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THE ECONOMIC POTENTIAL AND FEASIBILITY OF A LANDING SITE INVESTMENT IN THE ARTISANAL SMALL PELAGIC FISHERY OF SIERRA LEONE

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ABSTRACT

The marine artisanal fishery in Sierra Leone is based primary on small pelagic species, with the clupeids (*Sardinella species* and *Ethmalosa fimbriata*) constituting about 60% of total landings. The fishery is conducted by numerous small scale fishermen using simple technology. The goal of this study was to investigate possibilities for economic improvements in this fishery with a special focus on two fishing communities, the Portee and Old Wharf communities in the Freetown area. A simple bio-economic model was developed to describe the fishery. An economic and socially reasonable path from the current fishing effort was then calculated. The bio-economic model was used to calculate the net benefits of reduced fishing effort in the fishery and the possible net benefits of the construction of fishery landing site for the Portee and Old Wharf fishing communities. The results from this study indicate that the fishing effort (no. of boats) required to achieve maximum sustainable economic benefits from the pelagic fishery is about one-third of the current fishing effort. At this level of fishing effort, the model predicts that the sustainable harvest will increase and substantial net economic benefits in terms of profits and rents will be generated. A cost benefit study of the proposed landing site construction indicates that this project will have a positive present value provided a good fishery management is put in place.

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1 INTRODUCTION

Sierra Leone is located on the west coast of Africa, north of the Equator. It is bordered to the north and east by the republic of Guinea and to the southeast by Liberia. Off the southwest west is the Atlantic Ocean (Figure 1). Sierra Leone's landmass consists of a mainland and four offshore islands; Yelibuya, Banana, Turtle and Sherbro islands. It has an area of 71,000 km^2 with a continental shelf of about 120 km wide in the north at Yelibuya tapering to only 13 km wide at Sulima in the south. The length of the coastline is about 560 km with extensive mangrove swamps. The mangrove vegetation within the Yawri Bay is a major spawning ground for fish and shellfish.

Figure 1: A map of West Africa showing Sierra Leone.

Sierra Leone has a population of about 5.5 million and the capital Freetown has a population of over 900,000. Sierra Leone's main economic indicator is still lagging behind the average compared to the other fragile Sub-Saharan African countries. The GDP per capita is constant in US dollars and also remains well below these other countries, having the lowest domestic revenue-to-GDP ratio (IMF 2009). Income per capita in 2009 has been estimated about 380 US$ (CIA 2009). However, in terms purchasing power parity, the income per capita may be as high as 800 US$ (CIA 2009).

Sierra Leone has recently emerged from a prolonged (1992-2001) civil war which devastated its economy and much of the infrastructure and led to a major migration of the rural population to the urban areas especially Freetown. Since 2001 the World Bank and other international assistance organizations have been active in the country. Economic growth has been strong and the country shows clear signs of being on the mend (World Bank 2009, IMF 2009).

Sierra Leone's main industries are agriculture, fisheries and mining, with agriculture, fisheries and forestry employing about two thirds of the working population (GOSL 2003). The fisheries sub-sector plays a significant role in the national economy contributing about 9.4% to the GDP (GOSL 2003) and is the most important economic activity along the coastline of Sierra Leone.

In Sierra Leone there are four major rivers that affect the environmental conditions along the coastline. These are the Scarcies, Sierra Leone, Sherbro and the Sulima rivers. Seasonal changes in hydrographic conditions along the coast are due to the effects of the monsoonal wet season extending from May to October when high river discharges reduce surface water salinities and lower solar radiation (Payne and Coutin 1988).

The Guinea Current, which is an offshoot of the Canary Current, flows eastward along the coast meeting the westward flowing South Equatorial Current off the coast of Liberia. The influence of the relatively cold Canary Current is greatest during February to April when its flows towards the south bringing cold, nutrient-rich water from the upwelling areas (Payne and Coutin 1988).

The small pelagic fishery in Sierra Leone is a common property resource exploited by a large number of artisanal fishermen. Majority of people that moved to the capital Freetown during the civil war started fishing since it was one of the few income earning opportunities open to them, leading to an increase number of fishermen and fishing effort in the Freetown area. This fishery applied low technology targeting the juveniles of small pelagic stocks. There are many fishing communities in the coastal area of Freetown and the peninsula. The two community's relevance for this study is the Portee and Old Wharf fishing communities in the East end part of Freetown (Figure 2).

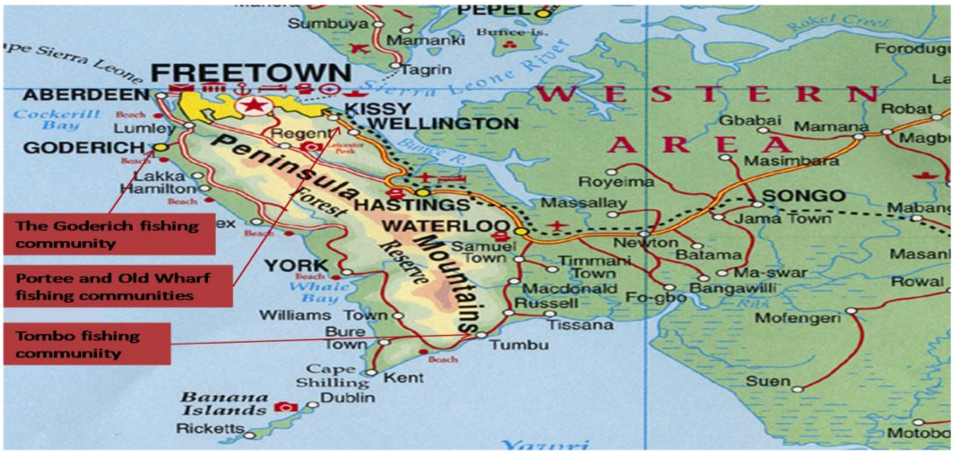

Figure 2: A map of Freetown showing the location of the Portee and Old Wharf fishing communities.

The Old Wharf and Portee communities have been one of the most backward fishing communities in the Western area. Looking at the location of these two communities in the Western area (Figure 2), it can be seen that they are in the centre from Goderich in the far west end of Freetown and Tombo in the far east- end of the Freetown peninsula, but never received any fisheries developments. The proposed building of a fish landing site in one of the two communities is to address the problem of value addition and quality by the World Bank project. These fishing communities were chosen from the fact that there are other projects currently supporting the construction of fish landing sites in four of the major fishing communities in the country; two in Freetown, one in Shenge and one in Bonthe district.

The two communities of Portee and Old Wharf have been left out of fishery development project mainly because it was not as populated as it is now and maybe it was not seen as a major landing site. One of the major reasons would have been the access to the Portee community. It is not accessible by road; access to the site is by a very steep stairway constructed with huge rocks. Since these two communities are now supplying a large part of the central area of Freetown with their fish product, there is a need for a proper community management system in these communities to be able to manage and control the proposed landing site.

The Portee fishing community has a landing site at Kissy, the East end of Freetown. The landing site lies at the mouth of a sewage outfall with no water and sanitation facilities. The area is overcrowded. The Old Wharf landing site is not far from the Portee and is a few hundred metres from the main tarred road leading to Tombo and Waterloo with a rock reef opposite the landing site (Sciortino 2009).

The proposed West Africa Regional Fisheries project (WARFP) funded by the World Bank is a regional project from Mauritania to Ghana with three major components. These are (i) reduction in IUU (Illegal, Unreported and Unregulated) fishing, (ii) increase the value of the product and (iii) a governance aspect that will develop a sustainable and realistic fisheries policy (World Bank country report 2009).

The implementation of such reforms will be supported by:

- Building the capacity of the decision makers and the stakeholders in the governance and management of the marine fisheries in the short term and reduce illegal fishing in the Inshore exclusion Zone (IEZ). The IEZ is an area five miles from the shoreline reserved for breeding and is also a nursery ground for fish and Shellfish. It is also an area reserved for the artisanal fishers, Industrial trawlers are not allowed to fish in this area.
- Strengthening the governance and management structure in the ministry of fisheries necessary to control the rational exploitation of the marine resources for fishing effort control.
- A fisheries management system based on access right, provide basic infrastructural facilities for value addition to the fish product thereby creating employment, food and income.

The West Africa Regional Fisheries project (WARFP) is planning to build a fishery landing site at the Old Wharf community to serve both the Porte and Old Wharf communities. The landing facilities will be able to maintain the quality of the catch landed, provide a fish market, improve the fish smoking facility, engine, boat repair and maintenance workshop, ice making and cold room facilities and fishing gear and supply material.

The main goal of this study was to examine the economic aspects of this project by conducting a cost benefits study on the landing site construction. This goal is in support of a more primary objective, namely that of promoting an economically beneficial fishing practice at the Portee and Old Wharf fishing communities in Freetown, Sierra Leone.

It is hoped that by developing a simple bio-economic model for the small pelagic fishery in the two communities, it will be possible to identify the optimal sustainable state of this fishery and calculate an economic and socially reasonable path from the current fishing effort to the optimal sustainable yield level. The result from this study will then inform decision makers about the possible net benefits of the construction of the fishery landing site. The study will also provide basic information on the bio-economics of the fishery and the results should provide preliminary answers to questions about the utilisation and management of the small pelagic in Sierra Leone

2 SIERRA LEONE FISHERIES

Sierra Leone has considerable fish resources that have the potential of contributing significantly to food security, income and employment in the country. About 200 different marine species have been identified of which about 100 are commercially valuable (Ndomahina and Chaytor 1991). The fish resources may be classified into four main categories: (i) pelagics, (ii) demersals (iii) crustaceans and (iv) others (mostly molluscs). The pelagic fish stocks of Sierra Leone are classified into the true pelagic, semi-pelagics and large pelagic (Ssentongo and Ansa-Emmin 1986). The clupeids (*Ethmalosa fimbriata (Bonga)*, *Sardinella maderensis*, *Sardinella aurita (Herrrings)*, *Illisha africana* and E*ngraulis encrasicolus*) are the most important of the small pelagic (Ndomahina and Chaytor 1991). The round herring, *Sardinella aurita* (Figure 3*)*, is a migratory species and has an offshore distribution in the upwelling areas and the flat herring, *Sardinalla maderensis* (Figure 4) is usually found inshore in estuaries and bays (Ndomahina 2002).

Figure 3: The round herring (*Sardinella aurita).*

Figure 4: Flat herring (*Sardinella marderensis).*

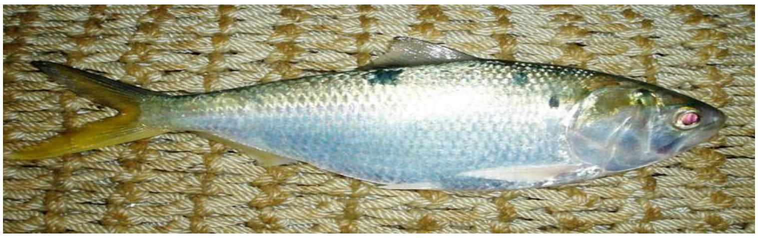

Figure 5: The Bonga (*Ethmalosa fimbriata).*

This study is mainly on the Bonga (Figure 5) and the Herring (*Sardinella aurita and Sardinella maderensis*) since they are the most important commercial species of the small pelagic.

Assessments of the fish stocks in Sierra Leone waters are limited. The Guinea trawling surveys were carried out in waters from Northern Sierra Leone towards Guinea to Southern Sierra Leone towards Liberia between August 1963 and June 1964 (Williams 1968). This survey showed that the wider northern waters of Sierra Leone towards Guinea are more productive than the relatively narrow southern end towards Liberia.

Acoustic surveys have been conducted sporadically to study the bottom type, distribution and biomasses of pelagic fishes. On the basis of these methods, Ndomahina (2002) estimated the potential yield of small pelagic species in Sierra Leone waters as 100,000 mt annually. With the support of the Guinea Current Large Marine Ecosystem (GCLME) and with the assistance from the FAO surveys were carried out in the Western Gulf of Guinea in 2006 and 2007 by the Norwegian research vessel Frithjof Nansen. These surveys (Table 1) indicate that the stocks are dominated by pelagic species, constituting over 80 % of the total fish biomass. The survey estimated that the flat herring, *Sardinella maderensis*, is the predominant pelagic species (Nansen 2006). The offshore small pelagics Sardinella *aurita* and the carangids (*Decapterus spp.*) are also important stocks in Sierra Leone territorial waters. In view of the draft of the survey vessel Nansen, it is highly probable that the biomass estimates of the near-shore species, e.g. *Sardinella maderensis* may have been underestimated.

The clupeid, *Ethmalosa fimbriata* is the dominant species of the commercial artisanal landings, contributing about 50 % of total landings. Also, due to the inshore distribution, including estuarine areas, the survey vessel did not capture the species.

Table 1: Pelagic Biomass estimates (mt) from the 2007 Nansen Survey.

Species	Guinea Bissau	Guinea	**Sierra Leone**	Liberia	Total
Sardinella aurita	118000	77000	**22000**	31000	248000
S. Maderensis	79000	115000	**117000**	17000	328000
Carangids etc	45000	63000	**100000**	16000	224000
Total:	242.000	275.000	**239.000**	64.000	

The Sierra Leone fisheries sector consists of (i) the industrial, (ii) the artisanal and (iii) aquaculture sectors. The industrial sector is capital intensive and operates mostly off-shore. The artisanal sector is generally of very low-technology and operates in the in-shore marine fisheries and in-land (fresh water) fisheries. There is some fairly primitive fresh water aquaculture mainly in ponds.

