194 000	194637

Source: Gordon *et. al. (*2000)

Since independence hake stock has been growing after the time of heavy fishing. Between 1987 up to 1991 the TAC remained stable at 60 000 tons. From 1991 there has been significant increase in the hake landings that was followed by a steady decline between 1996 and 1997. Year 1998 was again a good year.

2.4 Fishing fleets for hake

In Namibia, trawlers are divided into two parts for hake, the wetfish trawlers and the freezer fish trawler. The total allowable catch (TAC) for hake has been splitted into the wetfish vessels (land-based processing) and the freezer vessels (processed on sea). One of the reasons splitting the TAC was a necessity by the government to create employment. In 1993 only 20% of the hake TAC was allocated to the wetfish vessels and the rest was to freezer trawlers. In 1994, it was increased to 40% for the wetfish. In 1995 the government allocated 60% and 40% for wetfish and freezer respectively, in favour of wetfish trawlers but this target was not achieved in that particular year mainly because there was no increase in the TAC for the year 1994-1995, (Sumaila, 2000c). The wetfish quota, created some thousands new employment opportunities for the industry. The government's policy target to achieve the allocation of 6:4 ratio in favour of wetfish.
Sumaila (2000a,b&c) addressed the question of which type of vessel (wetfish or freezer) should land Namibian hake catches. In other words, if both vessel types are employed in the stock, what proportion of the catch in regard to TAC should each vessel group land? In his studies, he considered the government quota allocation policy (target) of 60:40 for the wetfish and freezer trawlers, respectively. Sumaila concluded that for both the wet and the freezer trawlers, the highest economic (market) gains will be achieved when only the wetfish trawlers are allowed to harvest hake, making the 60:40 policy not optimal if the maximization of market values was the only goal.

2.5 Marketing and Distribution

Namibian fish is sold in the international market. About 98% of Namibian fish is exported especially to Europe and other Africa countries. Only about 2% of fish is consumed within Namibia. This shows a decline in fish consumption that was estimated to be around 10kg in 1998. Namibia being a member of Lomé Convention has free access to the European market to export its fish and fish products. For the longline hake fisheries, the market is mainly in Spain because they are able to pay the price for the fresh hake products.

2.6 Fisheries Regulation

The fisheries regulations in Namibia play a big role in the development of the whole country. The policies are aimed at securing increasing benefits for Namibia. Because of the Namibian history of colonialisation and open access to all the marine resources, there was a need to set new regulations after independence. The marine resources have been overexploited to a high degree, and caused damage to the sector. On December 1991, the policy framework of the Government of Namibia in relation to the management of marine resources was set out in the Government White Paper titled "Towards Responsible Development of the Fisheries Sector" (1991). The policy was documented to serve the Namibian people, with the government taking over the responsibility in allocating rights and access to the marine resources. The White Paper describes the goal of fisheries management and development. Policies were translated into legislation by the new Sea Fisheries Act, which came into force on 1 October 1992. The main objective of exploitation rights and quota system is to limit and control fishing for resource management purposes.

The hake stock is currently managed on the basis of a total allowable catch that takes into consideration the rate of increases or decrease in the size of the resource, Van Der Westhizen, (2001).

The average total annual number of fishing rights issued by the MFMR is about 152 across all fisheries. The majority of the fishing rights (38) are for hake and the rest og to other fisheries. In February 2002, the ministry of fisheries announced that no new fishing rights would be awarded for the next six years until 2007. The only exception will be the horse mackerel sector. This limitation of rights is because of the need to monitor the fisheries for the few years to come.

2.7 Aspects of Trawling and longline

(i) Resource consideration

A good indication of the status of a resource as well as the likely effect of the fishing method to be employed on the stock can be achieved through modelling. In a longline fishery targeting hake, other types of longline fisheries can be affected depending on hake species, i.e. the deep-water hake and the shallow water hake when considering the impact of the longline fishery.

From the theoretical perspective, longlining has a more favourable impact on fish stocks than trawling. As stated in Anon.,(1997), a model consideration on the impact on the biomass of the cod stock caused by longlining and trawling with three different catch levels concluded that longlining reduces the biomass less than the trawling. In the scenario with the highest level of fishing, longlining was shown to reduce the biomass by only around half the biomass level of trawling (Anon., 1997). This clearly shows that from the same stock, longlining would support higher sustainable yields with sustainable catches from longlining being around double that of trawling under the heavier fishing pressure.

Anon.(1997), concludes that the low level of longlining in Namibia was not impacting significantly on the hake stock after a research directed on the implications for Namibia of hake-directed longlining in the Benguela region. The same study also concludes on the South African case study on hake stocks, that longlining is biologically acceptable, compared to trawling, it will provide less risk to the stock, as the spawning biomass will not be reduced to a low level. In a South African study by Hutton and Sumaila (2000), the greatest benefit accrues to the longliners if they engage in a non-cooperative strategy[1] and increase in fishing mortality, with the benefits achieved only if the trawl sector

[1] As explained in Sumaila (1999a): A non-cooperative strategy is one in which there is no 'good' communication between the players (i.e. considering a fishery with two groups of participants); no binding contracts can be entered into; and players take the actions of the other in the game as given, and then decide their own actions unilaterally. A game means, any activity involving two or more participants each of whom recognizes that the outcome for himself depends not only on his own actions, but also those of other

reduces effort. While the greatest benefits to the trawl sector occurs if they reduce fishing mortality under a cooperative strategy[2].

The effect that trawling and longlining have on fishing mortality also adds to the most effective gear. When trawling, some fish try to escape the gear through the mesh and in most cases they are heavily damaged and cannot survive anymore. Predators will either take them if not they die. In the case of longlining there are high concerns of seal predation reducing the recorded landed weight of the fish.

(ii) Economic efficiency

The handling of hake from trawling and longlining is very different. For trawling larger companies can easily handle the care but as for longlining, it is suitable also for even small business because it is less capital intensive, which is difficult for larger businesses to compete with. On economic grounds the direction of comparing trawling and longlinig is clear. It is important that the catches are processed in the most economically efficient manner. Time is used in handling the catches from a trawl that is landed at one time. Longlining on its side, handles one fish at a time as it comes on board, it is immediately packed on ice and therefore the quality is much higher than catches from trawl. These come along with the prices that the fresh longline hake market dictates internationally. The value between the two, longline and trawling catches, are recognised differently.

It is worth mentioning that even though longlining seems to be more favourable or best in almost all cases, the market for freshly exported airfreight fish is limited.

As one of the important policies for Namibia to create more jobs in the fishing sector, longlining creates more jobs than trawling. An example is presented in the table (Table 2.2) below extracted from the MFMR report. It is stated in Van Der Westhuizen (2001) that employment in the hake fishery as a percentage of the total employment in the

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participants. The management of each fleet takes the actions of the other as given, and chooses its own strategies to maximize own discounted economic rent.

[2] A cooperative strategy is the opposite of the non-cooperative. There is no commander, and players work together freely and cooperatively to determine a TAC and its allocation to themselves. The outcome and hence the payoffs to each player must be at least as much as what the player will receive if he decided not to cooperate.

fishing sector have increased from approximately 3% in 1990 to 60% in 1999, making it the major contributor to employment in the fishing sector.

Table 2.2 Employment by trawling and longline fisheries.