At present the marine fish production is estimated at about 130,000 mt (Figure 5) and most of it is discharged locally for local consumption (Seisay 2006). The total fishery production is shown in Table 2 and Figure 5 for both the Industrial and Artisanal fishery and the main types of species is also shown in the Table 2.

The marine artisanal fishery is based primarily on small pelagics. The clupeids, *Sardinella maderensis* and *Ethmalosa fimbriata*, constituting over 60 % of total artisanal landings in Sierra Leone. The demersals are mainly the Groupers (*Lutjanus*), crocus *Pomadasy),*Gwangwa (*Pseudotolithus*), Snappers (*Sparids*) and Sole (*Cynoglossus*). Most of the exports stem from the industrial fishery with shrimp (pink Shrimp (*Penaeus notialis*), rose shrimp *(Parapenaeus longirostris)* and tiger shrimp *(Penaeus kerathuru)* being most valuable. Other fish species exported are the Sole (*Cynoglossus spp*), Crocus (*pomadysys spp.*) Gwangwa (*Pseudotholithus spp),* snappers *(Sparids)* and grouper *(Lutjanid spp).* Due to the war the catch reduced greatly from the period (1992-2003).

Table 2: Total Fishery Production in MT, 1991-2006 (MFMR 2008).

	The Industrial Fishery								**Artisanal Fishery**	**Total**
Year	Shrimp	Lobster& Crab	Cuttlefish	Snail	Sharks & Ray	Demersal Fish	Tunas	Pelagic By-catch	Mix fish Mainly Small Pel	Indust and Artis
1991	1241	21	202	-	-	5045	3173	65555	48071	123308
1992	2484	47	644	-	-	15790	3644	31424	47477	101510
1993	2425	427	858	-	-	14655	2463	1000	46928	68756
1994	2010	186	885	-	-	11386	3358	516	46779	65120
1995	2420	278	658	-	-	9416	3029	299	46708	62808
1996	2443	353	1069	-	-	10612	1011	1109	46673	63270
1997	1989	197	557	-	-	5905	2010	479	46656	57793
1998	1317	111	398	-	-	5344	4980	467	46648	59265
1999	1483	157	537	-	-	9442	3662	537	46420	62238
2000	1505	298	308	-	-	11127	0	1061	45910	60109
2001	1277	337	1169	-	120	10993	6166	2536	30050	62548
2002	1119	194	3562	-	126	7315	-	1405	55659	69380
2003	1541	215	4598	-	150	9549	-	1112	65458	82623
2004	1445	127	1596	1266	175	8011	-	1611	106216	120447
2005	1378	106	2017	1883	135	7756	-	2522	116614	132411
2006	1354	159	982	1065	143	8526	-	1413	120490	134132

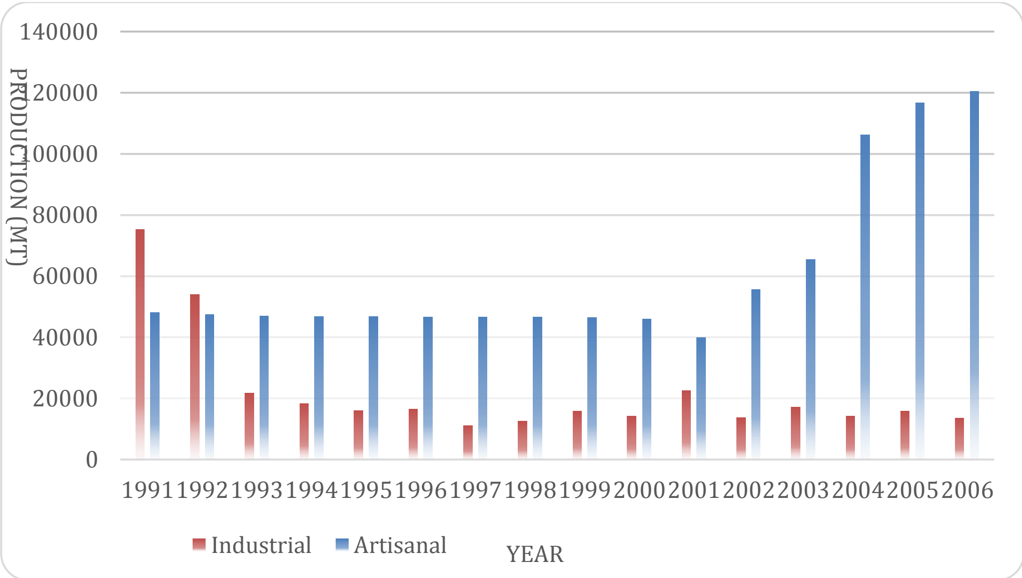

Figure 6: The total fish production from the Industrial and the Artisanal fishery (MFMR 2008).

Fish is the largest single source of animal protein for the Sierra Leoneans, supplying about 80% of the total animal protein consumption (MFMR 2003). The artisanal fishery provides significant employment and food supply to the rural population especially along the coast. The fisheries sector is an important foreign exchange earner for the nation besides contributing about 9.4% to the GDP in recent years (Figure 3).

Table 3: Contribution to the GDP by sectors (in percentage of the GDP) (Seisay 2006).

Sector	**1990-1994**	**1995-1999**	**2000-2003**
Agriculture	22.7	35.66	31.94
Livestock	2.07	2.18	2.91
Forestry	3.30	3.06	3.00
Fisheries	**10.30**	**10.37**	**9.39**

2.1 The Industrial Fishery

The industrial fishing fleet consists of foreign Chinese and Korean shrimp and demersal trawlers, a few Greek and Spanish shrimp trawlers and tuna purse seiners. There are no industrial vessels that target the small pelagics. However, small pelagics are caught as by-catch by the demersal fish trawlers and make up to about 6% of the total catch of these trawlers (Seisay 2006).

The industrial fishery is capital intensive and the relatively high investment and operational costs (working capital) make it very difficult for indigenous entrepreneurs to enter the fishery. There is a small number of locally owned (shrimp or demersal) trawlers but these operate only intermittently due to various problems and constraints which includes lack of initial investment capital and the operational cost, lack of land based facilities for most indigenous fishing operators.

There is only one land-based fish processing plant serving the industrial fishery. In the past this plant used to process shrimp and fish products for export to Europe. However, during the civil war it suffered extensive damages. The plant is now being repaired and refurbished and is near to completion. Currently most of the industrial fishery products are frozen and packaged onboard vessels for export. The exports go mainly to China, Korea and Las Palmas since currently Sierra Leone fish products cannot go the European Union due to the EU ban on fish and shellfish products from Sierra Leone. The lifting of the ban is being addressed by an EU project currently under way in the ministry of fisheries (Seisay 2008). These two projects are the EU Institutional Support to fisheries management project (ISFM) and the regional EU project focussing on strengthening fish production in Sierra Leone, Liberia and the Gambia.

Major challenges in the Industrial sector includes: the loss of revenue and employment due to the lack of a land based facilities for fisheries operations like a processing factory, poor surveillance system for the illegal fishing or poachers into the Sierra Leone waters, no fishery harbour complex for fishing vessels requiring dry docking or bunkering and the EU ban on fish export (Seisay 2008).

To have a successful fishery management regime there must be an effective Monitoring, Control and Surveillance system (Arnason 1993). Fisheries management consists of setting up of fishery management measures and enforcing them. For this reason, in Sierra Leone, the Ministry has a high priority on MCS (Seisay 2006).

In the industrial fishery, data collection is done by placing observers onboard all licensed fishing vessels except tuna purse seiners that do not come to port for licensing. These vessels are not monitored or surveillance because they operates far off the Inshore Exclusion Zone (IEZ) with no capacity by the naval boats to intervene. Based on scientific research done by the Institute of Marine Biology and Oceanography at the University of Sierra Leone (Ndomahina 2002) and from research surveys done by the Russian research surveys (Van der Knaap 1985) and recently by the Nansen Survey and the EU funded survey, effort is put in place to regulate mesh size, catch and effort control and now the Marine Protected Areas. At present the ministry has a memorandum of understanding with the Sierra Leone Navy to conduct fishery surveillance patrols with Ministry participation. Funds are provided by the Artisanal Fisheries Development Project (AFDEPT), which is, a project funded by the African Development Bank.

The surveillance aspect of the MCS is the most critical. It has gone through several difficulties since the days of the MPSSL (Marine Protection Services Sierra Leone), which was a private company, contracted to do MCS in the Sierra Leone and was funded by the EU (Seisay 2006).

There are several challenges in the implementation and effectiveness of these patrols due to; very limited number of days at sea. Patrols are only done in the inshore areas and not outside the Inshore Exclusion Zone (IEZ) since the size of the patrol vessels make it very difficult for them to go beyond the IEZ. Therefore there is a lot of poaching and piracy outside the IEZ that needs to be addressed for the effective management of the fishery. Enforcement in the Industrial fisheries is only done inshore and not offshore that is more the need for a proper surveillance system that will address the loss of revenues to the Government due to poaching.

2.2 The Artisanal Fishery

The artisanal fishery operates from 530 fish landing sites along the six major coastal districts of Sierra Leone. These are the capital Freetown, Port Loko, Kambia, Moyamba, Bonthe and Pujehun. The sector is characterised by a large number of fishing gears and crafts. Port Loko, Bonthe and the Western area are the most populated fishing district in Sierra Leone with Bonthe having the largest number of fish landing sites but with only about seven motorised fishing craft. The total number of fishermen, fishing crafts, engines and the total number of landing sites in the coastline is shown in Table 4.

Artisanal fish catches are dominated by the clupeids, principally bonga and herring (Figure 7). The rest of the catches are primarily various species of demersals. The clupeids (*Ethmalosa fimbriata*, *Sardinella spp*) constitute about 60 % of artisanal fishery production and are mainly exploited by the ringnet (purse seine) fishery. The clupeids are under increasing risk of overfishing due to the mass exploitation of the juvenile stages of these species (Seisay 2008b). It important to note that the juvenile or immature bonga, (awefu) and the juvenile or immature herring, (mina) contributed 30 % to total artisanal fishery production (Figure 8) between 2001 and 2005 (awefu 24.66 % and mina 5.41 %).

The artisanal fishery provides direct employment for about 30,000 fishermen (Seisay 2008a). Estimated 200,000 (MFMR 2003) additional jobs are provided by ancillary activities like fish processing, marketing, boat building and engineering with women playing major roles in the fish distribution channels (Seisay 2008b). In recent years around 100,000mt of fish is produced yearly in this sector, contributing to food for the poor fishing communities. Potential for increased fish production in this sector exists (Seisay 2008b) but this requires major investment in technology, fish handling and processing and data collection and analyses.

Table 4: Number of Fishermen, fishing sites, crafts and engines (2003 frame survey).

Coastal Districts	Fishermen	Fishing Crafts	Engines	Fishing Sites
Western Area	6033	1321	340	56
Port Loko	7674	1402	192	87
Kambia	2971	735	52	45
Moyamba	3430	846	20	62
Bonthe	6826	2644	7	241
Pujehun	3545	994	2	39
Total	**30479**	**7942**	**613**	**530**

The five main types of artisanal fishing crafts operating in Sierra Leone are: the Kru canoe, boats classified as Standard 1-3, Standard 3-5, Standard 5-10 and the Ghana boat. The Kru canoe is usually operated by one man using handlines, castnets and propelled by a paddle. The Standard 1-3 boats are operated by 1 to 3 persons and propelled by a paddle. Standard 3-5 and up to the 5-10 are powered by motors and have crew of 3-10. The Ghana boat is biggest and usually motorized (between 8 and 40 hp engines). The motorized boats use various fishing gears like gillnets, driftnets, handlines and longlines.

Presently about 40% of artisanal fishing gears are surface driftnets that target pelagic species at their juvenile stages (Seisay 2006). Figure 7 shows the difference between the demersal and artisanal landings from the artisanal fishery, whilst Figure 8 gives the total landings for the bonga and herring in the artisanal fishery from 2001 to 2007. Figure 7 shows the increase in the artisanal production after the war in 2002 with the increase in donor support to the sector in terms of the provision of fishing gear, engines and loans to fishers to start up after the war. The industrial figures show that these mostly foreign owned vessels left the country during the war years and only started appearing after 2002. It has been increasing gradually after 2002 to present, but it still shows that the artisanal fishery lands 70% to 80% of the catch.

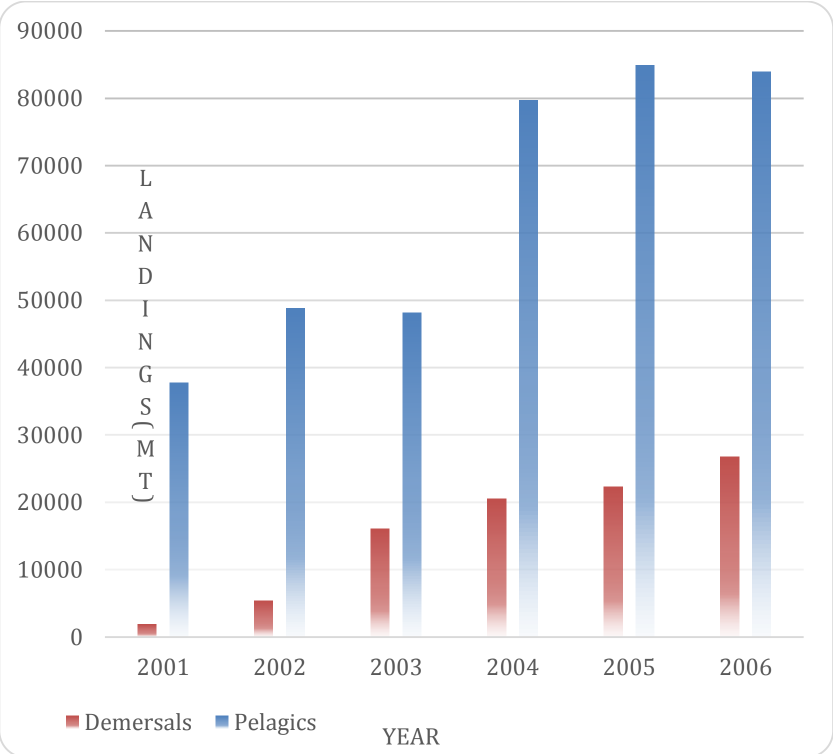

Figure 7: Landings of demersal and the pelagic species (MFMR data).

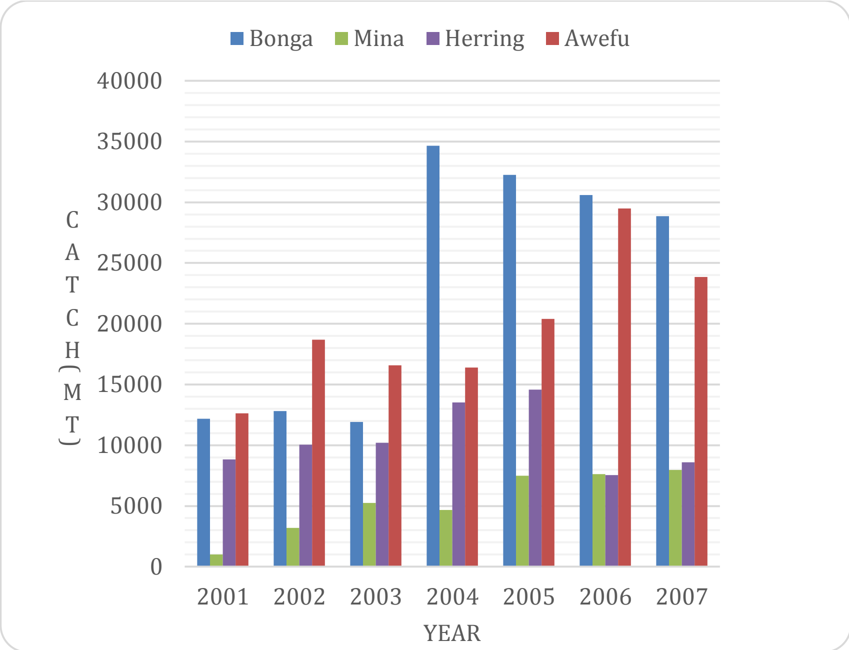

Figure 8: Total landings for the Bonga and Herring (MFMR data).

2.3 Limitations and Challenges

Both the industrial and artisanal fisheries are hampered by poor infrastructure on land. This applies to landing facilities, the availability of refrigeration and freezing storage, the availability and reliability of electricity, roads and other communication infrastructure. This leads to (i) limited landing from the industrial fishery which generally resorts to transhipments of their catches off-shore, (ii) high post-harvest losses and unnecessarily low quality of fish from the artisanal sector (Seisay 2008a). There are several additional problems in the fisheries sector in addition to the lack of adequate monitoring and enforcement in the industrial sector, there is an area conflicts between the artisanal and the industrial fishers with the resulting damage of fishing gear primarily for the former. The artisanal sector suffers from limited technology (i.e. low degree of vessel motorisation), which means that this sector is generally restricted to fishing very close to the shore. The degree of monitoring and enforcement in the artisanal sector is also poor leading to widespread use of illegal fishing gears (channel nets, dynamite, fish poisons etc). Poor fish processing and handling due to lacking facilities on land has already been mentioned. Licence, royalties and transhipment fees from the industrial fishery constitutes an important source of revenue for the Government of Sierra Leone and the main source for the Ministry of Fisheries and Marine Resources (MFMR)

3 THE GOVERNMENT FISHERIES POLICY

The goal of the National Fisheries Sector Policy is to foster responsible fishing practices and sustainable development of fisheries amongst the stakeholders for the present and future generations. The policy for fisheries development has been pronounced in various Government Policy documents and public statements: the National Development Plan (1974/75 – 1978/79) and the Green Revolution Programme (1986). A recently ratified national fisheries policy (2003) focuses on the following broad objectives:

- To improve national nutrition and food security through responsible fishing and the reduction of spoilage and wastage.

- To increase employment opportunities.
- To raise socio- economic status of the people in the fisheries sector including women.
- To improve the skills of the fishing communities and increase export earnings in the industrial fisheries.

The fishery policy for the artisanal fisheries sector is mainly geared towards poverty alleviation through the promotion of sustainable livelihoods and enhanced nutritional, socio-economic conditions. These policy objectives sometimes do overlap with the industrial sector where there is added emphasis on revenue generation. At present, artisanal fishery is virtually an open access venture. In 1993-1994 fishing year, the Ministry introduced licensing system in a bid to exercise control on effort, net specifications, fishing methods etc. The licensing functions of fishing canoes have now been devolved to Local Government Authorities (since 2004). The devolution of the this function has been a major problem for the Local Government since no training of the staff of the Local Councils was done and this has created a major setback in the control of the registration and licensing of the artisanal canoes and the conflict between the Industrial and artisanal sector.

3.1 The Fisheries Management Instruments

The fisheries management instruments include the National Fisheries Policy of 2003, the Fisheries Management and Development Act, 1994. The Fisheries Regulations in 1995 and recently the Local Government Act 2004 (the devolution of functions to the Local Councils) and the Fisheries Product Quality and Standards Act of 2007. The 1994 Fisheries Act is one of the most commonly used management measures by the ministry of Fisheries. It includes the following measures:

- Effort control regulation (limiting access by licensing).
- Input control regulation (Mesh size regulation, gear restrictions etc.).
- Area limitations (Inshore Exclusion zone).
- Landing, import and export obligations (e.g. 30% fish landing obligation for the Shrimp Trawlers).
- Biological control (No-take regulation for berried lobsters, etc).
- Enforcement of fisheries regulations (MCS and penalties for violations).

It should be noted that most or all of this regulations and controls are for the Industrial sector. In the artisanal fishing gears (both coastal and inland waters), the mesh size regulations are hardly enforced and there is even an established (though illegal mesh sizes) open seine net fishery for juvenile *Sardinella spp* (locally referred as mina fishery).

3.1.1 The Artisanal Fishery Management Regime: Institutional Arrangements

The Local Councils

The overall responsibility for the management and development of the artisanal fisheries is with the Ministry of Fisheries and Marine Resources (MFMR), but the Ministry with the assistance of the EU funded Institutional support to fisheries development project is currently working on the implementation of a territorial user right fisheries (TURF) arrangement where in the function of licensing of artisanal fishing crafts have been devolved to the Local Councils under the 2004 Local Government ACT. This ACT gives powers to the local councils in the six coastal districts of Sierra Leone (Western Area, Port Loko District, Kambia District, Moyamba District, Bonthe District and Pujehun District) to issue license to fishing canoes and their fishing gears. The license will give access right to fishers and the economic rent will be used to develop these local communities by complimenting government support for basic livelihood amenities such as hospitals, schools, drinking water and toilet facilities. It is hoped that the devolution of this function will enhance community management of the small pelagic fisheries in promoting the control of the resource by the community. The Local Councils are now being trained by staff of MFMR in various aspect of licensing of fishing canoes as stipulated in the third and fourth schedules of the 1995 fisheries regulations.

Fisherfolk's organizations

The fishermen have formed two unions that have been recognised by the Ministry, which aims to address the concerns of the fishing communities. These are:

- Sierra Leone Artisanal Fishermen Union (SLAFU).
- Sierra Leone Amalgamated Artisanal Fishermen Union (SLAAFU).

The two union works with the Ministry in the promotion of responsible fishing practices in the artisanal fisheries sector and the Local Councils in the licensing of artisanal fishing crafts.
The Union has become very instrumental in enforcing fishing gear regulations, which is aimed to gear toward the reductions of the high incidence of juveniles from the landings.
Through the assistance of donor funded projects, e.g. EU 'Institutional Support for Fisheries Management' (ISFM) project, the Ministry is currently conducting studies with a view of reviewing the 1994 Fisheries ACT for institutionalizing the role of fisherfolks in the community management of the fisheries.

3.1.2 The Artisanal Fisheries Management Measures

Proposed management measures, through stakeholder consultations by the EU funded (Institutional fisheries management project).

In order to promote community management of the fisheries, stakeholder consultations are held at the national level to discuss fisheries management issues. The following recommendations have been agreed upon during two consultative meetings (ISFM 2009):

- The proposed mesh size from the consultative meeting is 45 mm which is a bit higher than the current mesh size for the gill net of 43mm
- A Marine Protected area has been proposed for in Yawri Bay, Sierra Leone River Estuary, Sherbro River, Scarcies River but a lot of research has to be done for this to be implemented.
- Community Management was proposed from these consultative meetings involving fisher's organizations, local councils, village headmen, the Ministry of Fisheries extension staff, Sierra Leone Navy, Maritime police. This needs Stakeholder analyses and planning for it to be implemented as a policy instrument.
- Banning of beach seines Fishing nets by the small scale fisher men was proposed and had been implemented but with a lot of problems between the ministry and the Fishing Communities.

3.2 Regional Management of the Small Pelagics

The exploitation of the Small Pelagics is an economic activity for most of the countries in North-west Africa. That is the countries in the Sub-Regional Fisheries Commission (SRFC) whose head office is in Dakar, Senegal. The largest part of this stock consists of small pelagic species (mackerel, sardine, sardinella, anchovy and horse mackerel, bonga shad). These stocks represent about 80% of total production in Sub-Regional Fisheries Countries (SRFC 2007).

However, these small pelagic resources are exploited on national as well as on regional level and are not restricted to the territory of one country but extend across the borders of neighbouring coastal states known as shared stocks. There are other stocks that migrate along the coast. They may be present for a part of the year in the water of one country and the rest of the year in the waters of a neighbouring country. This trans-boundary character plus their natural diversity makes it necessary for a specific management and regional cooperation between these countries taking the trans-boundary context into consideration (SRFC 2007).

To improve the management of these resources in the Northwest African regional context, the Netherlands Government has supported research on the small pelagic stocks and has as part of its International Policy Program on Biodiversity put a project in place called "Towards regional policies for a sustainable fisheries for small pelagic in North-West Africa" that aims to contribute to the conservation and sustainable exploitation in the Sub- Regional Fisheries Commission member States and Morocco **(**SRFC 2007).

Small pelagic catches dominate West African fisheries, and represent 71% of the total landings, that is about 1, 7 millions of tons per year (FAO 2007). These fisheries present some different characteristics according to the countries of the region. Besides, their contributions in the national economies they have variable relevance and scale according to the background of the country.

In Morocco, for instance, small pelagics are exploited owing to integrated industrial networks whereas in Mauritania they are mainly exploited by foreign vessels, generating a substantial income for the government. In Sierra Leone, Senegal, Guinea-Conakry the small pelagics fishing is rather at the basis of small-scale activities whose economic and social role is tremendous.

The other West African countries, namely those situated in the southern zone of the Sub-Regional Fisheries Commission (SRFC) such as the Gambia, Guinea, Guinea-Bissau, and Sierra Leone the Bonga represents a major part of the catches and small-scale processing industries in the above-mentioned countries. This species also constitutes a vital item for the supplying of the markets of land-locked countries such as Mali and Burkina Faso.

4 THEORY AND MODELLING

The main objective of fisheries management is to maximise the benefits from the fishery. In the small pelagic fisheries in the coastal districts of West Africa including Sierra Leone access is generally open. Consequently these fisheries are subject to the common property problem (Harding 1967) and there is typically a very large number of fishermen and excessive fishing effort. To ensure the sustainability of these fisheries and maximize the flow of economic benefits a proper fisheries management system needs to be put in place (Arnason *et al*. 2000). Gordon (1954), Clark (1990), and others influenced fisheries economics by establishing a clear link between the economics of the fishery and the population dynamics of the resource. The resulting models, combining economics and biology, are referred to as bio-economic models. A bio-economic model in equilibrium (sustainable) may be illustrated as in Figure 9.