	Small Wetfish Trawler	**Freezer Trawler**	**Longliner**
Average Annual Catch (mts)	700	5000	500
Crew	12	50	24
Jobs at sea per 1 000 mt	17	10	48
Factory jobs per 1 000 mt	40	0	40
Total jobs per 1 000 mt	57	10	88

Source: Anon., (1997).

Table 2.2 compares jobs at sea and in the factory for both trawling and longlining. This data does not represent the entire industry but only takes into account a certain portion of it. Data here does not include other jobs on land outside the factory for maintenance, transport and so forth, where longlining creates more jobs because of the extra jobs involved in trucking and air freighting fresh fish compared to shipping frozen hake from factories or freezer vessels out of the port, (Anon., 1997). The table shows that longlining creates 70% more jobs than wetfish trawling, and more than eight times as many jobs as freezer trawlers.

This consideration seems to be the strongest of all, decreasing the level of unemployment for the Namibian people and at the same time making it one of the high valued species in the market when it comes to fresh hake.

With limited market one will not expect replacement of longlining over trawling in the short or medium term. As for the long term, one cannot predict at this stage. Hake directed-longline fishery was established in South Africa in 2001, whereby TAC is allocated right for fresh hake. If Namibia is to increase its longlining, certain effects may come its way from the South African selling market and therefore when considering this case, it will be important to detail the South African conditions.

(iii) Economic factors in the market for Hake

Prices are received for different hake species and they differ with time. The development of hake markets is influenced by factors such as the characteristics of the hake before harvest (intrinsic product characteristics); the effect due to harvest and post-harvest handling (extrinsic product characteristics). Other factors include improvements in technology; preferences of individual markets; trade globalisation; shifts in market demand; increases or reductions in quantities supplied and changes in public policy, including the implementation of the EEZs.

The need to improve and standardise the quality of the hake is very important and this is well taken care of by the longline catches. With a range of fresh and frozen products sold globally, the country's benefit will depend on the one that brings a high income into the country. In Namibia, the market for fresh fish is still slim. Larger-sized hake have a high price and they are mostly taken by the longliners.

(iv) Prices for hake products

Hake constitutes one of the species of high value found in the Namibia fishing grounds. Its price is lucrative although less competitive than that of other white fish of high values like snoek, monk or kingklip. The selling price for hake products can be difficult to tell because of the fluctuation from one market to another. Prices of hake have been increasing on the market since 1990. Hake sells at a lower price in Namibia than in the international market. And the only reason for these differences in the price of the same product paid in different markets over the same period is the demand for that particular product in a given market.

(v) Gear and vessel conflict

Many vessel owners have recently converted their fishing and catching technology from freezer trawling to wetfish trawling and longlining. This is because of the high margins obtained from the two kinds of vessel types compared to freezer trawling.

Areas with rough bottom and steep slope are not fished with trawlers because the trawl gear can easily be damaged. But such areas are well suited for longlining.

Companies involved with longlining in Namibia have developed informal protocols to manage potential conflicts between longline vessels. This is mainly because of high conflicts on the longline fishing grounds, which is increasing as the longline vessels increase. Longlines occupy wide areas of the sea for extended time period and can create gear and vessel conflicts (Anon., 1997). Longlining in Namibia is concentrated in limited areas where regular aggregations of hake give higher catch areas.

(vi) Selectivity

Longliners catch a significantly different size and age class of fish comparing to trawlers, Geromont *et al*. (1995). By difference, longliners exploit only larger hake while trawling catch a much different spectrum of fish, including the size range of fish caught by the longline fleet. The proportion of females in longline and trawlers increases with both the size/age of the fish. For the reason that longline catches older matured fish, they allow the stock to grow to the acceptable level. In trawling it can easily happen that rather young unmatured fish are also included in the catch because the trawl in not capable of being that selective to omit underage fish. Sorting grids in trawl and others are the new discoveries of technology to reduce the effect of young fish taken by trawlers.

The results from the South African pilot study have as well showed that for the same level of catch, longlining would result in a lesser reduction of the spawning biomass stock than does trawling, (Japp, 1993).

3. The basics of the model

In this section, a short description underlying the Pella and Tomlinson model is presented. In addition, a harvest function and an economic part consisting of prices and costs are included.

3.1 The biomass growth equation of Pella and Tomlinson.

The marginal growth in a stock can be expressed as:

$$\dot{X} = rX \quad + sX^{m} \tag{E.1}$$

Where $\dot{X}$ is the time derivative of the stock biomass as a function of time, r is the intrinsic growth rate when m>1 is a parameter, X is the stock biomass, and s is an intrinsic growth rate.

According to Eide (1989), the Pella and Tomlinson model can be expressed as:

$$\dot{X} = rX\left[1-\left(\frac{X}{K}\right)^{m-1}\right] \tag{E.2}$$

where K represents the natural equilibrium biomass level (the environmental carrying capacity). When m in Equation (E.2) equals 2, (m =2), then the model equals a Gordon/ Schaefer model.

From Equation (E.2), it can be shown that the stock size that gives the maximum sustainable yield (MSY), X_{MSY} is:

$$X_{MSY} = \frac{K}{\frac{1}{m^{m-1}}}, \qquad \text{(E.3)}$$

m can be expressed as:

$$m = \frac{1}{1 - \frac{MSY}{rX_{MSY}}}. \qquad \text{(E.4)}$$

with stock size and growth being positive, m< 1 when r < 0 (with r being the mortality rate in the stock), and m> 1 when r > 0.

Calculated from equation (E.3), the parameters *m* and *r* are found as follows:

$$m = \left(\frac{K}{X_{MSY}} \right)^{m-1}. \qquad \text{(E.5)}$$

When the value of *m* is calculated, *r* is determined as:

$$r = \frac{m}{m-1} \cdot \frac{MSY}{X_{MSY}}. \qquad \text{(E.6)}$$

The values in Equation E.5 & E.6 are found when MSY/X_{MSY} and K/X_{MSY} are known. Since the MSY is dependent on the age of first catch (t_c), the r-value will also depend on the t_c. In other words, the age of recruitment to the stock has a relation to the age of recruitment in fishing. A constant natural mortality and the sustainable biomass yield will determine the age of recruitment for the age at first catch.

The relation K/X_{MSY} in Equation (E.5) is assumed to be independent on the size of a constant product of recruitment and maximum individual weight (RW_{∞}). For this reason *m* and *r* can be determined from the parameters k, b, t_0, t_{rr} t_∞ and M, in Eide (1989). M is the natural mortality assumed constant for all age classes of hake; k is instantaneous growth rate; t_r refers to the youngest year class in a stock, denoting recruitment; t_∞ is the oldest year class in a stock; t_0 is a theoretical age when the fish length at an age is zero; and b is a constant[3]. Refer to Table 4.1 for the details of these parameters. Some input parameters needs to be calculated, but this is discussed in more detail in Chapter 4.

3.2 The harvest function

We assume a short-term catch equation, linear in effort and biomass.

$$h = qEX \tag{E.7}$$

Where *h* is the catch (harvest) size, the parameter *q* denotes the catchability coefficient, which represents the proportion of the biomass that is removed per unit of effort, measuring the technical efficiency in the fishery. *E* is the level of effort expended in the fishery, in other words, the number of trawlers or hooks taken out to fish and *X* is the level of biomass.