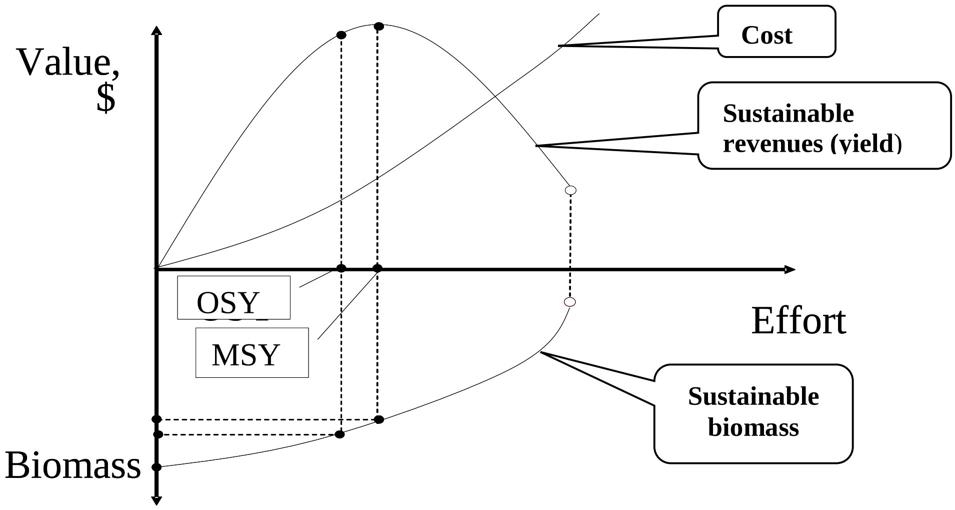

Figure 9: A Sustainable Fisheries Model showing the Optimal and maximum sustainable yields.

It should be noted from Figure 9 that it is the Optimal Sustainable Yield (OSY) effort level that is socially optimal; the Maximum Sustainable Yield (MSY) is not socially optimal (Arnason 2008a). The figure also shows that the OSY implies greater biomass than the MSY. The OSY is sustainable with little risk of stock collapse and generally substantial profits.

An efficient fisheries management system maximises the contribution of the fishery to social welfare. This means it maximises the difference between revenues and costs, which implies the OSY fishing effort. This also maximizes profits if prices are correct.

An Open access fisheries is an arrangement where every interested person can take part in the fishing activity. This is also called a common property fishery since the right to exploit the fishery is common to all.

In an unmanaged common property fishery, fishing effort converges at a point where there are no profits (e.g. the poor fishermen in the artisanal fisheries of Sierra Leone). The biomass is usually low (below the OSY level) and there is an increase or substantial risk of stock collapse. The harvest is often less than the Optimal Sustainable Yield (OSY).

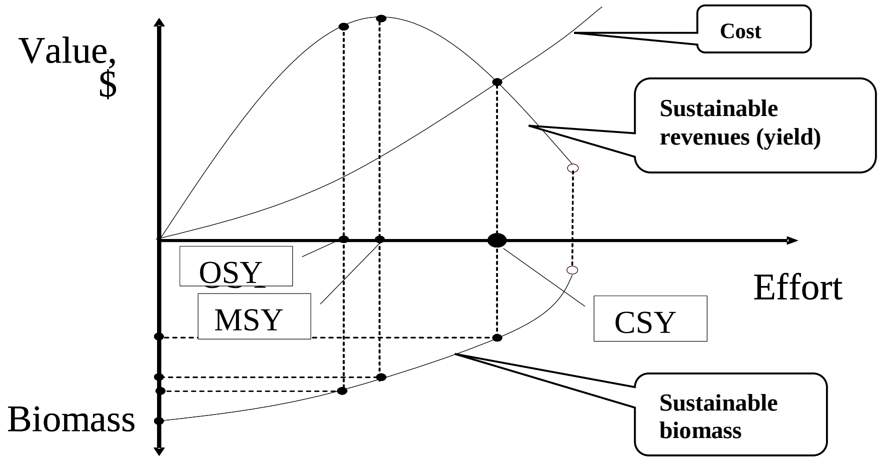

Figure 10: An Unmanaged common property fishery.

Figure 10 illustrates the open access or common property fishery, where existing fishers and new entrants into the fishery are attracted more into the fishery by profits and will leave it if they suffer losses. Thus, since the OSY and MSY effort levels are profitable, they will continue expanding until they hit the point of zero profits. This is the Critical Sustainable yield or the Open Access Yield, which is the CSY in figure 10. Fishing effort beyond CSY results in losses, which will reduce fishing effort until CSY is hit. Thus, the CSY effort level is the long term equilibrium point of the fishery. At this point the total revenues equal to the total cost and there are no profits in the fishery. The fish stock is also relatively small. Therefore with no fisheries management system in place (the unmanaged fishery) fishing effort will be excessive, stocks will be relatively small and there will be no net economic benefits from the fishery (Arnason 2008a).

Fisheries are rarely in equilibrium, they evolve over time in terms of fishing effort, stocks, harvests and profits with maybe complicated evolutionary paths. Since most fisheries spend most of the time travelling along these evolutionary paths we also need to obtain some understanding of them.

The evolution of the fishery over time is radically different depending on whether the optimal dynamic path is chosen or whether the open access dynamics apply (Arnason, 2008a). To explain the dynamics of a fishery it is useful to define two equilibrium curves; the biological equilibrium curve and the economic equilibrium curve. The biological equilibrium curve is simply the loci of points in effort biomass space such that harvest equals biomass growth so that biomass doesn't change. This curve is labelled x=0 in Figures 11 and 12. Economic equilibrium curve is simply the loci of points in biomass effort space such that profits are zero. This is indicated by the vertical curve in Figures 11 and 12 and labelled e=0. Full competitive equilibrium in the fishery is obtained where these two equilibrium curves intersect (Figures 11 and 12) (Arnason 2008a).

The optimal approach paths to the long run optimal economic equilibrium of the fishery are indicated in Figure 11. Note that, as indicated in the diagram, if biomass is low compared to the long run optimal equilibrium, it may be optimal to close the fishery down.

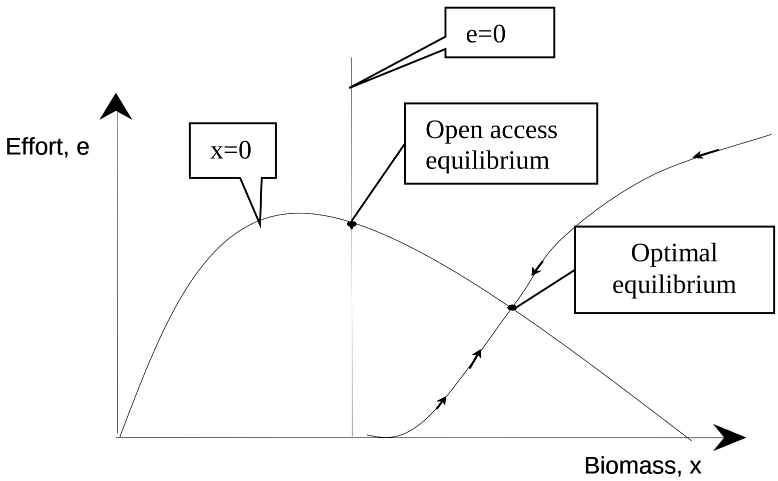

Figure 11: Optimal dynamic adjustment path.

Note also that if a positive fishing effort is optimal, then profits at that fishing effort must be positive. This can also be seen from the optimal path traced out in the diagram; to the right of the economic equilibrium curve profits are positive.

The open access or competitive approach paths to the open access equilibrium are illustrated in Figure 12. These paths are defined by the biological dynamics and the assumption that fishing effor rises in a liner fashion with profits, being unchanged if profits are zero. The result are cyclical adjustment paths as illustrated in Figure 12. Under certain circumstances these paths may be unstable, so that the cycles move away from equilibrium instead of toward it.

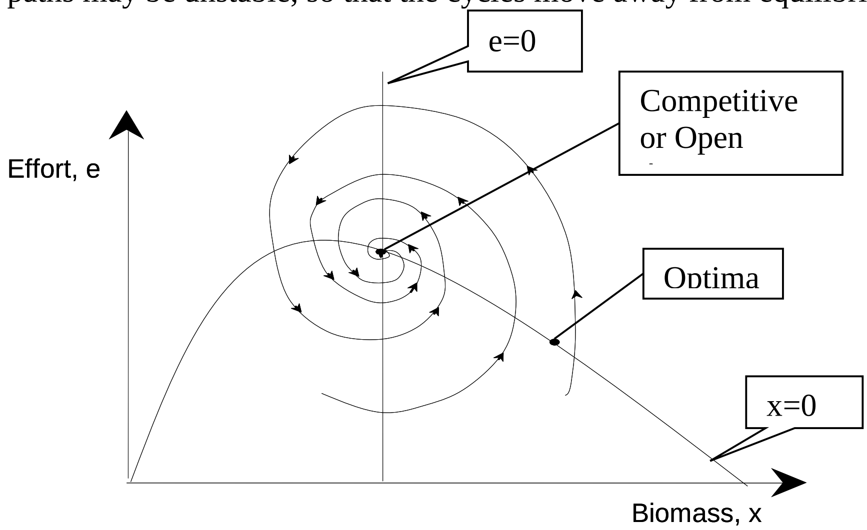

Figure 12: The Competitive fishery dynamic path**.**

The possible evolution of the competitive fishery from the initial level can be described in Figure 12. The biomass level with a path that starts at the virgin stock equilibrium (x) with zero or no fishing effort with the location of the economic equilibrium curve, **e= 0** represents an opportunity for a profitable fishery. At this point the increase fishing effort is very fast and the biomass decreases with the reduction in profits. This will happen until the fishery crosses the economic equilibrium line of zero profits. At this point the profits are negative and the fishing effort starts to decrease, and when the effort decreases substantially, the biomass will start to recover again with profits becoming positive again. When the equilibrium line is crossed again the fishery will become profitable with an increase in fishing effort (Arnason 2008a). It could be seen from the diagram and the explanation that the adjustment to a competitive equilibrium is a cyclical one. It is characterised by a periodically profitable fishery with an increase in fishing effort and harvest followed by decline in biomass and economic losses in the fishery.

4.1 Modelling the Sierra Leone small pelagic fishery

To describe the Sierra Leone herring fishery, the following basic fisheries model is adopted:

(1) $\dot{x} = G(x) - y$ (Biomass growth function).

(2) $y = Y(e, x)$ (Harvesting function).

(3) $\pi = p \cdot Y(e,x) - C(e)$ (Profit function).

(4) $p = P(y)$ (Landings demand function).

The five variables of this model, i.e. ***x*, *y*, *π*, *p*** and ***e*** represent biomass, harvest, profits, landings price and fishing effort, respectively. The first four are endogenous — determined within the model. The fifth, fishing effort, is exogenous; it is a control variable for the fisheries operators. All variables depend on time, i.e., they can change over time. The derivative, $\dot{x} \equiv \partial x / \partial t$ measures the change in biomass at a point of time. Note that parameters taken to be constants such as various prices and technological coefficients are not explicitly mentioned in the above presentation of the model.

In implementing the model, the following functional specifications, suggested by the available data, are employed.

(6)
$$x_{t+1} - x_t = G(x_t) = \alpha \cdot x_t - \beta \cdot x_t^2$$
$$Y(e_t, x_t) = q \cdot e_t \cdot x_t^b$$
$$C(e_t) = c \cdot e_t + fk$$
$$P(y_t) = p$$

where ***α*, *β*, *q*, *b*, *c*, *fk*** and *p* are constants and ***t*** refers to time. Note that time is in discrete units of years, in accordance with the available data. The constant ***α*** is the intrinsic growth rate of the biomass, the ratio ***α*/*β*,** is the carrying capacity of the biomass, ***fk*** represents fixed costs, ***q*** catchability, ***f*** is the elasticity of landings price with respect to the volume of landings. Note also that this model is linear in fishing effort. This seems to be appropriate for a fishery with a great number of largely identical fishing units (boats). The model, however, is non-linear in biomass, which complicates the calculations. The unknown coefficients are estimated with the help of the available data and other empirically motivated assumptions about the fishery. The Ministry of Fisheries and Marine Resources (MFMR) collects data on the fisheries, primarily data on catch volumes and composition. Some of the data is provided in Appendices 1 and 2. For the industrial fishery, the data collection activity includes placing observers onboard fishing vessels. They collect and records catch and effort data in log books, which is then entered into the industrial fisheries database system (IFDAS) in the Statistics Unit of the Ministry for analyses.

With the artisanal fisheries sampling methods are used. Twice every week, 25 landing sites are randomly selected out of the 530 landing sites for the collection of catch, effort and fish price data. The data is also sent to the Statistics Unit for the entry and analyses using the Artisanal fisheries stock assessment (ARTFISH) database software. A raising factor based on the number of boats sampled and an estimate of the total number of boats operating is utilised to raise the sample estimates from the sampling sites to the estimated figures at the national level (Seisay 2008b).

Unfortunately, however, apart from catch and some basic stock data, the information on the herring fishery is quite limited. This applies in particular to the economics of the fishery. Therefore this study had to resort to what can be described as informed assumptions. The empirical assumptions used in the study are summarized in Table 5.

Table 5: Data for the empirical assumptions

Empirical assumptions			
Variable	**Symbol**	**Value**	**Units**
Maximum sustainable yield	MSY=	120.00	1000 mt
Virgin stock biomass	XMAX=	498.50	1000 mt
Landings in base year	Xy(t*)=	69.30	1000 mt
Landings price in base year	p(t*)=	0.80	m US$/1000 mt
Net biomass growth in base year	xdot(t*)=	0.00	1000 mt
Profits in base year	prof(t*)=	-2.00	m US$
Fixed cost ratio in base year	eps(t*)=	0.00	No units
Schooling parameter	b=	0.70	No units
Elasticity of demand w.r.t. biomass	d=	0.00	No units
Effort (index or real base year effort)			
Actual fishing effort (No. of Boats) in base year	e(t*)=	6.60	1000 boats
Necessary fishing effort in base year	estar(t*)=	**6.60**	1000 boats

Employing a special fisheries program designed by Arnason (2008b) these empirical assumptions lead to the following model coefficients in Table 6:

Table 6: The estimated Parameters (Arnason 2008b).

	Estimated Coefficients						
Coefficients	α	β	q	b	c	fk	p
Estimates	0.96283	0.00193	0.46	0.7	8.703	0	0.8

For the logistic function it is easy to verify that the maximum sustainable yield, MSY, and the stock carrying capacity, X_{MAX}, are given by the expressions:

$$\text{MSY} = \frac{\alpha^2}{4 \cdot \beta}$$

$$XMAX = \frac{\alpha}{\beta}$$

It then follows from the estimates in Table 5 that the estimated MSY=120 thousand mt and the estimated X_{MAX}=499 thousand mt (metric tonnes).

Figure 13 provides a summary description of this fishery. The figure is drawn in the space of (fishable) biomass and landings (harvest) and applies at each point of time and, therefore, also in equilibrium. The parabolic graph represents the biomass growth function. As can be seen, it covers biomass from zero to the carrying capacity of almost 500 thousand mt. and has a maximum sustainable yield of about 120 thousand mt. If, for any biomass level, landings lie on this curve, a biological equilibrium prevails. The other curves in this diagram are variable iso-profit curves, i.e. loci of biomass and harvests, which represent constant variable profits.

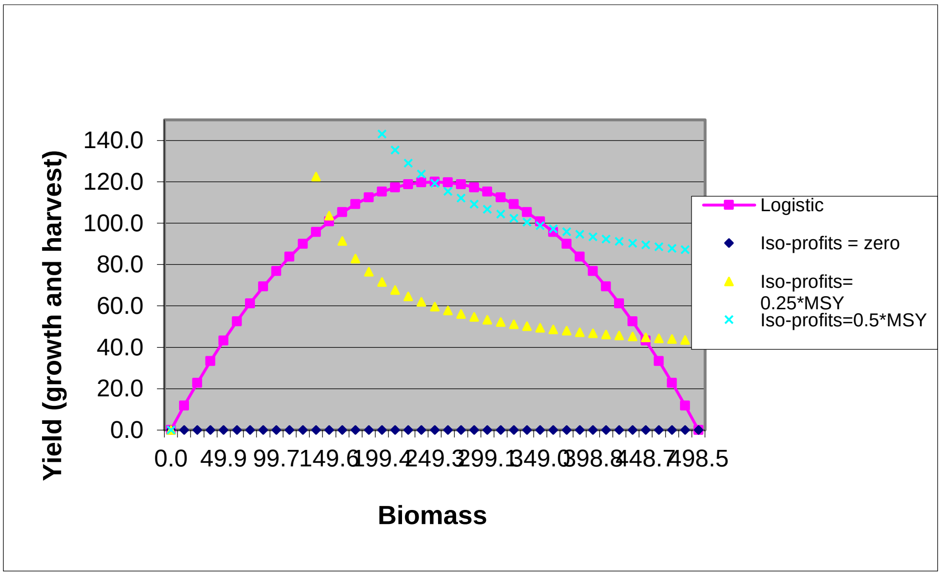

Figure 13: The estimated Logistic bio-economic fisheries model in biomass and harvest.

Any point where these curves intersect the biomass growth curve represents a sustainable fishery with the corresponding variable profits. Thus, the traditional, zero-profit bio-economic equilibrium is found where the zero-isoprofit curve intersects the biomass equilibrium curve. This happens, as indicated in the diagram, roughly where biomass is less than a quarter of the virgin stock equilibrium. The highest sustainable profits are obtained where an iso-profit curve is a tangent to the biomass growth function. As the diagram suggests, this occurs at biomass of some 300 thousand mt. and harvest of over 100 thousand mt. At this point, annual variable profits from the fishery (approximately rents) amount to approximately 50 thousand mt. of herring.

A different perspective on the same fishery is illustrated in Figure 14. This figure also describes the equilibrium or sustainable fishery but now in fishing effort revenue space. As can be seen from the diagram, the fishery is currently close to zero profits with 6.6 (1000) boats and, apparently, at or close to the backward bending part of the sustainable revenue curve which suggests a high degree of instability.

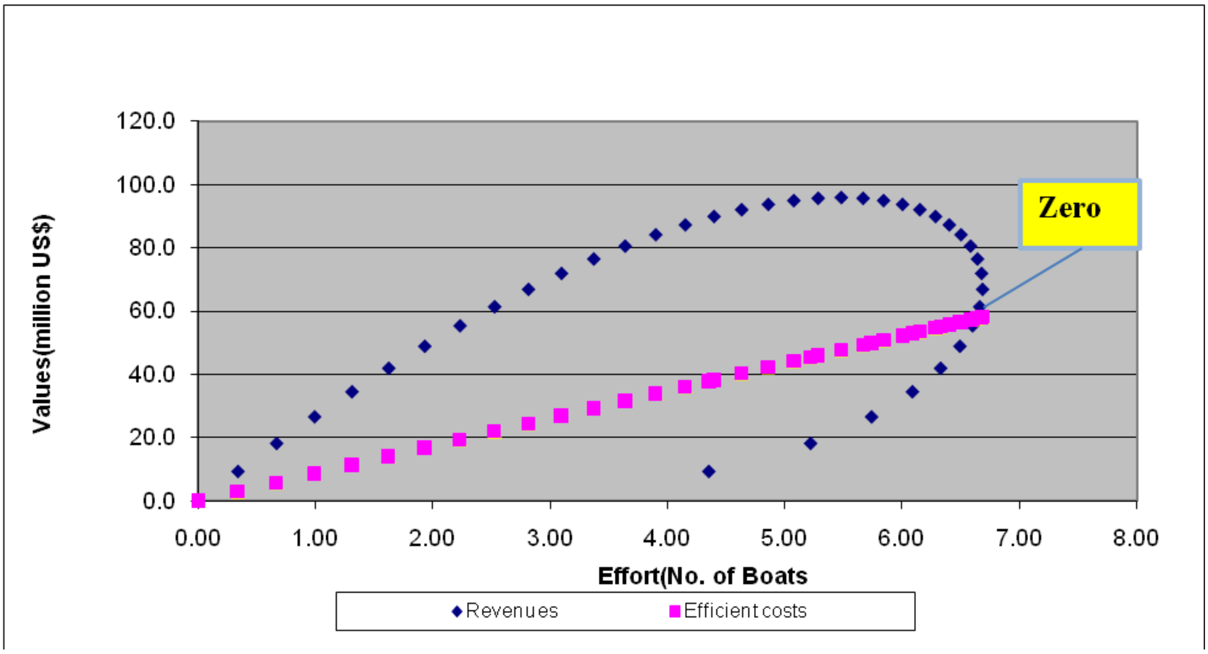

Figure 14: Result of the fishery from the bio-economic model in terms revenues and costs.

The representation of this fishery illustrated in Figures 13 and 14 seems reasonable. It is in accordance with what is known about the biology of this fishery. It also fits with the scant information about the economics of the fishery and it is in accordance with fisheries economic theory.

4.2 The Optimal Sustainable yield

The sustainable fishery is the equilibrium state of the fishery and the optimum is the maximisation of the total sustainable output (yield) from the fishery. The optimal sustainable yield is the yield level consistent with the biological capacity of the stock (King 1995). It takes into account economic, social and environmental factors and it is less than the MSY. As already mentioned, the small pelagic fishery of this study is an open access and unmanaged fishery with no control of the fishermen entering into the fishery. As a result the fishery is highly inefficient with greatly excessive fishing effort and depressed fish stocks. To bring the fishery to the long run, equilibrium optimal level requires a substantial reduction in fishing effort and a great increase in the fish stock.

Table 7 compares the features of the current fishery with those of the optimal fishery in equilibrium and the changes involved. The results from the table shows that the level of fishing effort in number of boats has to be reduced from the current of 6,600 boats to the optimal of 4,580 for the logistic biomass growth model. The optimal biomass level is some 300 thousand mt compared to the current level of perhaps 90 thousand mt. and the optimal long run harvest level is at 115 thousand mt compared to the current level of 70 thousand mt.

It is important to realize that the Portee and Old Wharf fishing communities, the specific subjects of this study, only account for a small part of this fishery, or approximately 5% in terms of the total fishing effort, harvest and profits reported in table 7. In these two communities the current number of fishing boats is 271 boats, which should be reduced to about 188 boats according to the results in Table 7. For the optimal fishery, the profits per boat would be about 11,000 US$ compared to a loss now of some 3,000 US$.

Table 7: The main results from the bio-economic model.

Main Results							
		Current		Optimal		Difference	
	Units	Logistic	Fox	Logistic	Fox	Logistic	Fox
Biomass	1000 mt	87.2	43.4	302.0	234.5	214.8	191.2
Harvest	1000 mt	69.3	69.3	114.6	115.7	45.3	46.4
Effort	No. of boats	6.60	6.60	4.58	3.38	-2.02	-3.22
Landings Price	m US$/1000 mt	0.80	0.80	0.80	0.80	0.00	0.00
Revenues	m US$	55.4	55.4	91.7	92.6	36.3	37.1
Costs	m US$	57.4	57.4	39.8	29.4	-17.6	-28.0
Profits	m US$	-2.0	-2.0	51.9	63.1	53.9	65.1
Profits per unit revenue	Ratio (percent)	-0.036	-0.036	0.566	0.682	0.602	0.718
Profits per unit effort	m US$/No. of bo	-0.303	-0.303	11.334	18.673	11.637	18.976
Profits per unit harvest	m US$/1000 mt	-0.029	-0.029	0.453	0.546	0.481	0.575
Rents	m US$	-2.0	-2.0	51.9	63.1	53.9	65.1

4.3 Dynamic adjustment paths

The dynamics of the current fishery as well as the optimal adjustment paths are also of great interest. The dynamics of the stock are specified in equations (6) and table 6 above. The dynamics of fishing effort are specified essentially by the equation below and the graph from the model show the theory of the dynamic adjustment path discussed above.

$$e_{t+1} - e_t = g \cdot \pi_t$$

Where $\boldsymbol{e_t}$ represents the number of boats operating in the fishery at time $\boldsymbol{t}$ and $\boldsymbol{\pi_t}$ denotes profits per boat in the fishery at time $\boldsymbol{t}$**.** The coefficient $\boldsymbol{g}$ is positive and a constant.

With these specifications it turns out that the unmanaged fishery inherently a fluctuating one and tends to instability with boom and bust cycles. This is illustrated in Figure 15, which draws two open access paths one (the blue one) for no price rise and the other red one for a price rise. It can be seen these paths exhibit cycles both in terms of biomass and fishing effort. This may or may not be realistic. The available data, which are very limited, doesn´t really allow us to judge that. What we know is that small pelagic fisheries worldwide tend to be unstable partly due to their short life span high intrinsic growth rates and schooling behaviour all of which seem to apply to this fishery.

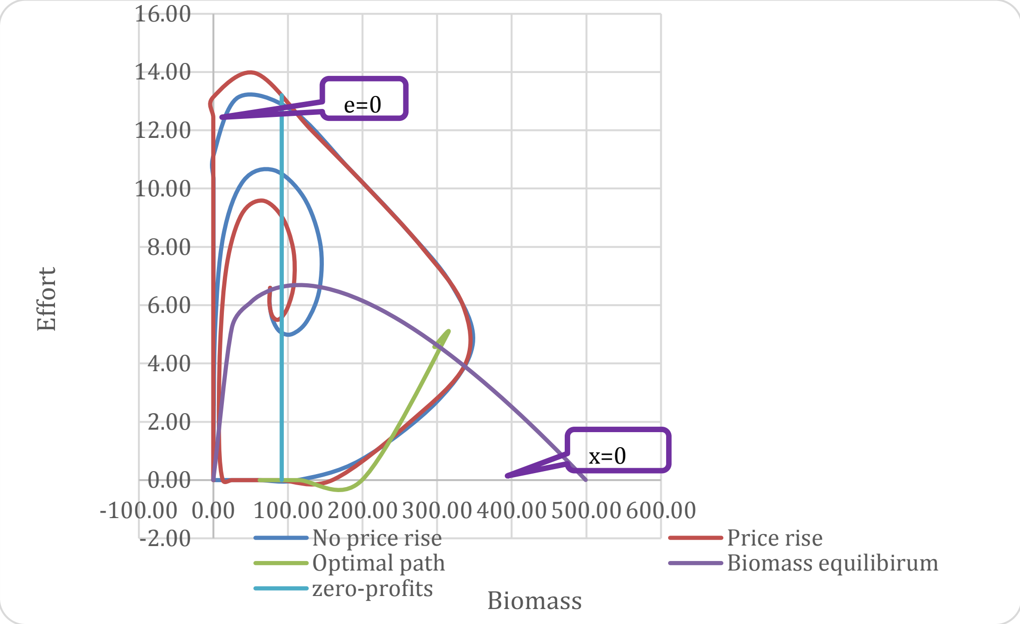

Figure 15: The results of the dynamic path.