In equilibrium the harvest function equals the marginal biomass growth of the stock:

$$h = r_{tc} \cdot X\left[1 - \left(\frac{X}{K}\right)^{m-1}\right] \tag{E.8}$$

---

[3] The constant *b* is defined as $\frac{\log W(t) - \log(d)}{\log L(t)}$, using a log-linear regression.

where $W(t)$ is the individual weight at age t,

$L(t)$ is the individual length at age, and

d is a constant defined as $\frac{W(t)}{L(t)}$.

This expression is derived from the von Bertalanffy (1934) growth equation and the individual weight of age equation.

The reader is advised to refer to Eide (1989) for more clarification and details.

Including Equation (E.7) into Equation (E.8) will result in the following:

$$qEX = r_{tc} X\left(1-\left(\frac{X}{K}\right)^{m-1}\right) \quad ,$$

and therefore, remembering our Equation (E.8) the stock biomass in equilibrium is:

$$X = K\left(1-\frac{qE}{r_{tc}}\right)^{\frac{1}{m-1}} \quad \text{(E.9)}$$

describing the equilibrium level of biomass for each level of effort (given).

Substituting Equation (E.9) into Equation (E.7) will give us:

$$h = q \cdot E \cdot K\left(1-\frac{qE}{r_{tc}}\right)^{\frac{1}{m-1}} \quad \text{(E.10)}$$

representing the equilibrium harvest equation. The r_{tc} represents the intrinsic growth rate for the different fishing gears.

3.3 Revenue

In this paper we assume a constant price per unit of harvest. Hake is one of the important white fish in the world market but the Namibian supply of hake is not so large that it can influence the international market for hake. The market price differs for hake fish from longline and trawling. For this specific study, a combination of both wet and freezer trawlers was explained. We use the following to determine the total revenue for both the trawlers and longline respectively:

$$TR_g = p_g \cdot h_g , \qquad g = t, l \quad \text{(E.11)}$$

Multiplying the price of fish per unit of time (*p*) by fish catch (*h*) for the different gears (*g*) of trawl (*t*) (wet, freezer), and longline (*l*).

3.4 Cost

We assumed that the cost of an additional unit of effort is constant and taken into account the average cost of effort for trawling and longlining, respectively. As for the total revenue equation, specific costs and effort are obtained from the different gears using the following cost equation formula:

$$TC_g = a_g . E_g \qquad \text{(E.12)}$$

where TC_g is the total cost for the different vessels, respectively, derived by multiplying the price of effort per unit of time, (*a*), (whereby *a* also includes the opportunity cost of labour and capital) by fishing effort, (*E)*.

3.5 Profit

Equation (E.11) less Equation (E.12), gives the resource rent (Π) as a function of fishing effort (E):

$$\Pi = TR - TC \qquad \text{(E.13)}$$

4. Data

The biological, technological and economic data are presented in this part with other parameters estimated. The data is of historical catch and effort since independence for hake from both trawling and longlining method, respectively. Catches from hake trawling are combined for both the wetfish and the freezer trawlers and observed since 1992 until 2000. The prices and cost data are taken from Hutton and Sumaila, (2000).

The data were estimated on the assumption that longline fisheries data are not well documented yet so we have to do the best we can. Therefore, a wide range of changes in effort between trawling and longline over a considerable time is used.

4.1 Biological Data

The model parameters k, b, t_0, M, are taken as estimates and used in the model from Geromont *et al.* (1995). Maybe its worth mentioning that the estimates used in Geromont were based on a South African study, but because of the similarity between the two country's and their fisheries, it will not be far-fetched to apply, the same values for the Namibian fisheries.

Table 4.1 Values of parameters used in the model, natural mortality rate, M, constant length/weight relationship, b, instantaneous growth rate, k, theoretical age when length/weight is zero, t_0, age at recruitment, t_r, taken from Geromont *et al*. (1995).

Parameter	Value
M	0,3
b	3,084
k	0,046
t_0	-0,825
t_r	0

In Table 4.2 (below) different ages of first catch (t_c) were taken from a period of t_c equal zero up to age of seven years. Concentration is focused to the level of age two and four years from the table analysis. A more detailed explanation of the step by step process involved in the data given in Table 4.2 is in Eide (2000). The reader is referred to this paper for more details.

Tables 4.2 Calculated age at first catch analysis with the use of Eide (2000) method.

t_c	$\frac{MSY}{X_{MSY}}$	$\frac{K}{X_{MSY}}$
0	0,141132	2,84322
1	0,194519	2,84322
2	0,247483	2,84322
3	0,290724	2,84322
4	0,322717	2,84322
5	0,347003	2,84322
6	0,367125	2,84322
7	0,386626	2,84322

On the basis of Table 4.2, Equation (E.5) and Equation (E.6), the *m*-values were calculated from MSY/X_{MSY} and K/X_{MSY} .

The *m*-value remains the same for all the ages of first catch with differences in recruitment.

Table 4.3 Calculated m-values and r_{tc} from Equation (E.5) and Equation (E.6), and Table 4.2.

tc	m	r_{tc}
0	0,915239	-1,52392
1	0,915239	-2,10039
2	0,915239	-2,67229
3	0,915239	-3,1392
4	0,915239	-3,48465
5	0,915239	-3,74689
6	0,915239	-3,96416
7	0,915239	-4,17473

4.2 Technological data

The catchability coefficient, *q* and the equilibrium biomass of the stock, K, were estimated by a linear regression on $(h/E)^{(m-1)}$ from Equation (E.10). The catchability coefficient levels for trawl and longline differs. One of the explanation to these could be because of differences in the age at recruitment in fishing and because effort is measured differently from the two methods.

The data used to obtain *K*, estimates was taken from the catch and effort data for trawling, while that for *q*, was taken from both trawling and longline data, respectively. A nine-year period was taken into account for trawling, the period after independence and only 3-year period for the longline fishery. The longline years are few because that was what was available at the time of collecting data, for the other years they were not clear and well organised to be included.

Table 4.4 Trawling data used in the model to obtain q, and K estimates.

Year	Effort (hours)	Catch (mt)
1992	45783	48481
1993	68419	76885
1994	104628	106910
1995	138112	123583
1996	171835	126086
1997	252251	109695
1998	125249	140227
1999	173266	153250
2000	217461	182637

Source: Anon., (2001)

Table 4.5 Longline data used in the model to obtain *q* estimates.

Year	Effort (# hooks)	Catch (kg)
1998	13464248	2211063
1999	27407500	6998953
2000	57942321	11822063

Source: Anon., (2001).

From Equation (E.10), the harvest equation is given and derived over the level of effort in the fishery as:

$$\left(\frac{h}{E}\right)^{m-1} = qK - \frac{q^2 K}{r} \cdot E$$

substitution of the different parameters is given as

$$\left(\frac{h}{E}\right)^{m-1} = A - (-B) \cdot E = A + B \cdot E \qquad \text{(E.14)}$$

where $A = qK$

and $$B = \left(\frac{-q^2 \cdot K}{r} \right) = \frac{-qA}{r}$$

The catchability coefficient of the different fishing methods therefore is

$$q_{tc} = -\frac{B \cdot r_{tc}}{A}$$

and the natural equilibrium biomass is

$$K = \frac{A}{q_{tc}}$$

A statistical linear regression was run for the hake trawl. The result from the regression indicates that the trawl fishery is statistically significant at a 5% significant level as shown in Table 4.6. with the P-value of 0.0065.

Table 4.6 Regression analysis of CPUE on total effort (Table 4.4) using Equation (E.14).