In Figure 15 we also draw an approximately optimal dynamic path of the fishery. As can be seen, this involves closing the fishery for some time (three years) in order to rebuild the stock and then a fairly rapid increase in fishing effort to the long run optimal equilibrium which corresponds to a biomass which is more than three times the current fishing effort and a reduction in fishing effort of about 1/3 of the current fishing effort. Note that in long run optimal equilibrium, there are substantial annual profits as that point is far to the right of the zero profit equilibrium curve (e=0). The key numerical features of the open access and optimal dynamic paths are listed in the appendix 3, 4 and 5 to this chapter.

5 THE INVESTMENT PROJECT: COST AND BENEFITS

This chapter investigates the costs and benefits of investing in new landings site facilities at the Old Wharf community in Freetown. These facilities are expected to improve the quality of landings substantially and thus increase the unit price of landed fish. However, the sustainability of these benefits depends wholly on the fisheries management in place. Under poor fisheries management, such as the current regime of essentially open access, the benefits will quickly be reduced with an increase in fishing effort. In that case, the present value of these benefits may not justify the cost of the investment project. Under good fisheries management, however, the benefits from increased fish price will be lasting and the overall present value of the project will be much higher.

5.1 Project description

The West Africa Regional Fisheries Project (WARFP) funded by the World Bank plans to construct a fish landing site at the Old Wharf fishing community. This was agreed upon based on the fact that the other major fishing communities in the Freetown area have had fisheries development projects before. There are presently four landing sites that have been constructed by the Artisanal Fisheries Development Project funded by the African Development Bank (ADB 2001).

Recently, a consultant ports engineer was sent by the World Bank to look at the two possible sites for the construction. Based from his recommendations, it was agreed that the new fisheries landing site would be constructed at the Old Wharf fishing community (Sciortino 2009). This then can serve the two communities, the Old Warf one and the nearby Portee community.

The proposed fish landing site will be equipped with coldrooms, ice making centre, fish market facilities and engine repair shop. It was also proposed that it would include store facilities for the sale of vessel engines and nets. Further it was proposed that a fuel service station should be built at this centre because of the incidences of accidents caused by fishermen storing fuel in their houses. At this point it is not clear whether the fuel service station and the engine and net trading store will be included in the investment.

The construction of this facility is thought to lead to a greatly improved quality of landings and the fish supply from these communities. The currently poor facilities to refrigerate the catch, due to shortage of ice and the landing of the catch onto a sandy beach, are believed to be the main causes for low quality of landings. A customs built wharf and easy access to inexpensive ice are expected to largely eliminate these problems. Further deterioration of landed catch is currently due to the unavailability of cold storage. This problem will be greatly alleviated with the cold storage included in the project. It is estimated from this study that the unit price of the landed value of catch may easily increase by 10-20% due to these quality improvements.

The new landings site facility is also expected to reduce operating costs for the fishers, due to speedier landings process and cheaper ice, and make it possible for them to employ improved technology. These impacts, however, are thought to be secondary to the gains due to improved quality of landings and fish supply.

The small pelagic fishery in Sierra Leone is an open access fishery and allows unlimited entry of fishermen into the fishery. In this system there is little or no incentive for the fishers to conserve the fish stock since the benefits of doing so will primarily befall other fishers. A phenomenon usually referred to as the 'Prisoner's dilemma'. The potential benefits obtained from harvesting the resource will be lost due to increase in fishing effort by new entrants into the fishery which leads to stock collapse if there is no fishery management or poor fisheries management. This is therefore the reason for the access limitation into the fisheries to maximise economic benefits.

This project is to do a cost benefit analyses of the poorly managed small pelagic fishery without investment and the assessment with an investment of a landing site to the Portee and Old Wharf fishing communities in Freetown. The study will therefore look at the impact of this landing site to these two fishing communities in terms of maximising their profit from the investment.

5.2 Project costs

Project costs consist of

(i) Investment costs.
(ii) Fishing site running costs.
(iii) Fisheries management costs.

5.2.1 Investment costs

The total cost of the investment has been estimated to be 1.717 m. US$ (Table 8) is spread over two years. We assume that the costs are equal in both years. We further assume that the investment commences in 2011.

Table 8: Landing Site Investment

Description	Amount (Le)	Amount (US$)
Preliminaries	80,000,000	26,667
Architectural works	1,717,866,200	572,622
Civil Structure Works	1,386,225,000	462,075
Mechanical and Electrical Equipments	1,500,000,000	500,000
10% added contingencies	468,409,120	156,136
Total Investment	5,152,500,320	1,717,500

5.2.2 Fishing site running costs.

The running costs of this facility consist of (a) maintenance and (b) supervision (harbourmaster etc.) and other labour. The rest of the costs are supposed to be paid by the users as service fees. We take maintenance to be 3% of the investment cost per year and the supervision and other labour to amount to 1% of the investment costs per annum. In total this, then is 4% which amounts to 68.704 US$ per year. We assume these costs to begin in the first year after the completion of the facilities, i.e. year 3.

5.2.3 Fisheries management costs

If a good fisheries policy is to be adopted, the appropriate fisheries management is necessary. This is inevitably costly. In this thesis, it is assumed that community fishing rights being awarded to the various inshore fishing communities will effect good fisheries management. As a result, the fisheries management costs will be minimal. Nevertheless, we assume that they amount to US$ 25.000 per year for these two communities (Old Wharf and Portee). If there is good fisheries management, these costs are assumed to commence in year 2 of the project, i.e. 2012.

5.3 Project benefits

The project benefits primarily consist of unit price rises of the landings. Here we assume these price rises are from the base price 0.8 US$ per kg to 0.9 US$ per kg. Moreover these rises are supposed occur in the following way over time (Table 9).

Table 9: Assumed unit price rise from the base year 2011 to 2014.

Year	2011	2012	2013	2014
Price	0.800	0.824	0.864	0.900

This price raises lead to improvements in profitability. Assuming continuing poor fisheries management the profits will soon be wiped away by the increased fishing effort (primarily new entry into the fishery) according to processes described in the previous section. The development of profits in this case will be described in the cost benefit table 10 below. If, on the other hand, there is a good fisheries management, the benefits from higher fish process will persist. In that case the net benefits of the investment project are as described in cost benefit table 11. Note that the two communities only have 5% of the total fishery.

5.4 Cost benefit analysis: Present values

First we consider the costs and benefits of the project assuming continuing poor fisheries management. The key results are outlined in Table 10. In this case the present value of the project is negative of about US$ 13 million. This may be mildly surprising given the fact that this is an open access fishery. The reason, however is that there are initial net benefits due to the price rise that are not completely wasted during the adjustment phase.

Table 10: The cost benefit table with poor fisheries management

Costs and benefits: Poor management					
	Investment	Price unchanged, 0.8	Price rise to 0.9	Gain from invest-ment	Net cash flow
Year	1000 US$	1000 US$	1000 US$	1000 US$	1000 US$
2011	858.8	-350.1	-350.1	0	-858.8
2012	858.8	-340.6	-271.6	69	-789.8
2013	68.7	-230.7	-58.6	172.1	103.4
2014	68.7	-37.5	231.1	268.6	199.9
2015	68.7	229.8	503.1	273.3	204.6
2016	68.7	589.9	779.8	189.9	121.2
2017	68.7	1023.1	877.2	-146	-214.7
2018	68.7	1291.8	498.9	-792.9	-861.6
2019	68.7	903.3	-456.9	-1360.2	-1428.9
2020	68.7	-381.9	-1556.6	-1174.6	-1243.3
2021	68.7	-1954	-2047.9	-94	-162.7
2022	68.7	-2707.5	-1564.1	1143.4	1074.7
2023	68.7	-2078.5	-442.5	1635.9	1567.2
2024	68.7	-474.5	0	474.5	405.8
2025	68.7	0	0	0	-68.7
2026	68.7	0	0	0	-68.7
2027	68.7	0	0	0	-68.7
2028	68.7	0	0	0	-68.7
2029	68.7	0	1181.9	1181.9	1113.2
2030	68.7	0	3139.8	3139.8	3071
2031	68.7	0	4656.3	4656.3	4587.5
2032	68.7	0	5056	5056	4987.3
2033	68.7	0	4330.4	4330.4	4261.6
2034	68.7	0	2351.1	2351.1	2282.4
2035	68.7	0	-1141.6	-1141.6	-1210.3
2036	68.7	214.7	-921.8	-1136.5	-1205.2
2037	68.7	1512.2	-921.8	-2434	-2502.7
2038	68.7	3149.2	-921.8	-4071	-4139.7
2039	68.7	4063.5	-921.8	-4985.3	-5054
2040	68.7	3970.7	-921.8	-4892.5	-4961.2
2041	68.7	2862.1	-921.8	-3783.9	-3852.6
2042	68.7	564.2	-921.8	-1485.9	-1554.6
2043	68.7	-2612.2	-921.8	1690.4	1621.7
2044	68.7	-922.7	-921.8	1	-67.7
2045	68.7	-922.7	-921.8	1	-67.7
2046	68.7	-922.7	-784	138.7	70
2047	68.7	-922.7	0	922.7	854
2048	68.7	-922.7	0	922.7	854
2049	68.7	-922.7	0	922.7	854
2050	68.7	-922.7	0	922.7	854
2051	68.7	-922.7	0	922.7	854
Present value=	2,657.30	-85.2	2,559.20	2,644.40	-12.9

Turning now to the case of good fisheries management, the results are summarized in table 11 below. In this case the present value of benefits from the investment is some US$ 6 m with a 23% internal rate of return (IRR).

Table 11: The cost benefit table with good fisheries management.

Cost and benefits: Good management						
	Landing Site Investment	Fisheries management costs	Price unchanged, 0.8	Price rise to 0.9	Gain from investment	Net cash flow
Year	1000 US$	1000 US$	1000 US$	1000 US$	1000 US$	1000 US$
2011	858.8	17.5	0	0	-17.5	-876.3
2012	858.8	17.5	0	0	-17.5	-876.3
2013	68.7	17.5	0	0	-17.5	-86.2
2014	68.7	17.5	3006.3	4055	1031.2	962.5
2015	68.7	17.5	2534.6	3133.5	581.3	512.6
2016	68.7	17.5	2563.6	3147.2	566.2	497.5
2017	68.7	17.5	2579.4	3155.3	558.4	489.7
2018	68.7	17.5	2587.9	3159.9	554.5	485.8
2019	68.7	17.5	2592.4	3162.6	552.6	483.9
2020	68.7	17.5	2594.9	3164.1	551.7	483
2021	68.7	17.5	2596.2	3165	551.3	482.6
2022	68.7	17.5	2596.9	3165.5	551.2	482.5
2023	68.7	17.5	2597.2	3165.8	551.1	482.4
2024	68.7	17.5	2597.4	3166	551.1	482.4
2025	68.7	17.5	2597.5	3166.1	551.1	482.4
2026	68.7	17.5	2597.6	3166.1	551.1	482.4
2027	68.7	17.5	2597.6	3166.2	551.1	482.4
2028	68.7	17.5	2597.6	3166.2	551.1	482.4
2029	68.7	17.5	2597.6	3166.2	551.1	482.4
2030	68.7	17.5	2597.6	3166.2	551.1	482.4
2031	68.7	17.5	2597.6	3166.2	551.1	482.4
2032	68.7	17.5	2597.6	3166.2	551.1	482.4
2033	68.7	17.5	2597.6	3166.2	551.1	482.4
2034	68.7	17.5	2597.6	3166.2	551.1	482.4
2035	68.7	17.5	2597.6	3166.2	551.1	482.4
2036	68.7	17.5	2597.6	3166.2	551.1	482.4
2037	68.7	17.5	2597.6	3166.2	551.1	482.4
2038	68.7	17.5	2597.6	3166.2	551.1	482.4
2039	68.7	17.5	2597.6	3166.2	551.1	482.4
2040	68.7	17.5	2597.6	3166.2	551.1	482.4
2041	68.7	17.5	2597.6	3166.2	551.1	482.4
2042	68.7	17.5	2597.6	3166.2	551.1	482.4
2043	68.7	17.5	2597.6	3166.2	551.1	482.4
2044	68.7	17.5	2597.6	3166.2	551.1	482.4
2045	68.7	17.5	2597.6	3166.2	551.1	482.4
2046	68.7	17.5	2597.6	3166.2	551.1	482.4
2047	68.7	17.5	2597.6	3166.2	551.1	482.4
2048	68.7	17.5	2597.6	3166.2	551.1	482.4
2049	68.7	17.5	2597.6	3166.2	551.1	482.4
2050	68.7	17.5	2597.6	3166.2	551.1	482.4
2051	68.7	17.5	2597.6	3166.2	551.1	482.4
Present value=	2,657.30	302.7	38,085.40	46,809.30	8,421.20	5,763.90
						23%

5.5 Sensitivity analysis

Sensitivity study was carried out on the following project variables:

(i) Price rise.
(ii) Investment cost.
(iii) operating cost.
(iv) management cost.

The sensitivity of the estimated present value of the project was calculated for the -30% to the +30% range of these variables. The sensitivity study was carried out for both the current poor management and good management. The results of the exercise are summarized in Figures 16 and 17.