Variable	Value
A	0,966236
B	3,17956*10^{-7}
R^2	0,676944
Adjusted R^2	0,630793
P-value	0.0065

R^2 is the coefficient of determination that describes 68% variation of the effort is explained by the CPUE and the adjusted R^2. The P-value describes the significance level of the variables in the regression. At 5% significant level (i.e P-value equal or greater than 0.05), the hake stock is statistically significant in explaining the variables.

The K-value (carrying capacity) is independent of the t_c-value and estimated to be at around 1,7 million tonnes.

In trawl fishing, the fish are caught from a younger age. In the analysis of this study, the first age of capture of fishing is set to 2-year old fish. Meaning that for each trawl, all the fish from age two are harvested. It is well known that longlines concentrate on older fish, the first age of harvesting fish by this vessels group is set to four-year-old fish. With *q*-value related to tc, the higher the tc, the lower catchability is expected and vice-versa.

Table 4.7 Parameter estimates calculated using the Pella and Tomlinson model and harvest equation.

Method	q	K (mill. tons)	t_c -value
Trawl	$8{,}79361 \times 10^{-7}$	1,7	2
Long line	$2{,}13627 \times 10^{-10}$	1,7	4

The data estimation of the biological specification of the Pella and Tomlinson model are provided in Table 4.3 and 4.7. This includes the catchability coefficient, q, the maximum biomass of the stock, K, and the ages of first catch for the two fishing methods; the exponent controlling the inflection point of production, m, and the intrinsic growth rate of the fishery. When *m*-value is smaller than one then *r*-value should be smaller than zero. As presented, the catchability level for trawl is higher than for longline due to the fact that the longline fleets for hake are very few; and also due to to the low recruitment age in fishing. Also note that a larger growth rate estimate is necessarily linked with a small carrying capacity and a larger catchability coefficient.

4.3 Economic data: price and cost

Prices for hake products are difficult to tell, they differ between different companies and fluctuate from one market to another. The products vary considerably for different sizes of the same product, (Sumaila, 2000b).

Price data used for the result analysis are partly taken from a study by Hutton and Sumaila (2000). Their study was based on similar research, but was based on a South African case study. As mentioned before, taking into account that the fisheries in Namibia and South Africa are very similar, the same price and cost data may well be used. The price for trawl caught is given as R10/kg[4]. This is the price paid in the wholesale market. For the longline hake caught the price is R30/kg, given that Spanish prices are not affected by imports of hake from other regions (Hutton and Sumaila, 2000). It was further given that in July 2000 there was a drop in prices to a relatively low level and it was not worthwhile to export longline caught hake. For this reason, a price of R15/kg for longline hake was used.

When modelling the cost of landing hake, different costs are involved and can be problematic to get the exact data needed. And because of high competition, most companies do not reveal cost information to the outsider. These include direct costs and indirect costs. Some of costs e.g. labour costs – include the size of the crew, number of officers and skippers, etc, capital costs – cost of acquiring a full equipped vessel, operating expenses – annual costs of fuel, repairs and maintenance, fishing gear renewal, management and administrative costs.

With the use of estimated effort over time for both trawling and longline, estimates and assumptions are used. In Sumaila and Hutton (2000) study, they have reasoned that in a long run, the unit cost both trawl and longline will increase at very high effort levels (or fishing mortality rates) as CPUE decreases and vice versa.

The average landed unit cost for trawling is R5.00/kg of hake landed, in 2000. For longlining a value of R5.00/kg of hake landed is used as the unit cost[5]. To obtain per effort cost, the given cost is multiplied by the harvest over the effort for the year 2000.

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[4]R- is the South African Rand money. Since Namibia's monetary policy is pegged to the South African, the money value are the same as to the Namibian dollar (N$), N$1 = R1.

[5] The cost data given by Hutton and Sumaila, as stated above was equated to the current effort level (2000) for each sector. Therefore for this study I also considered taking the effort level and harvest for 2000.
For example in trawl, to get the value per effort cost;
R5 x harvest (2000) / effort (2000),
therefore 5 x 115537756 / 217460.98,
equalling to 2656.52
The longline data was used for its cost.

The catch and effort data were taken from Table 4.4 and Table 4.5.The same procedure is used for longline.

Using this method, trawl per effort cost = 2656.52[6], and

Longline per effort cost = 1,020158

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[6] Please note that the harvest for trawling used to obtain the cost is not the same as that presented in Table 4.4. We used a harvest number of 115537756 /kg that was calculated from given information of the combined wetfish and freezer trawlers by the MFMR for 2000.

5. Results

The model results, the reference points from the bioeconomic theory will be presented in this chapter. A short description of the main points is highlighted with the rest referred to in the discussion chapter, Chapter 6.

The catch per unit of effort for trawling and longline respectively are presented in Figure 5.1 and Figure 5.2. From both the tables, a difference in the increment is observed, with the level of catch in the trawl maximised at approximately 150 000 metric tonnes, while longline has a maximum catch level of approximately 200 000 metric tonnes. We clearly see that for trawling, the catch per unit effort is declining, while for longlining, the catch per unit of effort is increasing.

Figure 5.1. The catch per unit of effort (CPUE), over a period for the trawl fishery.

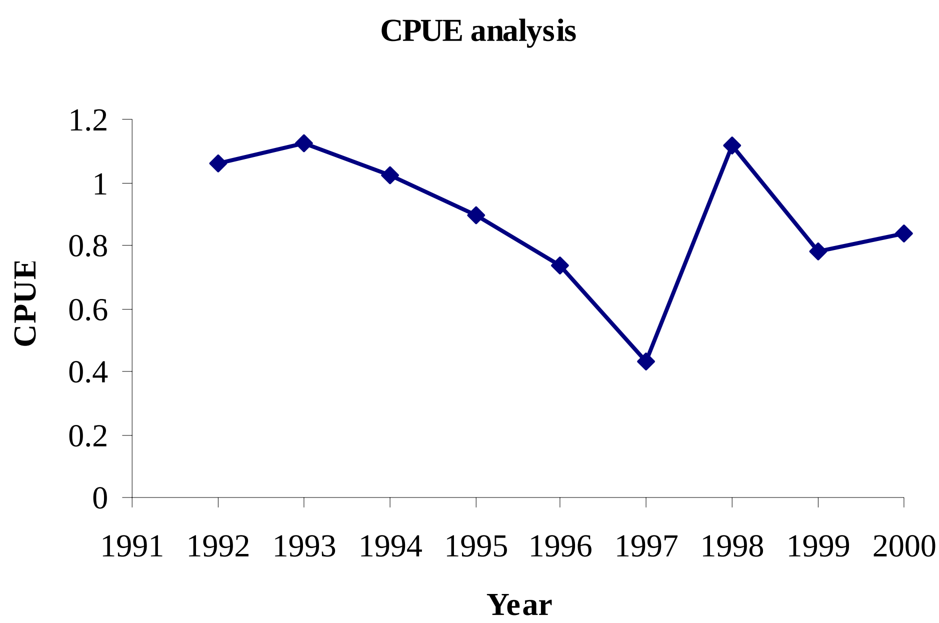
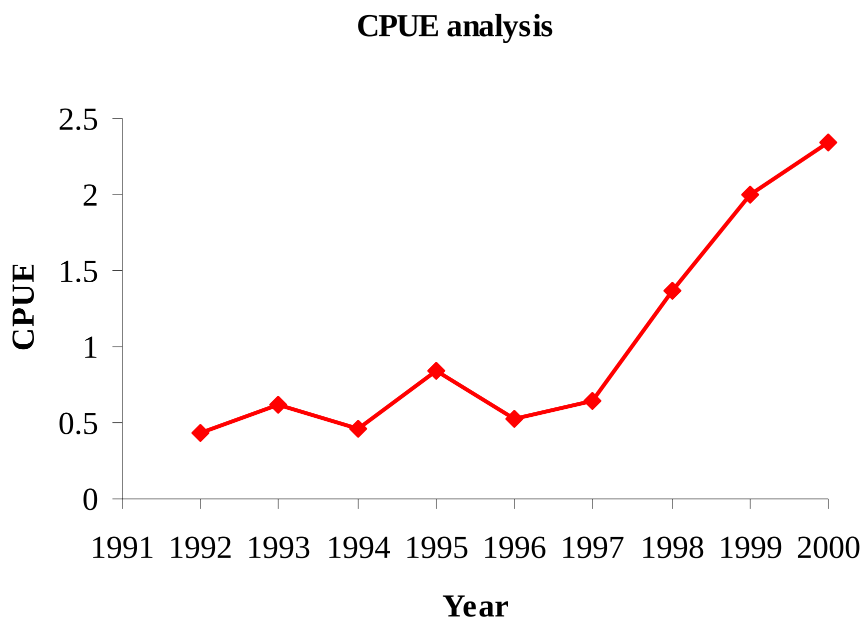