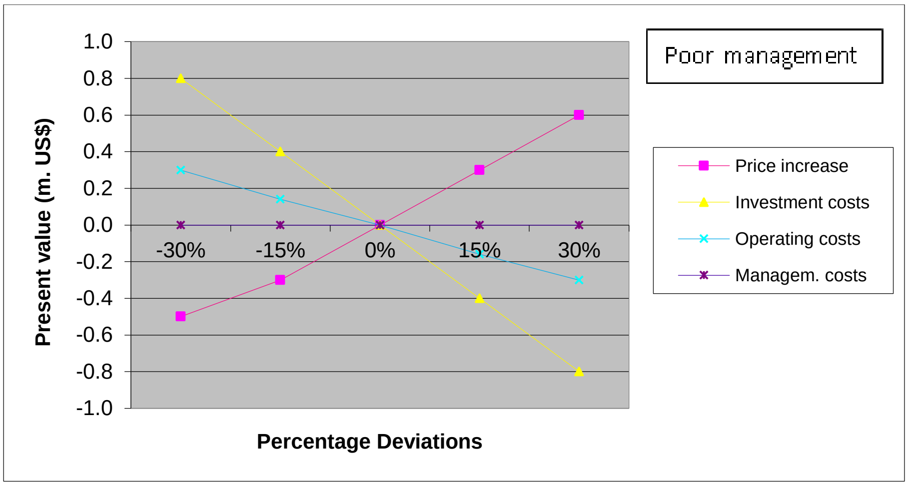

Figure 16: Sensitivity graph with poor management.

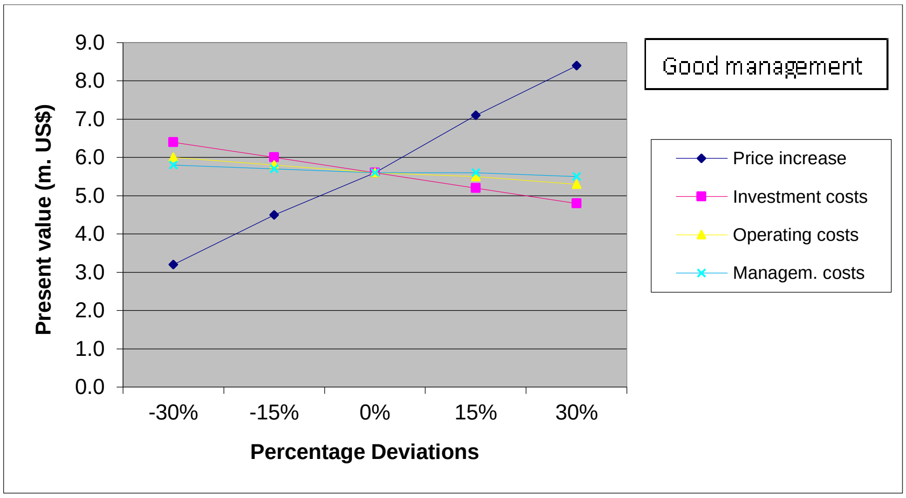

Figure 17: Sensitivity graph with good management.

From the figures we can infer that the sensitivity of the present value of the project is greatest to the predicted price increase. Nevertheless, even when the price increase is only 70% of what was predicted (deviation of -30%), the present value of the project under good management is still positive.

The second greatest sensitivity is to investment costs. However, even when investment costs are increased by 30%, the project under good management still exhibits a positive present value. The sensitivity of the project´s present value to landing site operating costs and the fisheries management costs is much less.

6 DISCUSSION

The results from the cost benefit studies leads to a brief discussion on the need for a good fisheries management at the community level. To achieve the double aim of maximising the economic benefit and to have a sustainable fish stocks, total catch and fishing effort must be controlled (Arnason *et al.* 2000). The fisheries management activities involve the enforcement of these fisheries management techniques.

Property right management regimes are well suited for generating fisheries efficiency (Arnason 2006). The apparently most applicable property rights regimes to traditionally unmanaged fishing communities like the Portee and Old Wharf are community fishing rights. Community fishing rights do not constitute a fisheries management regime, but they give the community the formal powers and opportunities to install an efficient fisheries management regime (Arnason *et al.* 2000).

Apart from their impact on fisheries management, community fishing rights serves a certain social role. They endow the community with a degree of self determination. Community rights are the rights to take part in the actual fishing and the rights to be involved in the management of the fishery (Charles 2006).

A good fishery management aims to move the fishery towards an economically optimal position, which is tied to the biological and social fisheries management aspect of the fisheries resource. This can all be done by balancing the biological, the economic and the social aspect of fisheries management normally referred to as the triple P triangle (Profits, People and the Planet). The most important issues in fisheries management is achieving the optimal benefit from the use of the resource through an effective fisheries management system and ensuring an equitable distribution of these benefits. Members of the fishing community will most times disagree with the optimal fisheries policy, that is who should get the harvesting rights. It then follows that for a collective fishing right, the fishing community finds themselves in a bargaining game situation. This bargaining game will depend on the rules of the structure of the fishing community (Arnason 2006).

The objective of fisheries management has shifted over the years as a result of the global trend towards the devolution and decentralisation of governance to the local level, which has resulted in the community management. The other reason for the shift in fisheries management in the recent years has also been the emphasis placed on the recognition and the establishment of rights over the use and the management of natural resources like fisheries (Charles 2006).

It should however be noted that the fishery is pursued with the context of Community User rights depending on the situation. The Community can choose to own the Capital (boats) as well as the rights. This means they can employ or hire fishermen to do the fishing and earn profits from the fishery or they can simply set the rules under which the fishers will agree to fish. This will cover the management cost and gives the profit to the individual fishermen. On the other hand 'Management rights' reflects on who has the right to take part in the management decisions. The main focus on this right fits with emphasis of sharing management responsibilities between the fisheries ministry, Stakeholders and the fishing community through the community management system.

The community fisheries management solution can simply be said to be the direct and formal involvement of the resource users in a community in the decision making process. This is usually done through the delegation of the regulatory functions to the fishermen organisations. One of the main objectives in community fisheries management is to bring further cooperation among the fishers in the community, create a more responsible attitude towards the use of the resource, and promote learning and compliance to the rules and regulations. The main reason for the community management in these two communities is the fact that it is supposed to strengthen or if lost restores social integration among the fishers within and among the community (Jentoft 2000).

In designing a co-management system with appropriate community integration, equal opportunity and collective action, the main goal should be the role of the community in the formation of the community management regime.

It must however be said that a viable functional community cannot rest on the fisheries management system alone (Arnason *et al.* 2000). It most put in place broader strategies and looks into all existing opportunities for community development. To get towards this direction, some decisions has to be made pending the enhancement of economic structures and organisations, the role of products and the labour markets, technology, health, education, Infrastructure and finance.

The saying that ‘a viable fish stock requires viable fishing communities’ (Jentoft 2006) is very well applicable to these two fishing communities. The saying means that if fisheries management requires Sustainable fish stocks, then as a consequence it can be an effective contribution to making fisheries based, human communities also viable.

A well functioning community is an important contribution to fisheries management. There is therefore the need to build stronger communities at Portee and Old Wharf if they are to get the optimal economic benefit of fishery and the investment in the harbour. The fact should also be noted that fishermen are born, raised and live in these communities. They are engaged in cultural and social systems that give meaning to their lives and therefore direction for their behaviour should also be noted. Their fishing practices are guided by values, norms and knowledge that are shared within the community. It therefore follows those communities that disintegrate socially and morally are a threat to the fish stocks (Jentoft 2006). Poor fisheries management (overfishing, wrong mesh etc.) results when the norms of self-restraints and community solidarity have eroded. It usually occurs when the fishermen do not care about the resource, the community and about each other. This then leads to them losing the ability to communicate among themselves, to agree and cooperate in their decisions. Instead their social relations are featured with opportunism, strife and conflicts. Their capacity for collective decisions and actions will then be severely weakened.

In Sierra Leone, Fisheries management was entirely operated and implemented by the government through the ministry of Fisheries and Marine Resources. In 2004, some functions were devolved to the local government. The ministry of fisheries has limited financial resources as well as enough trained staff to conduct most of the fisheries management activities, like the MCS, research, data collection and analyses etc. The fact that the ministry has devolved some of its functions to the local councils means that the ministry is willing to cooperate with the fishing communities and support community based initiatives in the management of the fishery. The ministry also recognises the need for Stakeholder involvement in the management of the fishery. There is currently a fisheries management committee but the ministry plans to expand it by bringing in more stakeholders.

This community based cooperative system of management means that the management responsibility of the fishery is shared between the fishing community by the beach management units and the Ministry of Fisheries and Marine Resources. This will reduce the fishing effort by allocating exclusive fishing rights to the fishing community through the beach management unit formed in the community.

7 CONCLUSIONS

The results from the bio-economic model show that the small pelagic fishery has an excessive number of boats and consequently a reduction in the net economic benefits (profits). These results are not surprising since the pelagic fishery in Sierra Leone is virtually an open access and unmanaged fishery. The most important thing to note is that this is a fishery that gives food, employment and with proper management it will create extra economic benefit to the fishers in terms of profits or rents.

The calculations from the model show that the optimal equilibrium fishing effort for the small pelagic is about two thirds of the current fishing effort. This corresponds to the reduction in the number of fishing boats from 6,600 to an optimal level of 4,580. This means that the optimal profit level that can be obtained by using the appropriate fishing effort is about US$51 million per year for the whole fishery. This gain if properly utilised can lead to the social and economic development and improvement of the fishers in the fishing communities.

The results also show that the for the Portee and Old Wharf fishing communities, the current level of fishing effort should be reduced from 271boats to 188 boats. This optimal effort level will give a profit maximisation of US $ 2.6 million per year in these communities with an optimal harvest level of 5,730 mt. The results also show that the profits per boat could be some US$ 11,000 instead of the current losses of some US$ 3,000.

The approximately optimal dynamic adjustment path for the fishery calls for a fishery closure of three years to allow the stocks to recover followed by a fairly rapid increase in fishing effort to the optimal long run level. It may well be the case that taking social considerations into account, the best policy would not reduce initial fishing effort this much and thus take a longer time to reach the optimal equilibrium level.

The cost benefit analyses of the landing site construction suggests that this may only be economical in the sense of a positive present value if good management of the fishery is also implemented. Thus, under continuing poor management, the present value of the investment is virtually zero, more precisely US$ -12 thousand. However, with good fisheries management, the present value of the harbour construction is US$ 5.8 million. This corresponds to an internal rate of return of some 23%. The present value calculations were done for a rate of discount of 5%.

If on the other hand, the construction of the landing facilities does not lead to benefits in terms of price rises of landed catch based on the quality and size or similar, then the investment is not economically necessary. In that case, it wold basically be wasted with a negative present value equal to the present value of the investment and the running costs of the facility.

The results from the bio-economic model and the cost benefit analysis gives an idea of how with improved fisheries management and infrastructure the small pelagic fishery can provide more benefits to the fishing communities at Portee and Old Wharf.

The policy recommendation from this study is to do further biological and socio-economic research into the small pelagic fishery. Most of the fisheries research surveys are done offshore and to capture the inshore pelagic, research surveys should be conducted further inshore for the maximum sustainable yield and the biomass level.

I will also recommend further studies with the use of the model in the high value industrial species like the Shrimp fishery, the Sparids, the groupers etc. The implementation of this policy will involve a lot of stakeholder consultation with the two fishing communities for them to know the benefits of the reduction in their fishing effort. The use of community fishing rights for the Portee and Old Wharf fishing communities will be recommended. This will involve the formation of a fishery management committee at the local level (at Old Wharf and Portee). There should also be a Beach Fisheries Management Unit that will have people assigned as beach wardens at this landing site and collectors of landing fees and any other fee agreed upon by the committee.

The reduction in the number of boats should be done in phases and the fishermen who will eventually lose should be provided for by compensation and alternate livelihood by the proposed World Bank Project. The compensation or alternate livelihood is a very important aspect of the fisheries policy because to have an economically beneficial fisheries policy every member in the community should at least be as well off as before the reduction in the boats policy.

The fishermen should form cooperatives, so that instead of each fisherman having a boat with increase in the fishing effort, they will be able to build larger boats that will go further off shore to get the bigger fish which will be of higher value. What remains then is to implement this fisheries policy. For that the best way may be to build a well functioning community fisheries management unit for the management and utilisation of the small pelagic resources in the two communities.

Finally a legal mechanism should be developed as a basis for the implementation of this policy.

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APPENDICES

Appendix 1: Bonga and Herring Landings 2001-2007.