Figure 5.2 The catch per unit of effort (CPUE), over a period for longline fishery.



Maximum Sustainable, Maximum Economic and Open Access Level

Using the data in Table 4.7 and the values for the price of fish and cost of effort, the maximum sustainable yield, MSY, E_{MSY}, maximum economic yield, MEY, E_{MEY}, open access yield, OAY, E_{OAY} were obtained by adjusting the estimated increment rate and the level of effort from a long time series of catch and effort data. These reference (biological and economic) points are used as a means to discuss the level of biomass stock for the given fishery. The MSY is achieved at the level where the largest equilibrium catch can be taken from a stock under average environmental conditions. It corresponds to a higher level of effort but where profits are less and fish catch is sustained through time. The MEY depends on the price of fish and the cost of effort. It is the total amount of resource rent that could be earned from a fishery if an individual owns it. When we talk of open access fishery then one refers to a fishery in which any person can legally participate. As indicated, OA point is achieved at the point where total revenues (TR) equals total cost (TC). This point is also referred to as the "Bioeconomic Equilibrium point", where both the resource and the industry will be in equilibrium. In most cases, at this point (OA), there are too many fishers (measured by effort) that catch fish (and therefore profits) and the stock drop down.

Figure 5.3 With the use of Equation E.9, E.10, E.11 and E.12 from the model; and Table 4.7, MEY, MSY and OAY is obtained for trawl.

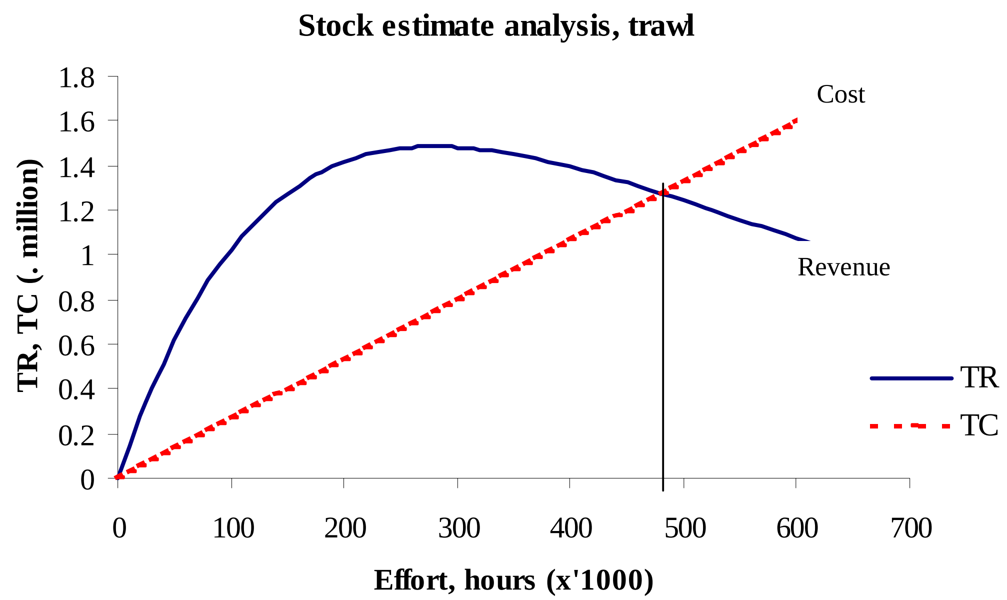


Figure 5.4 With the use of Equation E.9, E.10, E.11 and E.12 from the model; and Table 4.7, MEY, MSY and OAY is obtained for longline.

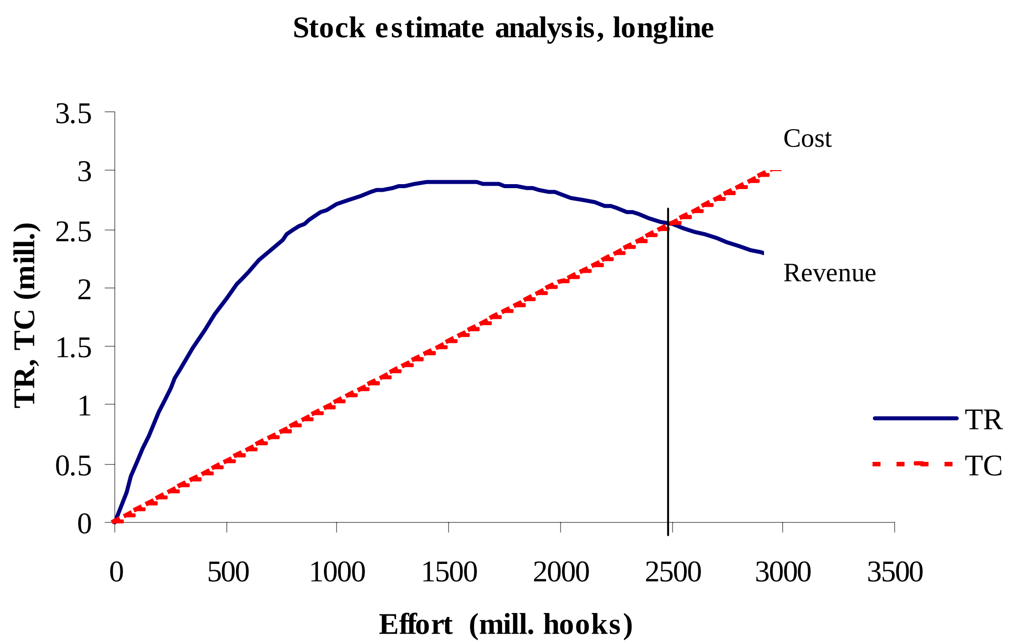
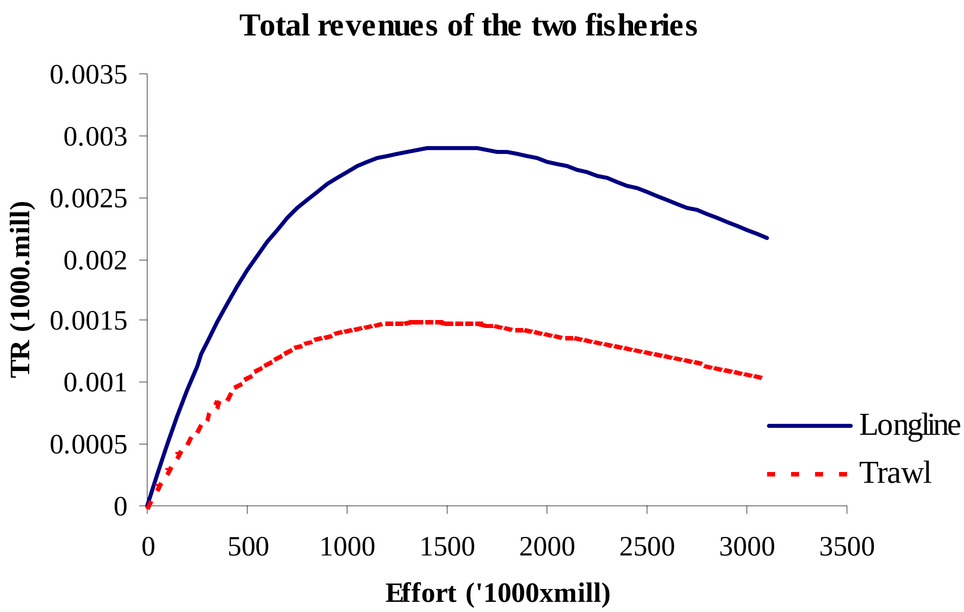


Figure 5.5 Combined total revenue curves for trawl and longline, data used are those presented in result of Figure 5.3 & 5.4.



In Figure 5.5, comparisons are made between trawling and longline fisheries. Higher effort, catches and profits are obtained from the longline fishery.

Results obtained from the bioeconomic model are presented in Table 5.1. The unit of measurements for catch is in ‘000 metric tons; the trawl effort is in trawling hours (‘000) and longline effort is in number of hooks used; revenue is N$ million; cost is N$ million and profit in N$ million. For trawling, MEY is at 136,407 metric tons valued at N$1,364 millions and generated with effort level of 178, 100 hours trawling. The MSY is at 148,441 metric tons valued at N$1,484 millions corresponding to a fishing effort level equivalent of 281, 000 hours trawling.

The OAY is at 127, 561 metric tons valued at N$1,276 millions and attained at the effort level of 480, 180 hours trawling. The current stock for trawling was calculated to be at the catch level of 144, 292 metric tons (in 2000), valued at N$1,443 millions generated at the effort level of 217, 461 hours trawling.

For the longline fishery, MEY is at 176, 888 metric tons valued at N$2,653 millions and generated at the effort level of 942 millions hooks used. The MSY is at 193,562 kg valued at N$2,903 millions and arrived at effort of 1500 number of hooks in millions. The OAY is at 169 597 kg, valued at N$2,544 and attained at the effort level of 2,493 number of hooks used in billions. The current stock for hake longline is observed to be at catch level of 20 244 metric tons, valued at N$303.4 thousands and generated at the effort level of 5,794,231 number of hooks used. For both the fishing methods, the optimal biomass is less than the carrying capacity, thus making the optimal catch and effort to be positive.

Table 5.1 The volume of catch, effort, TR and TC values from MSY, MEY and OAY for trawling and longline fisheries respectively.

Trawl parameters: q = 8,79361 x10^{-7}, r = -2,67229, K = 1,7 mill, price = 10, cost = 2656.52

Longline parameters:q = 2,13627 x10^{-10}, r = -3,48465, K = 1,7 mill, price = 15, cost= 1,020158

Fishing method and Indicators		Volume of catch (mt)	Effort (hours & hooks)	Revenue (N$ mill)	Cost (N$ mill)	Profit (N$ mill)
Trawl hake fishery	MEY	136 407	178 100	1364	473	891
	MSY	148 441	281 000	1484	746	737
	OAY	127 561	480 180	1276	1276	0
Current status of the stock		144 292	217 461	1443	578	865
Longline hake fishery	MEY	176 888	941	2653	959	1693
	MSY	193 562	1500	2903	1530	1373
	OAY	169 597	2493	2544	2544	0
Current status of the stock		20 244	57	303.7	59.1	244.6

* effort in number of hooks (longline) in millions.

* effort in hours trawling x`000.

The estimates of the current status of the stock indicate that the stock is not exploited in the trawl fishery. We expect that the catches and benefits from the trawl will be higher than those from longline, mainly because of the trawl industry that dominated the hake industry, with longline to still increase their fleets in Namibia.

In addition to the result presented in Table 5.1, sensitivity of the model was tested with regards to price changed in the longline fishery. This was taken as assuming that the selling price of fresh hake is the same as the selling price from trawl (hake fillets, chilled); hence making it to be N$10 for both fisheries. The biological parameters were kept the same. With the price changes, the model reacted very differently in comparison to the result given in Table 5.1 (see Chapter 6), where the prices are taken as they are now in the market. Again the price of longline was increased by 10% from N$10 to N$11, changes were observed from that level as well.

6. Discussion and Conclusion

The Namibian hake fishery has been studied using catch, effort, fishing price and cost data for the two fishing vessel types that harvest one same species; and biological parameters of other studies. The discussion is based on the bioeconomic reference points obtained. The section of the paper discusses how the results affect the existing knowledge of the subject.

6.1 Summary of findings (Trawling versus longlining)

The results of this study can be summarised as follows. The biological parameters estimated show that the carrying capacity, K (total biomass of hake), is standing at 1,7" million tons. The 1,7 million tons is close to the estimated biomass of hake that was reported to be in the region of 1,8 million tons before independence after a survey done in Namibia. However it was reported in Van Der Westhuizen (2001) that a total biomass of hake is currently estimated from the research survey to be 1.2 million tons. This differences may be explained by the model and data used. Table 5.1 presents the estimated results for MEY, MSY and OAY for the overall status of hake stock fisheries using the two methods, trawling and longline and sums up all the findings of this study. The current state (as at 2000) from the two methods are also presented in Table 5.1. From the hake trawling fishery, at the level of maximum sustainable yield (MSY), the potential rent is N$737 million with the corresponding values at the maximum economic yield of N$891 million. The highest resource rent (at MEY) is achieved with less cost and lower revenue than in the MSY equilibrium. In the open access fishery, the effort of 480 180 hours trawling results in 127,561 metric tonnes of hake catches. This is about 267,719 more effort employed compared to the current fleets that are at a stage of 217,461 hours trawling. Catches for the current fleets is 16,731 metric tons more compared to the open access fleets.

According to the model result, catches will be increasing over a period from both trawling and longline when accounting for the MSY level. Overall, the catches has been increasing since Independence, with a period (1996-1997) of low catches, which was known to be a cause of poor spawning and recruitment failure at the time from the El Ninõ current, (see Van Der Westhuizem, 2001). Vessels spend hours and days on sea but could only catch little. This increase and/or decrease can as well be explained by various factors such as environmental and weather condition impacting on the catches and growth rates.