Local	Scientific name	2001	2002	2003	2004	2005	2006	2007
Awefu	Ethmalosa fimbriata(juvenille)	12621	18675	16588	16395	20409	29498	23849
Bonga	Ethmalosa fimbriata(adult)	12169	12816	11928	34651	32268	30610	28865
Mina	Sardinella species(juvenile)	1006	3192	5253	4684	7487	7620	7971
Herring	Sardinella species(Adult)	8843	10059	10194	13527	14573	7553	8603
Total		**34639**	**44742**	**43963**	**69256**	**69256**	**75281**	**69289**

Appendix 2: Fishing Investment

		Fishing Investment	
		SLE(Le)	US $
Investment cost			
	Std.5-10	5,540,000	1,847
	Fishing net	19,600,000	6,533
	Engine	18,000,000	6,000
	Lead	10,000,000	3,333
	Ropes	1,120,000	373
	Twine	108,000	36
	Bouy	525,000	175
	Anchor rope	185,000	62
	Life Jacket	70,000	23
Fixed cost	**Total**	**55,148,000**	**18,382**
Maintenace cost	Boat	50,000	17
	Bear	100,000	33
	Engine	70,000	23
	Tota Main	**220,000**	**73**
Variable cost	Fuel	**120,000**	**40**
Total fishing Investment		**55,488,000**	**18,495**

Appendix 3: An optimal dynamic adjustment path(Parameters for the estimation)

	Competitive dynamics							
	alpha	0.963		Biomass equilibrium				
	beta	0.0019		x	e		x	e
catchability	q	0.46		0	0.00		91.75	0.00
	cc	8.703		24.948	5.22		91.75	0.66
	p	0.8		49.896	6.09		91.75	1.32
Schooling	b	0.7		74.845	6.49		91.75	1.98
dynamic adjustm	a	0.5		99.793	6.66		91.75	2.64
Adj. limitation	stepmax	2		124.74	6.68		91.75	3.30
				149.69	6.58		91.75	3.96
rate of disc.	rr	0.05		174.64	6.40		91.75	4.62
				199.59	6.15		91.75	5.28
Msy-x		249.48		224.53	5.84		91.75	5.94
X-virgin		498.96		249.48	5.48		91.75	6.60
steps		24.948		274.43	5.08		91.75	7.26
				299.38	4.63		91.75	7.92
Price gain	gain1	0.03		324.33	4.15		91.75	8.58
	gain 2	0.08		349.27	3.64		91.75	9.24
	gain3	0.125		374.22	3.10		91.75	9.90
				399.17	2.52		91.75	10.56
				424.12	1.93		91.75	11.22
				449.07	1.31		91.75	11.88
				474.02	0.66		91.75	12.54
				498.96	3E-15		91.75	13.20

Appendix 4: The dynamic model result for the open access fishery.

				BASE CASE (no price increase)							Corrected	
Time	x(t)	Growth	e(t)	y(t)	c(t)	Profits	Profits/ effort	Potential profits/eff ort	x(t+1)	e(t+1)	e(t+1)	e(t+1)
2011	76.20	62.17	6.60	63.05	57.44	-7.00	-1.06	-1.06	75.33	6.07	6.07	6.07
2012	75.33	61.59	6.07	57.51	52.82	-6.81	-1.12	-1.12	79.40	5.51	5.51	5.51
2013	79.40	64.29	5.51	54.16	47.94	-4.61	-0.84	-0.84	89.54	5.09	5.09	5.09
2014	89.54	70.75	5.09	54.43	44.30	-0.75	-0.15	-0.15	105.86	5.02	5.02	5.02
2015	105.86	80.31	5.02	60.31	43.65	4.60	0.92	0.92	125.86	5.47	5.47	5.47
2016	125.86	90.63	5.47	74.30	47.64	11.80	2.16	2.16	142.19	6.55	6.55	6.55
2017	142.19	97.91	6.55	96.85	57.02	20.46	3.12	3.12	143.24	8.11	8.11	8.11
2018	143.24	98.34	8.11	120.56	70.61	25.84	3.18	3.18	121.02	9.71	9.71	9.71
2019	121.02	88.28	9.71	128.17	84.47	18.07	1.86	1.86	81.13	10.64	10.64	10.64
2020	81.13	65.42	10.64	106.16	92.57	-7.64	-0.72	-0.72	40.39	10.28	10.28	10.28
2021	40.39	35.75	10.28	62.95	89.44	-39.08	-3.80	-3.80	13.18	8.38	8.38	8.38
2022	13.18	12.36	8.38	23.43	72.90	-54.15	-6.46	-6.46	2.11	5.14	5.14	5.14
2023	2.11	2.02	5.14	3.99	44.76	-41.57	-8.08	-8.08	0.14	1.10	1.10	1.10
2024	0.14	0.14	1.10	0.13	9.59	-9.49	-8.61	-8.61	0.15	-3.20	-3.20	0.00
2025	0.15	0.15	0.00	0.00	0.00	0.00	0.00	-8.60	0.30	-4.30	-4.30	0.00
2026	0.30	0.29	0.00	0.00	0.00	0.00	0.00	-8.55	0.58	-4.27	-4.27	0.00
2027	0.58	0.56	0.00	0.00	0.00	0.00	0.00	-8.45	1.15	-4.23	-4.23	0.00
2028	1.15	1.10	0.00	0.00	0.00	0.00	0.00	-8.30	2.25	-4.15	-4.15	0.00
2029	2.25	2.15	0.00	0.00	0.00	0.00	0.00	-8.05	4.40	-4.03	-4.03	0.00
2030	4.40	4.20	0.00	0.00	0.00	0.00	0.00	-7.66	8.60	-3.83	-3.83	0.00
2031	8.60	8.14	0.00	0.00	0.00	0.00	0.00	-7.04	16.75	-3.52	-3.52	0.00
2032	16.75	15.58	0.00	0.00	0.00	0.00	0.00	-6.06	32.33	-3.03	-3.03	0.00
2033	32.33	29.12	0.00	0.00	0.00	0.00	0.00	-4.51	61.45	-2.25	-2.25	0.00
2034	61.45	51.89	0.00	0.00	0.00	0.00	0.00	-2.13	113.33	-1.06	-1.06	0.00
2035	113.33	84.35	0.00	0.00	0.00	0.00	0.00	1.39	197.68	0.69	0.69	0.69
2036	197.68	114.95	0.69	12.91	6.04	4.29	6.19	6.19	299.72	3.79	2.69	2.69
2037	299.72	115.26	2.69	67.11	23.44	30.24	11.23	11.23	347.86	8.31	4.69	4.69
2038	347.86	101.45	4.69	129.79	40.85	62.98	13.42	13.42	319.52	11.40	6.69	6.69
2039	319.52	110.66	6.69	174.41	58.25	81.27	12.14	12.14	255.77	12.76	8.69	8.69
2040	255.77	120.05	8.69	193.84	75.66	79.41	9.13	9.13	181.98	13.26	10.69	10.69
2041	181.98	111.33	10.69	187.88	93.07	57.24	5.35	5.35	105.42	13.37	12.69	12.69
2042	105.42	80.07	12.69	152.19	110.47	11.28	0.89	0.89	33.30	13.14	13.14	13.14
2043	33.30	29.93	13.14	63.23	102.83	-52.24	-3.98	-3.98	0.10	11.15	11.15	11.15
2044	0.10	0.10	11.15	0.20	18.61	-18.45	-1.66	-1.66	0.10	10.32	10.32	10.32
2045	0.10	0.10	10.32	0.20	18.61	-18.45	-1.79	-1.79	0.10	9.43	9.43	9.43
2046	0.10	0.10	9.43	0.20	18.61	-18.45	-1.96	-1.96	0.10	8.45	8.45	8.45
2047	0.10	0.10	8.45	0.20	18.61	-18.45	-2.18	-2.18	0.10	7.36	7.36	7.36
2048	0.10	0.10	7.36	0.20	18.61	-18.45	-2.51	-2.51	0.10	6.10	6.10	6.10
2049	0.10	0.10	6.10	0.20	18.61	-18.45	-3.02	-3.02	0.10	4.59	4.59	4.59
2050	0.10	0.10	4.59	0.20	18.61	-18.45	-4.02	-4.02	0.10	2.58	2.58	2.58
2051	0.10	0.10	2.58	0.20	18.61	-18.45	-7.15	-7.15	0.10	-0.99	-0.99	0.00
					NPV=	-1.70						

Appendix 5 : The adjustment path with price increase.

				Price increases								
									Corrected			
Time	x(t)	Growth	e(t)	y(t)	c(t)	Profits	Profits/ effort	Potential profits/effort	x(t+1)	e(t+1)	e(t+1)	e(t+1)
2011	76.20	62.17	6.60	63.05	57.44	-7.00	-1.06	-1.06	75.33	6.07	6.07	6.07
2012	75.33	61.59	6.07	57.51	52.82	-5.43	-0.89	-0.89	79.40	5.62	5.62	5.62
2013	79.40	64.29	5.62	55.28	48.93	-1.17	-0.21	-0.21	88.42	5.52	5.52	5.52
2014	88.42	70.06	5.52	58.50	48.02	4.62	0.84	0.84	99.98	5.94	5.94	5.94
2015	99.98	76.99	5.94	68.59	51.67	10.06	1.69	1.69	108.38	6.78	6.78	6.78
2016	108.38	81.70	6.78	82.93	59.04	15.60	2.30	2.30	107.15	7.93	7.93	7.93
2017	107.15	81.03	7.93	96.21	69.05	17.54	2.21	2.21	91.96	9.04	9.04	9.04
2018	91.96	72.24	9.04	98.50	78.67	9.98	1.10	1.10	65.70	9.59	9.59	9.59
2019	65.70	54.94	9.59	82.59	83.47	-9.14	-0.95	-0.95	38.05	9.11	9.11	9.11
2020	38.05	33.85	9.11	53.55	79.33	-31.13	-3.42	-3.42	18.35	7.41	7.41	7.41
2021	18.35	17.02	7.41	26.12	64.47	-40.96	-5.53	-5.53	9.25	4.64	4.64	4.64
2022	9.25	8.74	4.64	10.14	40.40	-31.28	-6.74	-6.74	7.86	1.27	1.27	1.27
2023	7.86	7.45	1.27	2.48	11.08	-8.85	-6.95	-6.95	12.83	-2.20	-2.20	0.00
2024	12.83	12.04	0.00	0.00	0.00	0.00	0.00	-6.51	24.86	-3.25	-3.25	0.00
2025	24.86	22.75	0.00	0.00	0.00	0.00	0.00	-5.21	47.61	-2.61	-2.61	0.00
2026	47.61	41.48	0.00	0.00	0.00	0.00	0.00	-3.20	89.09	-1.60	-1.60	0.00
2027	89.09	70.48	0.00	0.00	0.00	0.00	0.00	-0.18	159.57	-0.09	-0.09	0.00
2028	159.57	104.52	0.00	0.00	0.00	0.00	0.00	4.12	264.09	2.06	2.00	2.00
2029	264.09	119.71	2.00	45.61	17.41	23.64	11.82	11.82	338.20	7.91	4.00	4.00
2030	338.20	104.93	4.00	108.45	34.81	62.80	15.70	15.70	334.68	11.85	6.00	6.00
2031	334.68	106.12	6.00	161.49	52.22	93.13	15.52	15.52	279.31	13.76	8.00	8.00
2032	279.31	118.41	8.00	189.72	69.62	101.12	12.64	12.64	208.00	14.32	10.00	10.00
2033	208.00	116.80	10.00	192.93	87.03	86.61	8.66	8.66	131.87	14.33	12.00	12.00
2034	131.87	93.43	12.00	168.29	104.44	47.02	3.92	3.92	57.02	13.96	13.96	13.96
2035	57.02	48.63	13.96	105.65	117.92	-22.83	-1.64	-1.64	0.10	13.14	13.14	13.14
2036	0.10	0.10	13.14	0.20	18.61	-18.44	-1.40	-1.40	0.10	12.44	12.44	12.44
2037	0.10	0.10	12.44	0.20	18.61	-18.44	-1.48	-1.48	0.10	11.70	11.70	11.70
2038	0.10	0.10	11.70	0.20	18.61	-18.44	-1.58	-1.58	0.10	10.91	10.91	10.91
2039	0.10	0.10	10.91	0.20	18.61	-18.44	-1.69	-1.69	0.10	10.07	10.07	10.07
2040	0.10	0.10	10.07	0.20	18.61	-18.44	-1.83	-1.83	0.10	9.15	9.15	9.15
2041	0.10	0.10	9.15	0.20	18.61	-18.44	-2.01	-2.01	0.10	8.14	8.14	8.14
2042	0.10	0.10	8.14	0.20	18.61	-18.44	-2.26	-2.26	0.10	7.01	7.01	7.01
2043	0.10	0.10	7.01	0.20	18.61	-18.44	-2.63	-2.63	0.10	5.70	5.70	5.70
2044	0.10	0.10	5.70	0.20	18.61	-18.44	-3.24	-3.24	0.10	4.08	4.08	4.08
2045	0.10	0.10	4.08	0.20	18.61	-18.44	-4.52	-4.52	0.10	1.82	1.82	1.82
2046	0.10	0.10	1.82	0.17	15.83	-15.68	-8.62	-8.62	0.03	-2.49	-2.49	0.00
2047	0.03	0.03	0.00	0.00	0.00	0.00	0.00	-8.67	0.06	-4.34	-4.34	0.00
2048	0.06	0.06	0.00	0.00	0.00	0.00	0.00	-8.65	0.11	-4.33	-4.33	0.00
2049	0.11	0.11	0.00	0.00	0.00	0.00	0.00	-8.62	0.22	-4.31	-4.31	0.00
2050	0.22	0.21	0.00	0.00	0.00	0.00	0.00	-8.57	0.44	-4.29	-4.29	0.00
2051	0.44	0.42	0.00	0.00	0.00	0.00	0.00	-8.50	0.85	-4.25	-4.25	0.00
					NPV=	51.18						