The current effort is required to be decreased by 18% (the difference in effort level of 217,461 less 178,100 trawling hours) to be at the MEY effort level. In case of MSY, the current effort will increase by 30% (difference in effort between 217,461 and 281,000 trawling hours) to reach the MSY effort level from the model. Therefore, the total equilibrium catch will continue to grow when the effort is increased by up to 30% of today's level (of MSY). However, it will be best to consider a decrease in the current effort in order for the stock to approach the MEY level of effort and maximise economic profit, the level where every fishery wants to be operating at. The effort level in the trawl fishery is thus operating below the maximum sustainable effort level of MSY of the model. The revenue and cost will be high but less resource rent will be gained at MSY level. Should the current stock operate at MEY the effort and catch will decrease but the earnings will be higher than the current level.

In the longline fishery, the model result in high catches, revenue, cost and profit due to higher average individual age of fish in catch. The maximum economic yield or resource rent is N$1,7 billion. At MSY, the resource rent is N$1,3 billion. The highest profit from longline (that of N$ 1,7 billion) is almost 100% higher than the corresponding profit from the trawl fishery (which is about N$ 891 million). As presented in Table 5.1, the highest cost of N$959 million is used for longline compared to N$473 million in trawling. This is more than 100% more in comparison to the cost for trawling. Therefore the potential growth in resource rent (by up to 100%) is in the conversion from trawl to longline. If the Namibian hake fishery is able to decrease the catches in trawl, that will be substituted to the longline catches, a sustainable level for both effort and catches in hake stock will be reached. In Anon., (1997), it is stated that according to current situation for Namibian hake, it seems highly desirable to increase the number of longline licences to allow the landings to increases. This will be possible with a conversion of a certain portion of landings of trawl to longline, and would create an additional number of jobs in the sector and more earnings in terms of export revenue. The revenue of N$2,653 million is obtained from longline in comparison to N$1,364 million of trawling at MEY. Even though longline results in higher cost, the potential economic rent still outweigh that in trawling. Hence, longline will still collect the best outcome compared to what is received by trawling. In relation to the current status presented for the longline fishery, the total equilibrium catch and effort will continue to grown as long as the fishing fleets increases yearly. With the current number of fleets amounting to only 23 vessels for longline and 82 for trawl vessels as at year 2000, the proportion of fishing effort is relatively still at a low level in longline. We have to bear in mind that the results of the model assumes that longline fleets or trawling fleets are the only one harvesting hake one at a time. In a game theoretical modelling approach by Hutton and Sumaila (2000) they concluded that: “The long-term benefits to longliners decrease when high proportions are allocated to the sector because the cost of harvesting at high effort decreases the profitability of the fleet”.

The result from the present model indicates that with highest benefit from longline fishery, low effort will be used. This can be regarded as one of the benefits of longline compared to trawling; maximising income earnings at a level where effort used is relatively low. The opposite will be that less economic rent will be collected where high effort is used. This is so because as fishing effort is increased in a fishery, the stock will decrease. There will be allot of pressure in the water, hence, overfishing or depletion of stock may exist and the stock level will be low as the fish are not allowed to reproduce and grow to a reasonable level of fishing. One has to remember that effort in longline is measured differently from trawling. The selectivity of longline is another factor that benefit the impact on stock biomass compared to trawling, because of the older fish they target with less growth potential while trawling targets smaller fast growing fish. Also remember, as stated before, the current low stock level is because of the longline fleets being not at the level where trawl fleets are. Indeed, less than 10% of the total hake landings is harvested by longline with more than 90% allocated to trawlers (wetfish and freezer).

A difference in resource rent of about N$802 million accrues to the fishery under the longline method. In contrast, the resource rent gained from trawling is only 53% (N$891 million) of the total from longline. In other words, there is a 47% (N$1693 less N$891 million) loss in rent when the trawling fleet is employed compared to longline fleets. Regarding the two fishing methods/fleets, such a loss (47%) that could have been received can be overcome once longline fleets for hake are increased in Namibia. This high difference in resource rent is due to two main factors. Firstly, the higher price that is reflecting the quality of fish from longline landings; and secondly the different selection patterns between the two fishing methods, and consequently higher catch rates from longline. This is under the same stock with the differences in catchability and selectivity. It is worth mentioning that this study gives an outcome of a long-term theoretical reference for discussion. In other words, there is no thought of how possible will the Namibian hake industry make an immediate shift from harvesting hake with trawlers to using longliners. The current fishery does not allocate an amount of catch to longline fleets, it is from the fishing companies that decide how much to take out of their quotas and direct to longline. The Namibian hake fishery is still making good profit despite changes in the stock itself with the actual effort still at the level where it is less than the maximum equilibrium effort. Since current catches of hake are lower than what can be sustained under sustainable level of current effort, future harvests are expected to increase even if the current effort levels remain the same. Even though the hake fishery has been growing since 1990 the catches are still below those of earlier years. However, whether this increase is sustainable is not clear because it is based largely on an influx of deep-water hake rather than an increase in abundance of local hake.

6.2 Trawl: Current fisheries status versus model output

From the model results in Table 5.1 (for the trawl fishery), and today's level of effort of 217 461 hours as at year 2000, the equilibrium catch level from the model result in 144, 293 mt compared to the original catch obtained in that year of 182, 637 mt. This indicated that with the same effort used, the hake fishery has been more affective than the estimated from the model with catches less than those landed. In other words, the equilibrium catch from the model is different from the catch of today (2000). We have to bear in mind that this equilibrium catch is never occurring, but serves as a useful reference point. The discussion here is therefore based to the point of what will be the case should today's level of catch be the same as that estimated by the model? How is today's hake fishery by trawl? As stated before, the current stock is operating closer to the MEY. This is rather interesting and is a rather positive state for the Namibian hake fishery. The model therefore suggests that keeping the effort level as it is now (at 217, 461 hours); we will expect either a rise or a decline in catch depending on the regulation measures at the time. Without regulations an increase in effort is more likely to occur, but with regulations, effort can be kept constant or even be decreased up to the level where catches will approach the equilibrium point. The model result suggest that effort be reduced to that of the MEY level (178, 100) that corresponds to a catch (136, 407mt) that is lower than today's catch (in 2000) and also lower than the catch at MSY (148, 441). By reducing today's effort, the fishery will not only be in a positive state, considering long-term benefits, but will also benefit the resource in both economic and biological terms. High earnings will be achieved with less pressure on the stock.

The need for less effort can be linked to the current stock, which are depressed over the unfavourable conditions accounting from the Benguela Nino in 1995 (see Boyer and Hampton, 2001), which has left some of the Namibian stock size fisheries currently to be in a decline state. It is reported in Boyer and Hampton, (2001), that adult hake tolerate temperature and survive well in less favourable environments. Therefore with the current environment conditions, longline vessels may well suit because of their target to adult hake. The longline fishery will than reflect to the decrease in effort and catch from trawl. Substituting one thing for another and yet maximise both the sustainable level points.

Considering the trawl fishery since 1990, (Table 4.4), the fishery has been improving in effort with a corresponding catch. In 1998, effort was less compared to the previous year but landed catch was higher than the previous year. Between 1999 and 2000 (based on the current stock), effort and catch increased as expected but effort in 1999 was less than the MEY level of effort from the model, but received more catches compared to the estimates. An increase in 2000 led to higher catches. Indicating that between 1999 and 2000, the effort was increased in 2000 up to the level above that of the MEY level but catches increased even more. But since TAC does not reflect much on the fishing effort, even though TAC has been increasing during the recent years, a controlled effort can still be used for the hake fishery. Considering only short-term production, catches are most likely to increase but at a certain point the catches will drop down to reach the MEY level. Under precautionary approach, the best is always to be at the lowest effort level in order to allow the stock to grow enough especially when there are unfavourable environmental conditions contributing to the state of the fishery.

6.3 Price Sensitivity

Using the same data, the biological estimates for longline and the price of N$10/kg was tested. The price of N$10 is equal to the price received by the trawlers. The outcome obtained resulted in less resource rent compared to the same price under the trawl fishery over the same period of time. When a price was increased by 10% from N$10 to N$11, high catches and benefits resulted from the longline compared to the trawling. This suggests that the longline fishery for hake is very much dependent on its market price, which is reflected by the good quality of fish landed by longline. Should people harvest hake with trawling and longline, having same price such as that of N$10 (going to both fishing methods) run in this model, it will be more beneficial in economic terms to only harvest with trawlers. In this case, other factors such as environment and selectivity, and protection of juveniles are not considered. A small price difference between longline and trawling brings such a difference in catches, and profit earnings in the industry. It is because of high demand of fresh hake and a high market price received from Spain that longline in Namibia will be more beneficial in economic terms than trawling.

6.4 Export earnings

With the majority of Namibian fish product exported to foreign markets, the entire industry depend much on the outside income. Over time both the export value and final value follows the same path. The value and price of fresh hake from longline is double the price of hake gutted and hake fillets from trawling. This is with respect to the price of N$30/kg not considering the fluctuation in the market price. In this regard, some of the industries have been concentrating much on wetfish trawler and longline fishery and less on the freezer trawler. Fish processed on shore as that of fresh hake from longline, has high final values than that landed by trawlers because of the extra job needed before it's exported. Because of the increasing prices in Namibian fish, each year the overall value of landed fish rises, even in the years where total catches has fallen. One of the unpredictable situations in longline is the fact that in one year, prices change depending on the season and this could be a problem in some cases where earnings either bring a boom or low market earnings will be received.

Had longline hake fishery existed in Namibia, investors will put their effort to wetfish and longline only, with no consideration for freezer trawlers. This relates to a study by Sumaila based on wetfish and freezer trawlers. The study's main objective was the question of which vessel type, wetfish or freezer trawlers should land Namibian hake catches, and what proportion should the vessels group land? Considering economic and social arguments, it was concluded that freezer trawlers should be banned from the exploitation of hake where both economic efficiency and employment criteria are supporting such a change (Sumaila, 2000b). In other words, only wetfish trawlers and longline fleets should be harvesting hake.

As stated before in the data chapter, the prices of fish landed by longline in 2000 declined by up to 50% and at the time, and it was just as much worth to export hake from trawling only. According to a study by Stephanus (2000) on import demand for Namibian hake in Spain, his finding concluded that there is an increased demand for Namibian fish products and particularly hake, in the northern markets due to their depleted resources. Therefore as long as we keep the stock at a sustainable level, export earnings will keep increasing from those countries where their resources are overfished and are in need of fish from abroad.

6.5 Implications for Management

A plan to manage our hake stocks into the future needs to develop. A need for experimental research for longline hake is the next step. This paper studies just a small part of the effects using longline to harvest hake. It still leaves a gap to answer many questions, but only a well-structured research programme will manage all the uncertainties of this study. For instance, taking a pilot study for a period of time, collecting all the results by the use of experiments on board such as sex-split yield per recruit analysis, length frequencies, and so forth for both trawl and longline catches to compare the manner in which the two methods impact on the hake resource. The study shows that an effect on bioeconomics benefits from the resource needs to be looked at under the estimated level of harvests from the model. With proper data, the model gives more insight for the management of hake fisheries in Namibia. The fisheries management must plan to keep the effort level at a sustainable level as a means to reduce the fishing mortality rate, as this will generate benefit to the whole industry in terms of higher profits. Most importantly, with the current pressure of fish stocks due to environmental conditions off Namibia, there is a need to keep a moderate level of effort that will provide less catches and still profitability will outweigh other factors such as high effort and catch. From this study, it will be worthwhile for the management committee for hake to consider an increase in longline and a possible decrease in trawling fleets/quota by allocating a proportion of the current trawl quota to the longline fleet. As in the case of South Africa's study and policy management, though they have a quota allocation to longline, a small percentage of the overall TAC is allocated. It is reasoned that information concerns and resource consideration still needs to be studied, only then could the longline fishery be increased further. One other effect that the management has to study and is not well documented in this case is the impact of cannibalism by hake. According to Sumaila (1999b), part of the annual hake production is consumed within the stock itself. Therefore when the adult hake fish eats the younger juvenile hake and two different vessel types are harvesting the same stock, determining the total annual quota as to how much to be allocated to the different vessel types is not trivial. It is further stated that it becomes even more of a concern when one considers the different cost structures and different prices received in landings by the different fleets.

With the presence of cannibalism in hake, both biological and economic losses can be expected. The management should consider such effects once its known that cannibalism affects the overall economic benefits and the annual quota of landed hake. Should it not be the case, then there is no need for a concern for cannibalism. However, Sumaila studies confirms that cannibalism do exist in the Namibian fishery and can indeed have an impact on the economic benefits and allocation to the different fleets. The need for management to reduce catches of undersized hake from trawling should therefore be of a concern. One way of doing this will be to use special devices that are able to select out those very small fish when trawling. Of course there will be a need to allocate resources for the development of relevant new techniques.

6.6 Thesis limitations

Data is very much scarce for longline leading to the discussions to be limited within the framework of what is available. The subject of longlining is very new in Namibia and is still not addressed in many aspects. More detailed information could have been studied from the aspect of laboratory, field studies of behaviour to experiment with the hake stock from the two gears. However, due to the very limited time, it was not possible in this study.

6.7 Conclusion

This study aimed at providing insights that would increase the ability of Namibia to benefit economically (and biologically) from the resource in a sustainable manner. The results of this study indicate that the hake biomass off Namibia as of today will decrease in response to a decrease in effort level for the years to come to approach the estimated current MEY level. Therefore we will expect the catch to decline at some point in years to reach the equilibrium catch reflected by the stock size. In addition, the maximum resource rent of trawling and longline according to the model result to N$891 million and N$1,7 billion respectively. Therefore a possible increase in longline fleets may be considered in response to a decrease in trawling fleets. This brings the highest long-term economic gains to the industry and maximum economic yield will be reached. According to the model, the potential benefit of replacing trawlers by longliners will bring an amount of N$809 million more in profit. With the existence of longline hake in Namibia, we will expect higher employment generated in the sector, reducing the level of unemployment in the country, and high export revenue will be generated.

To the extent that expansion of the longline fishery is dependent on the high prices received in the market for fresh fish, there is no real prospect of longlining substantially replacing trawling in the short or medium term in Namibia; still the trawl industry continues to dominate the sector.

The issue of longlining catches in Namibia is that, it has good quality but then there is only one market for it. Again it has a good price, but then if hake-directed longlining is established in Namibia, it is likely that the market will not be on high increase as expected because of the forces from the neighbouring country of South Africa which has just established a hake-directed longline industry last year (2001). Hence there can be management implications if South Africa were to increase its own catches substantially and longline fleets.

In future a study that will use more accurate data on effort and prices will be useful. There is a concern as to the reliability and accuracy of the data used. Even though, there is a high need for the fisheries management to involve fully in managing the fishing effort for hake. Areas of consideration such as environmental factors are not studied here and should be looked into in future studies. Still there is also a need to continue testing the longline market potential.

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